PROCEEDINGS OF 17TH STUDENTS' SCIENCE CONFERENCE

Students' Science Conference

"Ocean of Knowledge"

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Edited by Wojciech Wodo and Adam Sulich

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PREFACE

Ladies and gentleman, dear colleagues,

The Students' Science Conference has been traditionally and continuously held since 2002. Wroclaw University of Science and Technology organised the 17th Students Scientific Conference 2019 (SSC2019) in partnership with the Lviv Polytechnic National University (Ukraine), The Óbuda University (Hungary) and the Riga Technical University (Latvia). The conference was held from September 18 to September 21, 2019 in Oleśnica (Poland). Each year conference is unique due to participants – young scientists who just begin their adventure in science and want to also popularize their research and discoveries. The conference creates a platform to support young scientists to boost their research careers and gain scientific excellence. This statement has been implemented because of double-blind review and proofreading of papers selected to be presented during the conference. These are criteria to publish scientific articles in the hereby proceedings. All submitted papers undergone careful selection and were reviewed by two reviewers. We selected the best papers in English that were published in this book.

The 17th Students Science Conference 2019 as the previous conferences was a place of exchange for international knowledge and experiences between participants. We want to thank all who participated in the conference and thank you for your high-quality work.

The Students' Science Conference 2019 proceedings entitled „Ocean of Knowledge" is divided into chapters which cover division of the participants of the SSC2019 in their sessions, therefore the book is organised in three main sections:

1. Fundamental Problems of Science,
2. New Materials and Technologies,
3. Biodiversity and Human Well-being.

We thank everyone involved for organizing and participating at this event, which will surely help to gain good start position for future scientists and Ph.D. candidates and to contribute to the science. The science popularization is urgently needed not only outside academia to inform society about scientific progress and to invite a new generation of students to start higher education but also inside the universities to build a strong community and multidisciplinary teams. Sail then towards the Ocean of Knowledge!

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FUNDAMENTAL PROBLEMS OF SCIENCE

Key words:
morphodynamics, morphology, geomorphology, abrasion, pebble

Dániel CSALLÓKÖZI[1]

ANALYSIS OF DISTANCE-DRIVEN SHAPE EVOLUTION MODELS*

The first known written thought about the shape evolution of pebbles originates from Aristotle. He observed that pebbles, drifting in a river or at a seashore, become smooth and round as a rule. Since then this question, supplemented by other similar topics, became an actively researched area of science. This branch of science, morphodynamics, studies the alteration of morphology of inorganic bodies, such as asteroids, rocks and pebbles, through the process of abrasion.

Two of the most spectacular results of researching morphodynamics are the mathematical proof of the late existence of water rivers on Mars, and the explanation of the unique shape of the asteroid Oumuamua, arriving to our solar system, from outside of the solar system.

In morphodynamics, one assumes that the material of the observed object is homogeneous and has even mass distribution. Therefore, a closed surface can be observed instead of a body. At a given time, surface K is given, and one observes the movement of points P of surface K towards the inside of the body, defined by rules of geometry. Discussion of these rules gives different model classes and types.

In the class called distance-driven shape evolution models, there are radial and parallel models, each defined by some rule (function). My analysis of these models is based on article [1], in which theorems are drawn up analytically. In my study, I draw up some further theorems, numerically verify the existing analytic statements, and give conjectures in further topics based on numerical studies.

1. INTRODUCING MORPHODYNAMICS

The first known written thought about the shape evolution of pebbles originates from Aristotle. He observed that pebbles, drifting in a river or at a seashore, become smooth and round as a rule. Since then this question, supplemented by other similar topics, became an actively researched area of science. This branch of science, morphodynamics, studies the alteration of morphology of inorganic bodies, such as asteroids, rocks and pebbles, through the process of abrasion.

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* Paper awarded in the Best Paper Contest.

Two of the most spectacular results of researching morphodynamics are the following. In 2015, scientists reconstructed the transport history of Martian pebbles [1]. Their models were based on calculations worked out on Earth, and they gave a mathematical explanation for Martian pebbles' shapes. This explanation assumes the late existence of water rivers on Mars. (Fig. 1)

In 2017, humanity observed an asteroid arriving to our solar system, from outside of the solar system, for the first time in history. Based on observations, this asteroid, named Oumuamua, had a unique shape, which is either a flat disc-like or a long pen-like shape, with the smallest ratio in size of about 1 to 10. This unusual shape gave a strong reason to assume extraterrestrial life. Thanks to mathematical models of rock abrasion, researchers were able to give a mathematical justification on the shape of Oumuamua, excluding extraterrestrial life [2]. (Fig. 2)

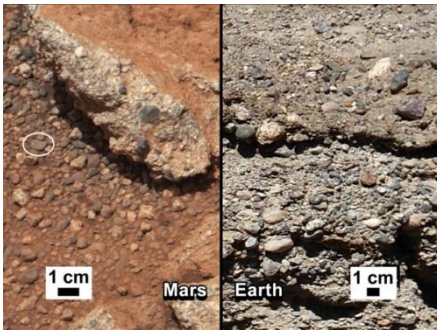

Fig. 1. [3] Rock Outcrops on Mars and Earth.

Fig. 2. [4] Artist's concept of interstellar asteroid 1I/2017 U1 ('Oumuamua).

In my study, in chapter 2 I introduce the types of mathematical models that are being analysed. In chapter 3, I define the most important formal characteristics of describing rock shapes. I introduce the analytic statements drawn up by scientists [5] and by me,

on which I base my numerical studies, explained in chapter 4. Finally, I summarize my results.

2. MODEL TYPES AND CLASSES

In morphodynamics, one assumes that the material of the observed object is homogeneous and has even mass distribution. Therefore, a closed surface can be observed instead of a body. At a given time $t = 0$, surface K is given, and one observes the movement of surface points of K towards the centre of the body, defined by rules of geometry. Discussion of these rules gives different model classes and types.

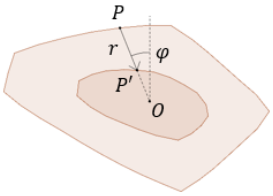

Fig. 3. Example of an observed surface.

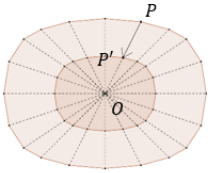

Fig. 4. Radial distance-driven model.

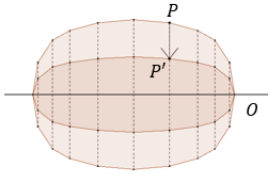

Fig. 5. Parallel distance-driven model.

Surface point P is given in a coordinate system, such as polar coordinates on the plane or spherical coordinates in the space (Fig. 3). P' on $K(t > 0)$ is the image of P on $K(t = 0)$. If the distance between P and P' is r, the velocity of point P is r_t, the derivative of distance r by time. The model classes differ by the functions that define

r_t. Models in class (1) $r_t = f(r)$, where this function of velocity is the function of distance r only, are so-called distance-driven models. Models in class (1) are object to analyse the abrasion of seashore pebbles. Models in class (2) $r_t = f(r, r_\varphi)$, where the function of velocity (derivative by time) is a function of the derivative of the surface in space, are object to analyse the abrasion of asteroids. Models in class (3) $r_t = f(r, r_\varphi, r_{\varphi\varphi})$, where the second spatial derivative is used as well, e.g. the so-called curvature-driven models, are object to analyse the abrasion of river pebbles. In this paper, I analyse three-dimensional models of class (1).

In the models of class (1), beyond functions that define the movement of the surface K in time, the spatial direction of points of K is also defined. Surface point P of K is moving towards an object O inside the body.

Model types (1.1), when O is a point (e.g. the geometric centre of the body), are called radial distance-driven models (Fig. 4). The direction of movement of P at a given time is on the line OP. P moves on a straight line when O is constant, P moves on a curve when O moves in time.

Two essential functions can be related to radial distance-driven models, where $r_t = f(r)$. It can be proven [6], that in model (1.1.1) $r_t = c * r,\ c \in \boldsymbol{R}$, the shape of K is self-similar; in model (1.1.2) $r_t = c * r^2,\ c \in \boldsymbol{R}$, the shape of K is converging to a sphere. More than two thousand years ago, Aristotle drew up the first mathematical model of abrasion, which – with contemporary mathematical science – is this model exactly.

Model types (1.2), when O is a plane, are called parallel distance-driven models (Fig. 5). The direction of the movement of P at a given time is on a straight line not parallel with O, towards O.

Adding a condition, in model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$, when P moves on a straight line perpendicular to O, we get the orthogonal affinity of K to O.

In this paper, I examine models (1.1.1), (1.1.2) on symmetric bodies, and model (1.2.1) on ellipsoids, the geometric centre of which are constant in time.

3. ANALYSED SHAPE DESCRIPTORS, EXAMINED THEOREMS AND CONJECTURES

In morphodynamics, to be able to analyse the characteristics of the model and compare it to reality, one must describe surfaces, which are (mostly) of an irregular shape. Shape descriptors used in geology are mathematical quantities, so that the value of a shape descriptor is a non-injective function of the shape (shape descriptors do characterise, but do not define the shape). These shape descriptors are the axle ratios, the isoperimetric ratio and the number of equilibrium points. Hereinafter, $K(0)$ means

the initial shape, $K(T)$ means a general abraded shape, K and $K(t)$ means the surface throughout the whole process.

The **axle ratios** of a body are calculated as following. Three axes $a \geq b \geq c$ can be measured with different methods (edges of smallest bounding cuboid, axes of smallest bounding ellipsoid, etc.) on a three-dimensional body. The two axle ratios are $y_1 = c/a,\ y_2 = b/a$.

Theorem 1: In the radial model (1.1.1) $r_t = c * r,\ c \in \boldsymbol{R}$, when K is self-similar, $\frac{a(T)}{a(0)} = \frac{b(T)}{b(0)} = \frac{c(T)}{c(0)}$, where $a(T), b(T)$ and $c(T)$ are the axes of $K(T)$, and $a(0), b(0)$ and $c(0)$ are the axes of the initial surface $K(0)$. The axle ratios of $K(t)$ are constant.

Theorem 2: In the radial model (1.1.2) $r_t = c * r^2,\ c \in \boldsymbol{R}$, when K converges to a sphere, the axle ratios of $K(t)$ converge to the axle ratios of a sphere. $\lim_{t\to\infty} \frac{b(t)}{a(t)} = 1,\ \lim_{t\to\infty} \frac{c(t)}{a(t)} = 1.$

In the parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$, one theorem is drawn up about axle ratios. According to Remark 8 of article [5], under orthogonal affinity of an ellipsoid, where the plane of affinity intersects the geometric centre of the ellipsoid, and one of the axes of the ellipsoid is perpendicular to the plane of affinity, y_1 is a quasiconcave function, while y_2 may have several maxima. For the same model with less conditions, I later draw up *Conjecture 1*, based on numerical analysis (to be discussed in chapter 4).

The **isoperimetric ratio** (I) of a real body is a dimensionless number, so that $0 < I \leq 1$, and only the isoperimetric ratio of the sphere equals to 1. In three dimensions, $I = \frac{V*6\sqrt{\pi}}{S^{\frac{3}{2}}}$, where V is the volume and S is the surface of the body.

Theorem 3: In the radial model (1.1.1) $r_t = c * r,\ c \in \boldsymbol{R}$, when K is self-similar, $\frac{V(T)}{V(0)} = \left(\frac{S(T)}{S(0)}\right)^{\frac{3}{2}}$, where $V(T)$ and $S(T)$ are the volume and surface of $K(T)$, and $V(0)$ and $S(0)$ are the volume and surface of the initial surface $K(0)$. The isoperimetric ratio of $K(t)$ is constant.

Theorem 4: In the radial model (1.1.2) $r_t = c * r^2,\ c \in \boldsymbol{R}$, when K converges to a sphere, the isoperimetric ratio of $K(t)$ converges to the isoperimetric ratio of a sphere. $\lim_{t\to\infty} I(t) = 1.$

In the parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$, according to article [5] (Theorem 6), under orthogonal affinity of smooth convex bodies $I(t)$ is a quasiconcave function.

The **equilibrium points** of a body are stationary points of the centre-surface distance function that describes the surface. Mathematical quantities define if the given point on the surface is an equilibrium point, such as the first derivatives by two non-parallel directions r_φ and r_ϑ, and the second non-mixed derivatives by the same directions $r_{\varphi\varphi}$ and $r_{\vartheta\vartheta}$. There are three types of equilibrium points in three dimensions. These points have mathematical and physical content as following.

A stable equilibrium point (S) is a point on the body, placed on which the body stays still. Scrolling the body in either direction causes the centre to move upwards (e.g. a face of a cube). This point is a local minimum point of the surface, therefore $r_\varphi = 0,\ r_\vartheta = 0,\ r_{\varphi\varphi} > 0,\ r_{\vartheta\vartheta} > 0$.

An unstable equilibrium point (U) is a point on the body, placed on which the body stays still in theory (in practice it cannot be done). Scrolling the body in either direction causes the centre to move downwards (e.g. a vertex of a cube). This point is a local maximum point of the surface, therefore $r_\varphi = 0,\ r_\vartheta = 0,\ r_{\varphi\varphi} < 0,\ r_{\vartheta\vartheta} < 0$.

A saddle point (H) is a point on the body, placed on which the body stays still in theory (in practice it cannot be done). Scrolling the body in two opposite directions causes the centre either to move upwards, or to move downwards in both directions (e.g. an edge of a cube). This point is mathematically a saddle point, therefore $r_\varphi = 0,\ r_\vartheta = 0,\ r_{\varphi\varphi} > 0,\ r_{\vartheta\vartheta} < 0,$ or $r_\varphi = 0,\ r_\vartheta = 0,\ r_{\varphi\varphi} < 0,\ r_{\vartheta\vartheta} > 0$.

According to the theorem of Henri Poincaré and Heinz Hopf [7], the number of equilibrium points on a given three-dimensional surface is $S + U - H = 2$.

Theorem 5: In the radial model (1.1.1) $r_t = c * r,\ c \in \boldsymbol{R}$, when K is self-similar, $\frac{P_i(T)}{P_i(0)}$, where $P_i(T)$ is a surface point of $K(T)$, and $P_i(0)$ is the same surface point of the initial surface $K(0)$. The number of equilibrium points is constant.

In the radial model (1.1.2) $r_t = c * r^2,\ c \in \boldsymbol{R}$, I later draw up *Conjecture 2*, based on numerical analysis (to be discussed in chapter 4). In this paper, I do not analyse the number of equilibrium points under parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$.

4. NUMERICAL ANALYSIS

For numerical modelling and analysis of the abrasion process in these model types, I use MATLAB.

First, I define an **initial shape** $K(0)$, which is a so-called super-ellipsoid. The equation of the surface of the super-ellipsoid in orthogonal coordinate system:

$\frac{x^n}{a^n}+\frac{y^n}{b^n}+\frac{z^n}{c^n}=1$, in spherical coordinate system: $\frac{r^n*\cos^n\varphi*\sin^n\vartheta}{a^n}+\frac{r^n*\sin^n\varphi*\sin^n\vartheta}{b^n}+\frac{r^n*\cos^n\vartheta}{c^n}=1$, where $n\in\boldsymbol{R}^+$ and a,b and c are the axes of $K(0)$. Forms of a super ellipsoid are the following: the regular ellipsoid when $n=2$, the cuboid when $n=\infty$, and the forms in between (called super-ellipsoid).

For the parallel model (1.2.1) $r_t=-c*r,\ c\in\boldsymbol{R}^+$, I also define the plane of affinity O, and the relation between $K(0)$ and O. To be able to analyse any relation, a spatial angle (two plane angles) can be defined the way I rotate $K(0)$ around axis z with α, then around axis y with β. The matrix of this linear transformation is

$$\underline{\underline{A}}=\begin{bmatrix}\cos\alpha*\cos\beta & -\sin\alpha*\cos\beta & -\sin\beta\\ \sin\alpha & \cos\alpha & 0\\ \cos\alpha*\sin\beta & -\sin\alpha*\sin\beta & \cos\beta\end{bmatrix}.$$

For modelling the **process of abrasion**, according to the described models I define numerous abraded forms, on which I calculate shape descriptors. In the radial model (1.1.1) $r_t=c*r,\ c\in\boldsymbol{R}$, when K is self-similar, Fig. 6 shows two super-ellipsoids ($n=2,\ n=100$) in the process. In the radial model (1.1.2) $r_t=c*r^2,\ c\in\boldsymbol{R}$, when K converges to a sphere, Fig. 7 shows two super-ellipsoids ($n=2,\ n=100$) in the process. In the parallel model (1.2.1) $r_t=-c*r,\ c\in\boldsymbol{R}^+$, Fig. 8 shows ellipsoids with "special" and "general" initial conditions in the process.

For calculating the **axle ratios** of $K(T)$, I use the following definition. Axis $a(T)$ is the distance of the longest line segment fitting in $K(T)$, axis $c(T)$ is the shortest line segment fitting in $K(T)$, and axis $b(T)$ is the line segment fitting in $K(T)$ perpendicular to $a(T)$ and $c(T)$. I calculate $y_1(T)$ and $y_2(T)$ as defined in chapter 3.

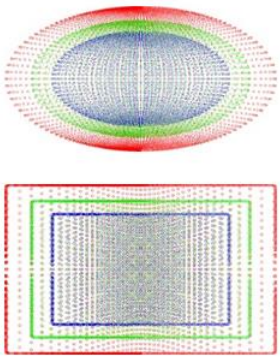

Fig. 6. Self-similar radial model of abrasion of an ellipsoid and a cuboid, orthogonal views.

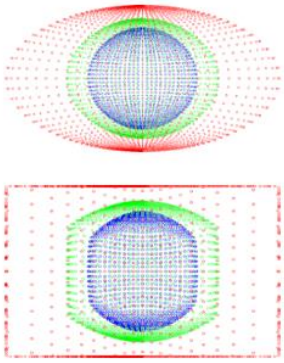

Fig. 7. Converging radial model of abrasion of an ellipsoid and a cuboid, orthogonal views.

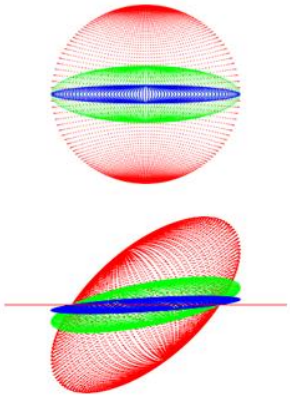

Fig. 8. Parallel model of abrasion of an ellipsoid under "special" (above) and "general" (below) conditions, orthogonal views.

In the radial model (1.1.1) $r_t = c * r,\ c \in \boldsymbol{R}$, when K is self-similar, numerical analysis confirms *Theorem 1* (Fig. 9). In the radial model (1.1.2) $r_t = c * r^2,\ c \in \boldsymbol{R}$, when K converges to a sphere, numerical analysis confirms *Theorem 2* (Fig. 10). In the parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$, numerical analysis confirms Remark 8 of article [5] (Fig. 11).

Conjecture 1: In the parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+$, under orthogonal affinity of an ellipsoid, where the plane of affinity intersects the geometric centre of the ellipsoid, y_1 is a quasiconcave function, while y_2 may have several maxima. (Remark 8 of article [5] (with "special conditions") is true also when removing one condition (with "general" conditions)) (Fig. 12 and 13).

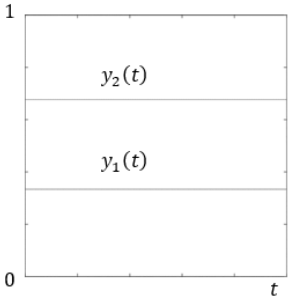

Fig. 9. Axle ratios of a convex body under self-similar radial abrasion.

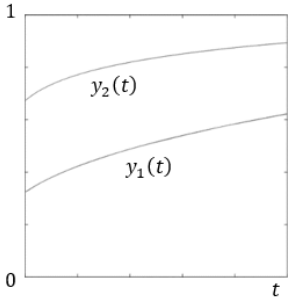

Fig. 10. Axle ratios of a convex body under converging radial abrasion.

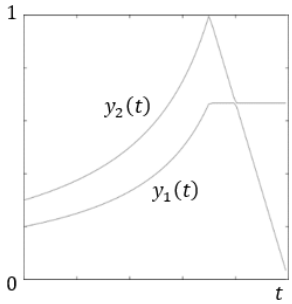

Fig. 11. Axle ratios of an ellipsoid under parallel abrasion with “special” initial conditions.

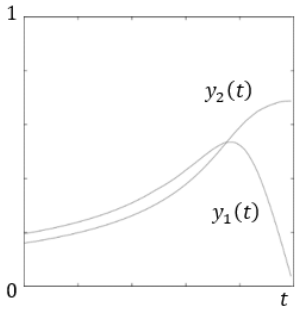

Fig. 12. Axle ratios of an ellipsoid under parallel abrasion with "general" initial conditions.

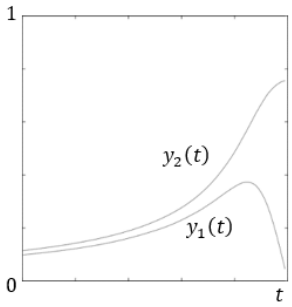

Fig. 13. Axle ratios of an ellipsoid under parallel abrasion with "general" initial conditions.

For analysing the **isoperimetric ratio**, the volume and surface values of $K(T)$ must be calculated. As a numerical model, $K(T)$ has only finite number of points defined on the surface. I divide $K(T)$ to small triangles, the vertices of which are these points. The approximate value of the surface of $K(T)$ is the sum of the areas of these triangles $S(T) = \sum_{i=1}^{N} \sqrt{s(s_i - l_{1_i})(s_i - l_{2_i})(s_i - l_{3_i})}$, where $S(T)$ is the surface of $K(T)$, N is the number of triangles defined on the surface, l_{1_i}, l_{2_i} and l_{3_i} are the sides of the triangle indexed i, and s_i is half of the perimeter of the triangle indexed i. I assign tetrahedra to these triangles, the fourth vertex of which is the centre of $K(T)$. The approximate value of the volume of $K(T)$ is the sum of the volumes of these tetrahedra $V(T) = \sum_{i=1}^{N} \frac{1}{6} * \left| det \begin{bmatrix} \underline{m}_{1_i} \\ \underline{m}_{2_i} \\ \underline{m}_{3_i} \end{bmatrix} \right|$, where $V(T)$ is the volume of $K(T)$, N is the number of tetrahedra defined in the body, $\underline{m}_{1_i}, \underline{m}_{2_i}$ and $\underline{m}_{3_i}$ are three edges of the tetrahedron indexed i, from the centre of $K(T)$. I calculate $I(T)$ as defined in chapter 3.

In the radial model (1.1.1) $r_t = c * r, \ c \in \boldsymbol{R}$, when K is self-similar, numerical studies confirm *Theorem 3* (Fig. 14). In the radial model (1.1.2) $r_t = c * r^2, \ c \in \boldsymbol{R}$,

when K converges to a sphere, numerical studies confirm *Theorem 4* (Fig. 15). In the parallel model (1.2.1) $r_t = -c * r,\ c \in \boldsymbol{R}^+,$ numerical studies confirm Theorem 6 of article [5] (Fig. 16).

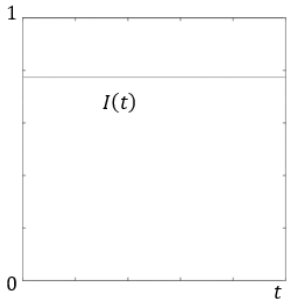

Fig. 14. Isoperimetric ratio of a convex body under self-similar radial abrasion.

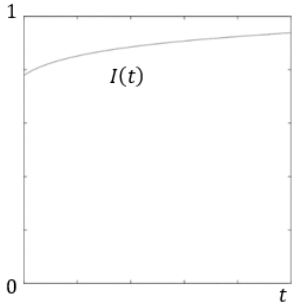

Fig. 15. Isoperimetric ratio of a convex body under converging radial abrasion.

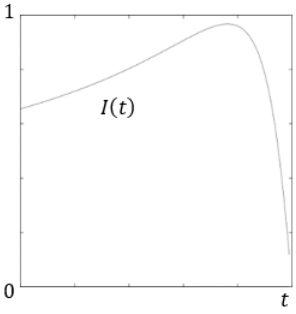

Fig. 16. Isoperimetric ratio of an ellipsoid under parallel abrasion with both “special” and “general” conditions.

For analysing the **equilibrium points**, the first and second derivatives of $K(T)$ are needed. The approximation of the first and non-mixed second derivatives of $K(T)$ in (φ_0, ϑ_0) in direction φ are $r_\varphi(\varphi_0, \vartheta_0) = \frac{r(\varphi_0+\Delta\varphi, \vartheta_0) - r(\varphi_0, \vartheta_0)}{\Delta\varphi}$ and $r_{\varphi\varphi}(\varphi_0, \vartheta_0) = \frac{r_\varphi(\varphi_0+\Delta\varphi, \vartheta_0) - r_\varphi(\varphi_0, \vartheta_0)}{\Delta\varphi}$. The limit of these values when $\Delta\varphi \to 0$ result the analytic definition of differentials. In direction ϑ, similarly. I calculate $S(T), U(T)$ and $H(T)$ as defined in chapter 3.

In the radial model (1.1.1) $r_t = c * r, \ c \in \boldsymbol{R}$, when K is self-similar, numerical studies confirm *Theorem 5*.

Conjecture 2: In the radial model (1.1.2) $r_t = c * r^2, \ c \in \boldsymbol{R}$, when K converges to a sphere, the number of equilibrium points is constant.

5. SUMMARY OF RESULTS

Morphodynamics is an interdisciplinary task of science. The models of abrasion of rocks requires the use of geology, astronomy, physics, mathematics, and so on. In this paper, I analysed parts of the mathematical models. I managed to numerically verify some already existing, outstanding analytic results, and to draw up some new theorems and conjectures based on both numerical and analytic studies. Formulating conjectures according to numerical calculations might be the base of further analytic research. I hope that this branch of science will be able to show up such important and spectacular results in the future, as it could in the past.

This paper was created by summarising my previous Scientific Student Conference studies [8] and [9]. These documents were never submitted to any journal or another conference with proceedings.

ACKNOWLEDGEMENTS

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Key words:
optimal power flow, heuristic algorithms, global minimum, power systems

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REVIEW OF HEURISTIC APPROACHES TO OPTIMAL POWER FLOW

This paper presents a brief review of the heuristic approaches applied to solving optimal power flow (OPF) problems. The optimal power flow problem represents a crucial problem for utilities depending on goals that are set, power flow can be optimised in order to minimise operational costs, to reduce line losses, to reduce the emission intensity of numerous sources of power in a power system amongst other goals. Traditionally, the OPF problems are solved using mathematical methods such as quadratic programming, linear programming and interior point methods but, these methods have some inherent issues such as the inability to converge to a solution when the starting point given to the method is inaccurate, entrapment in the local minima of the solution instead of minimizing the global objective function etc. To overcome these issues a set of algorithms that mimic natural processes called heuristic algorithms are applied to the OPF problem and recent research has demonstrated its effectiveness in obtaining a reliable optimal solution. This paper reviews some of the popular heuristics that have been applied to the OPF problem with their applicability to the IEEE30 bus test case system.

1. INTRODUCTION

The need for optimal power flow (OPF) comes from numerous goals of varied stakeholders, typically the utilities are interested in the OPF problem in order to re-duce the cost of producing power, reducing transmission line losses etc. [1,2]. The society in its drive towards a sustainable future is focused on the OPF problem with an objective to reduce emissions intensity of the sources in a power system along with other objectives such as energy security and reliability [3].

The OPF problem can be defined as a non-linear, non-convex, heavily constrained problem with an objective function that cannot be differentiated [3]. The approach to solving OPF problems can be classified into two broad categories: conventional and

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heuristic. The conventional methods include linear programming [7], quadratic programming [7], gradient method [3], interior point methods amongst others. The use of linear programming to solve the OPF problem for micro grids consisting of renewable energy sources is described in [6]. The conventional methods are mathematical approaches to solving the problem. Recent research is ongoing in the use of heuristic approaches which can be defined as approaches that mimic or replicate the behavior of numerous natural phenomena in order to find a solution to the OPF problem.

A few examples of the same are as follows: [1] uses genetic algorithm to solve the OPF problem wherein, an initial set of population (solutions) is created. Thereon, the fitness of each solution (individual) is calculated according to the objective function of the OPF problem. Further steps involve crossover and mutation of the best individ-uals to create a new population also called a new generation of individuals that have higher fitness. This process is repeated until a population of the desired fitness is achieved, the stopping criterion in certain cases can also be the run time of the algo-rithm or the total number of generations evaluated.

Another popular heuristic approach is the particle swarm optimization (PSO) [4,8], while in [8] the traditional PSO is used where the particle (solution) is able to learn from its previous experiences and from that of the best particle of the population, [4] presents a modified PSO where the particles are able to learn not only from their pre-vious experiences and the best individual but also from other individuals. Both ap-proaches are demonstrated in microgrids.

Artificial bee colony algorithm which is based on the foraging behavior of bees to find a solution to the OPF problem is described in [5] and is evaluated on 4 different test cases.

The rest of the paper is organized into two sections, one presenting the OPF problem in its general mathematical format and another presenting a comparison of the different heuristic approaches to OPF applied to a standard IEEE 30 bus test case.

2. MATHEMATICAL DESCRIPTION OF OPTIMAL POWER FLOW

The OPF problem though can be solved with different objective functions the most common objective function used is that of the costs involved in producing power. This paper also considers minimizing the fuel costs involved in ($/hr).

$$\text{Minimize } f(x,u) \tag{1}$$

$$g(x,u) = 0 \tag{2}$$

$$h(x,u) \leq 0 \tag{3}$$

Here, *f(x,u)* is the objective function to be minimized subject to equality constraints *g(x,u)* and inequality constrains *h(x,u)*.

$$f = \sum_{i=1}^{N_{gen}} F_i(P_i) \tag{4}$$

Here, F_i, is the cost function of the individual generators of the system P_i. The equality constraints for the system are the balance equations for active and reactive power as described in equations (5) and (6).

$$P_{gi} = |V_i| \sum_{k=1}^{n} |V_k||Y_{ik}| \cos(\theta_{ik} + \delta_k + \delta_i) + P_{di} \tag{5}$$

$$Q_{gi} = -|V_i| \sum_{k=1}^{n} |V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k + \delta_i) + Q_{di} \tag{6}$$

Where P_{gi} , Q_{gi} , P_{di} , Q_{di} are the active and reactive powers generated and demand at nodes *i* and *k* of the power system. V_i and V_k represent the voltage magnitude at nodes *i* and *k* of the power system. Y_{ik} is the admittance of the line between nodes *i* and *k*. δ_i and δ_k are the voltage angles at buses *i* and *k*. Whereas, θ_{ik} is the admittance angle of the line between *i* and *k*.

The inequality constraints of the system are described in equations (7) – (10).

$$P_{gi}^{\min} \leq P_{gi} \leq P_{gi}^{\max} \; \forall \; i \; \in No.of \; gen. \tag{7}$$

$$Q_{gi}^{\min} \leq Q_{gi} \leq Q_{gi}^{\max} \; \forall \; i \; \in No.of \; gen. \tag{8}$$

$$V_i^{\min} \leq V_i \leq V_i^{\max} \; \forall \; i \; \in No.of \; gen. \tag{9}$$

$$\left|S_{ij}\right| \leq S_{ij}^{\max} \; \forall \; i \; \in No.of \; gen. \tag{10}$$

Where, apart from the variables defined earlier Q_{gi} is the reactive power generated at node *i*. S_{ij} being the line limits for apparent power between nodes *i* and *j*.

3. HEURISTIC ALGORITHM PERFORMANCE

The comparison of different heuristic algorithms presented here is based on their performance on the IEEE 30 bus test case system. Fig. 1 Presents the IEEE 30 bus test case single line diagram. The system has in total 6 generators spread across the system with different cost coefficients. The cost coefficients are presented in Table 1 and are expressed in the form of a quadratic equation as shown in (11).

$$F_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 \quad (11)$$

Here, $F_i(P_i)$, represents the cost function of the individual generators of the system and α, β, γ represent the cost coefficients in \$/hr.

Table 1. Cost coefficients of generators

Generator (Bus)	γ	β	α
1	0.004	2.000	0
2	0.018	1.750	0
5	0.063	1.000	0
8	0.008	3.250	0
11	0.025	3.000	0
13	0.025	3.000	0

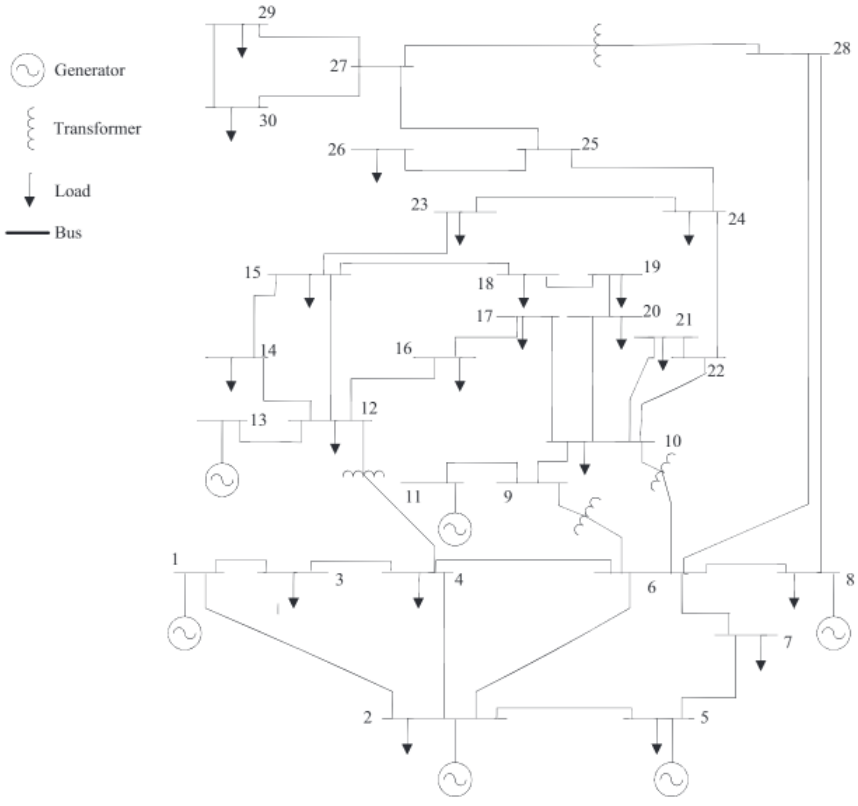

Fig. 1. IEEE 30 bus test case

Table 2 represents the final minimum cost obtained by 4 different heuristic algorithms and 1 conventional algorithm, which are the Teaching-learning based optimization [8], PSO, Improved genetic algorithm [10], Artificial bee colony [5] and the gradient method. A more comprehensive set of results along with other heuristic algorithm performances can be viewed in [8,3].

Table 2. Final minimal costs achieved by each algorithm

Algorithms	Min. Cost ($/hr)	Time (sec)
Teaching learning Based Optimization	800.42	24.27
Particle Swarm Optimization	801.89	20.19
Improved Genetic Algorithm	800.80	NA
Gradient Method	804.85	4.32
Artificial Bee Colony	800.66	NA

Source: Authors' own elaboration.

4. CONCLUSIONS

It can be concluded from the results that the Teaching-Learning based optimization approach was able to find the lowest cost in ($/hr) for the given test case as against the other methods though it should be noted that the difference amongst all techniques is not profound. The category of heuristic algorithms on the whole were able to minimise the cost when compared to the traditional gradient algorithm. With regards to the time taken by each and every method to arrive at the solution it can be said that the conventional mathematical approach was the quickest to do so within 4.32 seconds whereas the heuristic algorithms took much longer time with the information on time being unavailable for artificial bee colony and improved genetic algorithm. The time factor is crucial for power systems as real time networks are often spread across vast geographical areas and are heavily complex with regard to the number of different of system components and their interconnection. This makes the traditional approach more suitable for the large-scale system as it is still able to arrive at an acceptable cost in a very short span of time. Further research has to be conducted in order to reduce the computational time related to the heuristic algorithms as their final solution is better and with decreased computational times can lead to cost savings and their applicability to systems of scale.

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Key words:
general relativity; Penrose mechanism; black holes

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PENROSE MECHANISM IN SPHERICALLY SYMMETRIC SPACETIMES

It was shown by Bañados et al. [1] that collisions of the particles in vicinity of a black hole horizon result in energy outcome bounded by $2\sqrt{5}m_0$ in case of Schwarzschild black holes. It is shown here that such collisions would lead to an arbitrary large value of the (centre of mass) energy under very specific circumstances. We also show that for the collisions of uncharged particles in vicinity of Reissner–Nordström black hole horizon in general case the centre of mass energy can be unbounded as well as infinite in case of extreme Reissner–Nordström black hole. Such a process is also studied in the case of a Schwarzschild black hole.

1. INTRODUCTION

The aim of this paper is to reconsider the problem of an energy outcome in the case of colliding particles in vicinity of black hole in spherically symmetric spacetime geometries. Bañados et al. have shown that in Schwarzschild geometry the maximum centre of mass energy of the two colliding particles falling from infinity is $E_{cm}^{max} = 2\sqrt{5}m_0$ [1] where m_0 is the mass of the two colliding particles. We generalize this result in terms of initial conditions for total energy and obtain rather counter intuitive result that collision of two particles falling from a finite distance would yield arbitrary large energy during collisions near black hole horizon. Furthermore Bañados et al. [1] and Abramowicz et al. [2] showed that for extreme Kerr black hole the centre of mass energy of colliding particles diverges at the horizon. This inspired us to extend our considerations to Reissner–Nordström geometry where we first have considered the general case and then studied the case of extreme Reissner–Nordström black hole. Centre of mass energy is given as follows [1]:

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$$E_{cm} = \sqrt{(\boldsymbol{p_1} + \boldsymbol{p_2})^2} \tag{1}$$

where $\boldsymbol{p_1}$ and $\boldsymbol{p_2}$ are the four-momenta of the colliding particles. We see that:

$$E_{cm}^2 = (\boldsymbol{p_1} + \boldsymbol{p_2})^2 = \boldsymbol{p_1}^2 + \boldsymbol{p_2}^2 + 2\boldsymbol{p_1} \cdot \boldsymbol{p_2} = m_1^2 + m_2^2 + 2m_1 m_2 \boldsymbol{u_1} \cdot \boldsymbol{u_2} \tag{2}$$

Hence $E_{cm}^2 \sim \boldsymbol{p_1} \cdot \boldsymbol{p_2}$ throughout the paper we will infer about the centre of mass energy based on the dot product of the four-velocities of the particles. Throughout this paper we will use the $(+,-,-,-)$ signature and use geometrized units where c = G = 1.

2. CENTRE OF MASS ENERGY

We will discuss the problem of two-particle collisions in the Schwarzschild geometry and in Reissner–Nordström geometry. Both geometries are spherically symmetric and time independent hence there are two Killing vectors and two resulting conserved quantities. Killing vector associated with time independence: $\boldsymbol{\xi} = (1,0,0,0)$ and with azimuthal angle independence: $\boldsymbol{\eta} = (0,0,0,1)$. We define constant of motion A as total energy per unit mass i.e.

$$A \equiv \boldsymbol{\xi} \cdot \boldsymbol{u} = g_{\alpha\beta}\xi^{\alpha}u^{\beta} = g_{tt}u^{t} \tag{3}$$

and l as total angular momentum per unit mass i.e.

$$l \equiv -\boldsymbol{\eta} \cdot \boldsymbol{u} = -g_{\alpha\beta}\eta^{\alpha}u^{\beta} = -g_{\varphi\varphi}u^{\varphi} \tag{4}$$

As the angular momentum is conserved the motion of the particles is constrained to a plane e.g. the equatorial plane, $\theta = \frac{\pi}{2}$. For simplicity we assume that both particles move in the same, equatorial plane. In both cases we consider motion of uncharged particles. Then, the two metrics differ only in the explicit form of g_{tt} which is

$$g_{tt} = 1 - \frac{2M}{r} \tag{5}$$

for Schwarzschild geometry and

$$g_{tt} = \left(1 - \frac{r_S}{r} + \frac{r_Q^2}{r^2}\right) \tag{6}$$

for Reissner–Nordström geometry.
The metric is therefore as follows:

$$ds^2 = g_{tt}dt^2 - g_{tt}^{-1}dr^2 - r^2d\theta^2 - r^2d\varphi^2 \tag{7}$$

We find the geodesic equations without explicit form of g_{tt} using the constants of motion and normalization condition for four-velocity i.e. $\boldsymbol{u}^2 = 1$ so that the result is

suitable for both geometries. Therefore, we obtain the following components of the four-velocity:

$$\begin{aligned} u^t &= \frac{A}{g_{tt}} \\ u^r &= -\sqrt{A^2 - g_{tt}\left(\frac{l^2}{r^2}+1\right)} \\ u^\theta &= 0 \\ u^\varphi &= \frac{l}{r^2} \end{aligned} \tag{8}$$

Setting $A = 1$, our results reduce to that found in [1].

We choose the negative sign solution to the r component of four-velocity since we consider in-falling geodesics (i.e. moving towards the black hole). Then, the dot product of two four-velocities is as follows:

$$\boldsymbol{u_1 \cdot u_2} = \frac{A_1 A_2 - \sqrt{A_1^2 - g_{tt}\left(\frac{l_1^2}{r^2}+1\right)}\sqrt{A_2^2 - g_{tt}\left(\frac{l_2^2}{r^2}+1\right)} - g_{tt}\frac{l_1 l_2}{r^2}}{g_{tt}} \tag{9}$$

Now we shall derive the explicit expression for centre of mass energy in both cases, using (9) stated as above.

2.1. SCHWARZSCHILD GEOMETRY

We calculate the limit of expression (9) with g_{tt} in Schwarzschild space-time (5) as r approaches $r_S = 2$ (i.e. M=1).

$$\lim_{r\to 2} \boldsymbol{u_1 \cdot u_2} = \frac{1}{8}\left(\frac{A_2\left(4+l_1^2\right)}{A_1} - 2l_1 l_2 + \frac{A_1\left(4+l_2^2\right)}{A_2}\right) \tag{10}$$

One can see that this expression can get arbitrarily large when either of values A_1, A_2 will be small.

We expand the dot product (9) of two four-velocities of the particles in Taylor series around the horizon (r = 2):

$$\begin{aligned} \boldsymbol{u_1 \cdot u_2} = \frac{1}{8}\left(\frac{A_2\left(4+l_1^2\right)}{A_1} - 2l_1 l_2 + \frac{A_1\left(4+l_2^2\right)}{A_2}\right) + \\ + D_1(r-2) + D_2(r-2)^2 + \mathcal{O}((r-2)^3) \end{aligned} \tag{11}$$

The first term is then the limit at $r = 2$ (at the horizon) seems to be arbitrarily large. If this was the case, then one could come to conclusion that the value of this dot product based on its Taylor expansion around 2 can in fact be arbitrarily large everywhere even if one takes all terms into account, because the first one is. As the reality we know suggests (we do not observe arbitrarily large centre of mass energies away from black holes) and as can be viewed from the Fig. 1, this is not the case. This discrepancy

aroused because of naive inference about expression (10). It turns out that not all of the values of A_1, A_2 are allowed due to the fact that the expressions under the square roots in (9) must remain positive i.e. the values of A_1^2 and A_2^2 must be grater than $g_{tt}\left(\frac{l^2}{r^2}+1\right)$ which approaches 0 with r approaching the horizon. A_1 and A_2 are constants that result from initial conditions. Such initial conditions required for (1) to be arbitrarily large are possible, but only in the close vicinity of event horizon. One mechanism that could lead to creation of such particles is Hawking radiation [3].

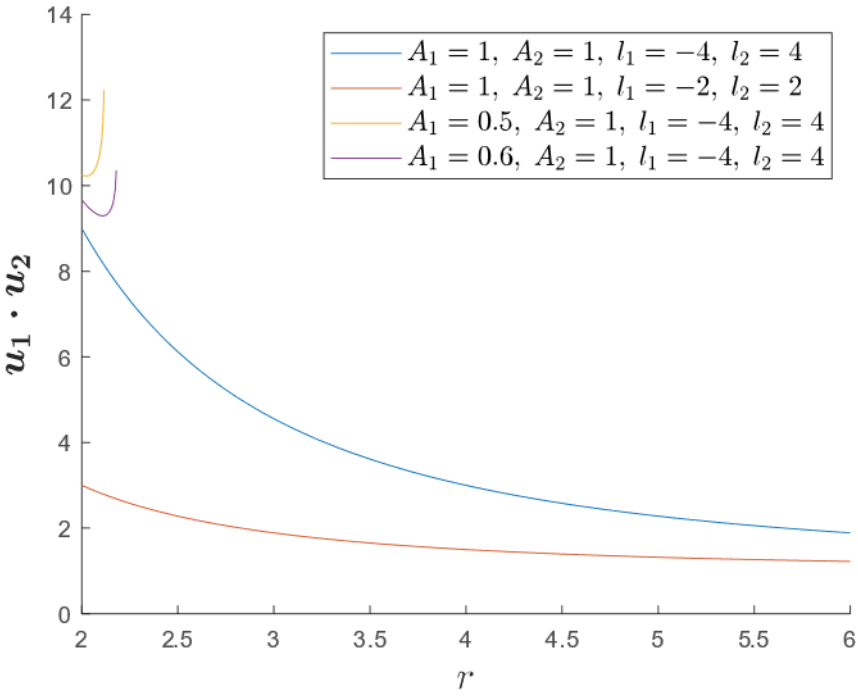

Fig. 1. Dot product of four-velocities of two particles as a function of their distance from the horizon for various initial conditions. The plot starts at $r = 2$ which having set the mass of the black hole to unity is the horizon of the black hole. Notice that the smaller is either of the values of A, the bigger the value of the dot product and the smaller the range in which this expression is well defined.

If we put $A_1 = A_2 = 1$, which is an unjustified oversimplification of a problem, then our result reduces to the one obtained in [1] where maximal value of E_{cm} is $2\sqrt{5}$.

In Reissner–Nordström geometry in addition to geometrized units we also put $4\pi\epsilon_0 = 1$ so that the $r_S = \frac{2GM}{c^2} = 2M$ and $r_Q^2 = \frac{Q^2 G}{4\pi\epsilon_0 c^4} = Q^2$. Then:

$$g_{tt} = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} \tag{12}$$

For the same reason as formerly, we look at the dot product. This time though, the location of the horizon is different and in principle for non- extreme Reissner–Nordström black holes we have two horizons. Those arise when g_{tt} is equal to 0. By solving $1 - \frac{2M}{r} + \frac{Q^2}{r^2} = 0$ we obtain:

$$\begin{aligned} r_- &= M - \sqrt{M^2 - Q^2} \\ r_+ &= M + \sqrt{M^2 - Q^2} = M + M\sqrt{1 - \left(\frac{Q}{M}\right)^2} \end{aligned} \tag{13}$$

We define $a \equiv \frac{Q}{M}$ as a parameter of extremity of a black hole. The area between the two horizons is the area where the g_{tt} is negative. One can see that for extreme black hole a = 1 (Q = M) the two horizons overlap.

The limit of the dot product with r approaching horizon (r_+) is as follows:

$$\lim_{r \to r_+} \boldsymbol{u_1} \cdot \boldsymbol{u_2} = -\frac{l_1 l_2}{2M^2 \varrho} + \left(\frac{l_1^2}{2M^2 \varrho} + \frac{1}{2}\right)\frac{A_2}{A_1} + \left(\frac{l_2^2}{2M^2 \varrho} + \frac{1}{2}\right)\frac{A_1}{A_2} \tag{14}$$

where we define $\varrho \equiv 2 - a^2 + 2\sqrt{1 - a^2}$.

One can see that due to the presence of quotient terms involving A_1 and A_2, expression (14) can be arbitrarily large if either of values A_1, A_2 is small. The interpretation and constraints on A_1 and A_2 are analogous to the ones presented in the former section. The behaviour of the dot product as the function of r is like the one presented in fig.1. As can be seen from equation (14), the extremity of a Reissner–Nordström is not necessary for it to be arbitrarily large since for a = 1, $\varrho = 1$. However as presented in fig. 2. the value of (14) is indeed the largest for extreme black hole.

3. INTERIOR OF A BLACK HOLE

Centre of mass energy problem may be also addressed inside the horizon of black holes.

For the Schwarzschild black hole interior, we use the metric used in [4] except that we change signature to match ours that is $(+,-,-,-)$. So, the metric looks as follows:

$$ds^2 = -\left(1-\frac{2}{t}\right)^{-1} dt^2 + \left(1-\frac{2}{t}\right) dr^2 - t^2 d\theta^2 - t^2 d\varphi^2 \tag{15}$$

As we can see the metric of the interior is analogous to that of exterior, except that r and t switch their roles. Detailed discussion can be found in [4]. In our part of the Universe i.e. outside of event horizon, r component of four-velocity can be both positive and negative (we can move either towards or away from the black hole) and the time is always increasing. Inside the black hole horizon, it is the radial component of the four-velocity which changes only in one direction that is towards decreasing r, so it plays the of temporal coordinate. Time component though can in fact be both positive and negative, so it plays the role of spatial coordinate.

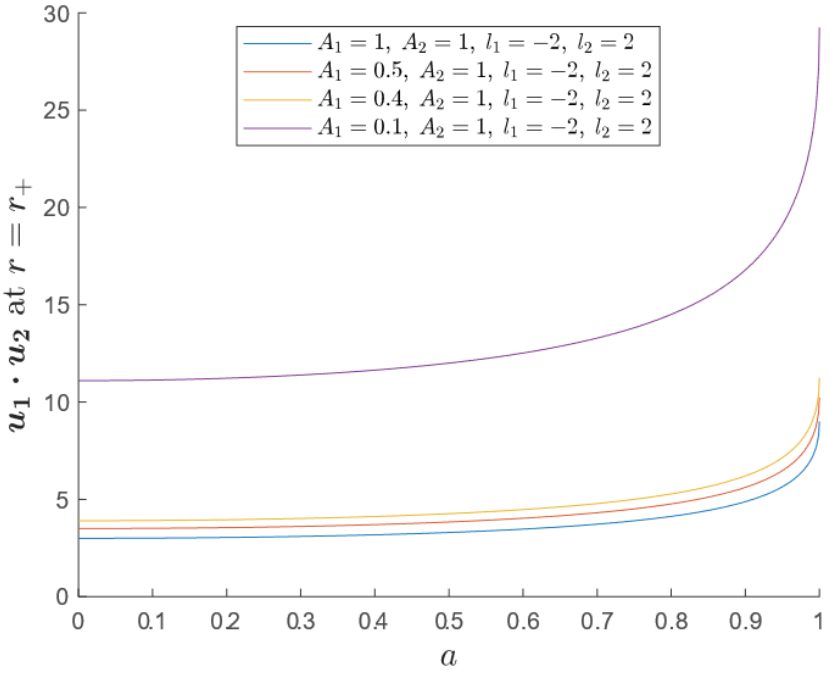

Fig. 2. Limit of the dot product of four-velocities of two particles on the outer horizon in Reissner–Nordström geometry as a function of the extremity of the black hole. Note that the value of the dot product is the biggest for the extreme Reissner–Nordström black hole.

The procedure of finding geodesics in the interior of the black hole is similar but one of the Killing vectors changes its character from time-like to space-like, that is $\xi = (1,0,0,0)$ becomes $\xi = (0,1,0,0)$ [5]. This fact changes the interpretation of the constant of motion generated by this Killing vector. In previous section we found constant of motion A as a dot product of ξ with the particle four-velocity and interpreted that as total energy per unit mass. Inside the black hole horizon, this constant can be interpreted as a component of particle's four-momentum [4]. Therefore, in order to avoid confusion, we define $P \equiv \xi * u$. Then, solution to the geodesic's equation is as follows [4]:

$$\begin{aligned} u^t &= -\sqrt{P^2 - \left(1 - \frac{2}{t}\right)\left(\frac{l^2}{t^2} + 1\right)} \\ u^r &= \frac{P}{1 - \frac{2}{t}} \\ u^\theta &= 0 \\ u^\varphi &= -\frac{l}{t^2} \end{aligned} \tag{16}$$

Hence the dot product is:

$$\boldsymbol{u_1} \cdot \boldsymbol{u_2} = -\frac{\sqrt{P_1^2 - \left(1-\frac{2}{t}\right)\left(\frac{l_1^2}{t^2}+1\right)}\sqrt{P_2^2 - \left(1-\frac{2}{t}\right)\left(\frac{l_2^2}{t^2}+1\right)}}{1-\frac{2}{t}} - \frac{l_1 l_2}{t^2} + \frac{P_1 P_2}{1-\frac{2}{t}} \tag{17}$$

Notice that since $t \in (0,2)$, $\left(1 - \frac{2}{t}\right)$ is always negative which makes all real values of P to be allowed (which is consistent with our interpretation of P as momentum which can be both positive and negative). We analyse the limit of this expression as it approaches 2 from below for different values of P_1 and P_2. In principle, there are only two cases that can occur:

$$\lim_{r \to r^-} \boldsymbol{u_1} \cdot \boldsymbol{u_2} = \begin{cases} \infty & : P_1 P_2 < 0 \\ \frac{1}{8}\left(\frac{P_2\left(4+l_1^2\right)}{P_1} - 2l_1 l_2 + \frac{P_1\left(4+l_2^2\right)}{P_2}\right) & : P_1 P_2 > 0 \end{cases} \tag{18}$$

As it can be seen from equation (18), the existence of particles with negative values of P allows the dot product of four-velocities and hence the centre of mass energy to diverge. Such situation may happen, when a particle crosses the horizon of black hole and collides with another particle bounded to the interior of black hole and thus allowed to have negative value of P. However, this divergence is not to be concerned with, as such situation can only happen inside of the black hole event horizon, which is a region of space-time forever lost to any outside observer. In our part of the universe (black hole exterior) one can approach the horizon as many times as one wish, for instance: getting close to the horizon of black hole, firing the rocket engines to fly away and repeat. On the other hand, things look different inside the black hole horizon. Once you're inside the only time you get close to the horizon of black hole is at the very instant of crossing

it. Since t and r switch roles in the interior of a black hole, the horizon becomes a place in time and once you pass it you can only move away from it.

3.2. EXTREME REISSNER–NORDSTRÖM BLACK HOLE

In section 2.2 we have shown that for generic case when both particles fall towards the black hole and collide near the black hole horizon the centre of mass energy can be arbitrarily large. In general, Reissner–Nordström black hole can have two horizons that is inner (r_-) and outer (r_+). Between those two the g_{tt} element of the metric is negative and thus $\boldsymbol{\xi}$ becomes space-like. It was shown by Zaslavskii et al. in [6] that possible collisions of charged particles near the inner horizon result in bounded energy. For extreme Reissner–Nordström black hole the two horizons overlap hence the g_{tt} element of the metric is always grater than or equal to 0. Thus $\boldsymbol{\xi}$ remains time-like on both sides of the $g_{tt} = 0$ surface. Therefore, we suppose the conserved quantity associated with it has the interpretation of energy on both sides and on both sides, we can move either towards or away from black hole horizon. This allows us to consider the collision of uncharged particles coming from opposite directions. Then the limit of the dot product of the four-velocities as r approaches M (that is the horizon for extreme Reissner–Nordström black hole) of such particles diverges and hence the centre of mass energy is infinite. However, possibility of such process requires further studies and provide grounds for further discussion.

3. CONCLUSIONS

In this paper we have studied the problem of the centre of mass energy of two particles in spherically symmetric space-times. We have found that by considering general case of collision of two particles near the horizon of the spherically symmetric black holes not all the possible values of constants of motion ($A_{1,2}$)representing their total energy are allowed. Bañados et al. [1] found that for $A_1 = A_2 = 1$ the center of mass energy is bounded by $2\sqrt{5}m_0$. We showed that for collisions of particles in which one of the particle's total energy (A) is small, the center of mass energy can reach arbitrarily large values. The particles with small values of A can only exist in close vicinity of a horizon of the black hole. It was shown that collision of two particles, one falling from infinity and the other one starting its fall in close vicinity of the horizon yields arbitrarily large centre of mas energy. Next, we have addressed this problem inside the horizon of a Schwarzschild black hole. Throughout our considerations we have used solution to Einstein equations corresponding to the Schwarzschild black hole interior as in [4]. We have found that for particles with momenta ($P_{1,2}$) of the same sign the limit of the dot product of the four-velocities of the two particles as t approaches

horizon of black hole from below (from interior side), is exactly the same as the limit we obtained for the collision of the particles approaching the horizon from the exterior of the black hole. For the particles with momenta ($P_{1,2}$) of opposite sign, the limit of the center of mass energy is unbounded. This is possible as in the interior of the black hole the constant of motion associated with energy (therefore positive) becomes the component of four-momentum of the particle inside the interior of the black hole. Then, such a collision of particles in which one crossed the black hole event horizon (and thus have a positive constant of motion) and second existed in the interior (and thus being able to have its constant of motion negative) seem to yield infinite centre of mass energy. This infinite energy though is not to be concerned with as such events can possibly happen only in the interiors of the black holes and therefore this energy is not accessible or detectable for any outside observer. Our results obtained for Schwarzschild geometry can be extended to Reissner–Nordström geometry. We have shown that for generic case the centre of mass energy of uncharged particles colliding in vicinity of outer horizon of Reissner–Nordström black hole is also unbounded. Then we considered collision of particles moving directly towards each other form different sides of the surface of $g_{tt} = 0$ of extreme Reissner–Nordström black hole. Centre of mass of such particles seem to be infinite in that case, however possibility of such process requires further studies.

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Key words:
nanophotonics, quantum dot, nanofiber, spin

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TUNING THE EXCITON POLARIZATION TO OBTAIN ALMOST FULL CONTROL OF SPONTANEOUS EMISSION DIRECTION FROM A QUANTUM DOT

The spin of light in subwavelength-diameter waveguides can be orthogonal to the propagation direction of the photons because of the strong transverse confinement. This transverse spin changes sign to the opposite when the direction of propagation is reversed (spin-orbit coupling – SOC). We do the theoretical simulation of spontaneous emission from a quantum dot (QD) into the fundamental mode of an optical nanofiber using SOC effect. The direction of emission of a nearby QD is correlated with the polarization of the excitonic transition. We tune this polarization to reach near unidirectional emission into the guided mode. This optimization of QD's exciton provides more than 95% of the optical power emitted in one direction. We expect our results to be of great importance for research in quantum optics and for implementations of a quantum computer.

1. INTRODUCTION

The main goal in quantum optics is to have full control of light and matter interaction. Photonic nanostructures can be a good candidate for this. In the nanostructures that are strongly confined transversely (in the plane orthogonal to the propagation direction) occurs a longitudinal component [1,2] of the electric field. This component and transverse field component oscillate $\pm\pi/2$ radians out of phase with each other. Consequently, the electric field is elliptically polarized and, therefore, a transverse component of spin angular momentum is present. The sign of spin flips with the inversion of propagation direction. This link between spin sign and the propagation

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direction of light is called spin-orbit coupling (SOC [2-6]). SOC can lead to propagation-direction-dependent emission, scattering [7, 8] and absorption of photons by quantum emitters. It can be explained by transverse spin coupling to quantum emitters with polarization-dependent dipole transitions. The direction-dependent light-matter interaction leads to chiral quantum optics [9]. The unidirectional process, e.g. spontaneous emission can be the basis for innovative applications in quantum communication and quantum information processing. The chiral coupling can be implemented with tapered optical fiber coupled to atoms [5, 7] or nanoparticle [8], whispering gallery mode micro resonators coupled to atom [10, 11], photonic-crystal waveguide coupled to quantum dot [12]. We show that nanofiber constitutes a good tool for coupling light and matter.

2. MODEL

Our system is very simple and contains a cylindrical single mode nanofiber with a core radius of 250 nm and core-cladding index contrast of 1.09 and pointlike quantum emitter (quantum dot). QD is placed in plane in the vicinity of a nanofiber containing fiber axis. Running-wave field has a wavelength of 852 nm.

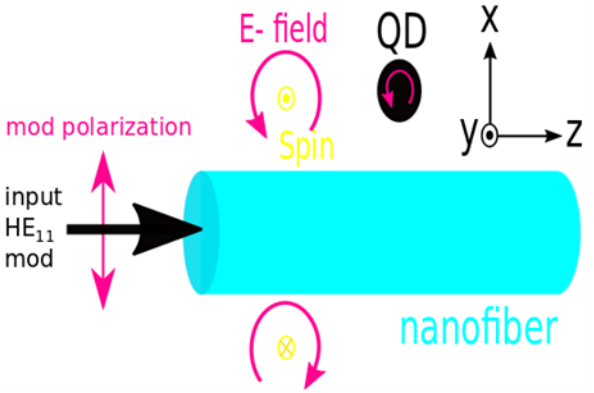

Fig. 1. For light polarized along the x axis and propagating in +z direction, this leads to nearly circular polarization σ+ on the top of the fiber and σ- polarization on the bottom of the fiber (circular magenta arrows). Rotating E field results in generation of spin angular momentum of the light (yellow arrows) that is oriented perpendicular to the propagation direction.

3. NUMERICAL RESULTS

3.1. ELECTRIC FIELD DISTRIBUTION IN NANOFIBER

In our model single mode (HE_{11}) regime is obtained. Guided light field can be decomposed into the quasi-linearly polarized fiber eigenmodes $HE^{\pm}_{11,x}$ (main polarization component points along the *x* axis; in cylindrical coordinate system $\varphi = 0^{\circ}$) and $HE^{\pm}_{11,y}$ (main polarization component points along the *y* axis; in cylindrical coordinate system $\varphi = 90\circ$) where ± sign refers to the propagation direction (±*z*). Fig. 2 shows the electric field components of HE^{+}_{11} mode. The $|E_r|$ and $|E_\varphi|$ components have maxima at the centre of the nanofiber, whereas $|E_z|$ has maximum closer to the edges.

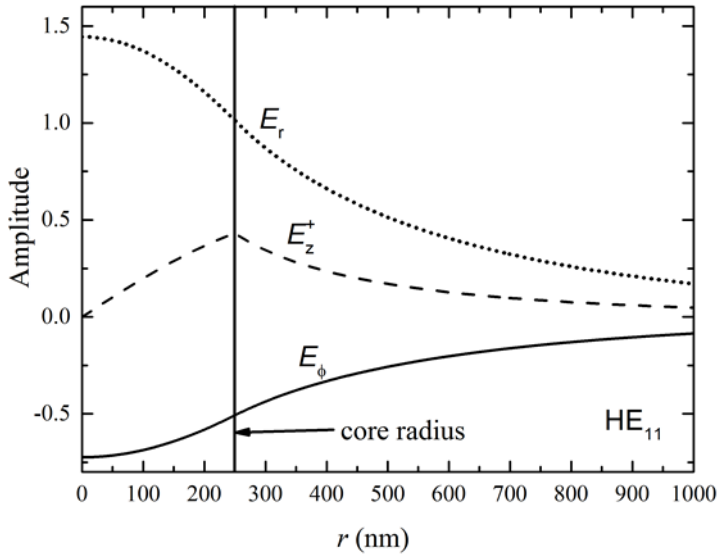

Fig. 2. Amplitudes of guided mode in our nanofiber.

3.2. POLARIZATION OVERLAPS AND DIRECTIONAL FACTOR

In the coupling described below is obtained by applying the dipole approximation. The total power of the light emitted into a given fiber mode is given by

$$I_{emitted} \propto \left|\vec{d}^{\circ}\,\vec{E}\,(r,\emptyset)\right|^2 \tag{1}$$

where ***d*** is electric dipole transition and ***E*** is a unit polarization vector od mode at (*r*, ϕ) position.

Fig. 3 shows a decomposition of the nanofiber-guided basis modes into the right circular (σ_+), linear (π), and left circular (σ_-) polarization components. It can be treated

as the polarization overlap and it is proportional to a total power of the light emitted into a given fiber mode. We see that $\xi_{\sigma+}$ ($\xi_{\sigma-}$) for +z propagation direction has maximum (minimum) value when quantum emitter is placed at the surface of nanofiber. Thus, the field outside the core is elliptically polarized. When the propagation direction in reversed, $\xi_{\sigma+}$ ($\xi_{\sigma-}$) has minimum (maximum) value for the position of quantum emitter on the surface of waveguide. Because the emission probability of the QD into the fiber is directly proportional to this overlap, a strong asymmetry of the emitting into the left (–z) and right (+z) direction of the fiber takes place. We can control the degree of this asymmetry by tuning the polarization of the emitted light. It is clearly seen that the overlap ξ_π does not depend on the propagation direction. Therefore, a π polarized photon emitted by a quantum emitter couples equally to the two counter propagating modes, while a $\sigma_\pm$ polarized photon preferentially couples to one of the HE_{11} modes. Moreover, these overlaps are constant along the nanofiber axis and vary only slowly in the radial direction.

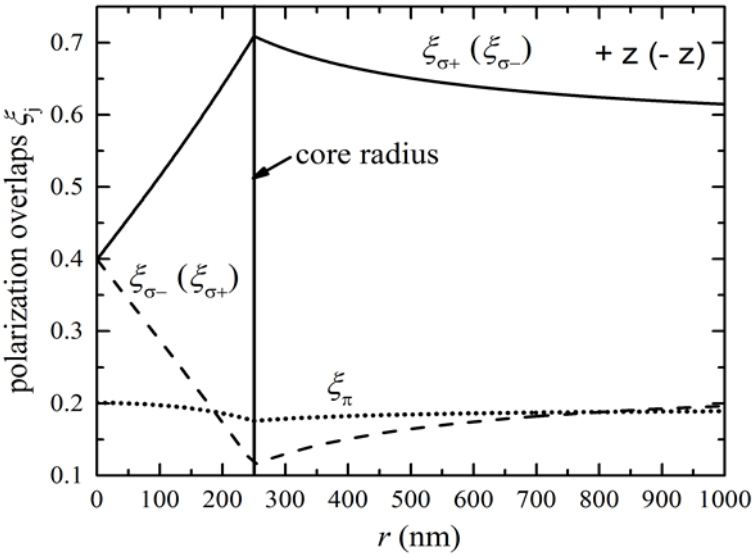

Fig. 3. Polarization overlaps defined as |d · E(r, φ)|2 for two propagation directions (±z)., where E is the unit mode's electric field and d is the unit polarization vector (linear - π and two circular - σ±).

Directionality factor is defined as normalized intensities for emission to the left and to the right and has the following form

$$D_{L/R} = \frac{\xi_{\sigma+}^{L/R} - \xi_{\sigma-}^{L/R}}{\xi_{\sigma+}^{L/R} + \xi_{\sigma-}^{L/R}} \quad (2)$$

where the superscripts L and R refer to the left and right direction of emitted photons respectively. The directionality was averaged over the QD position and results are shown in Fig. 4.

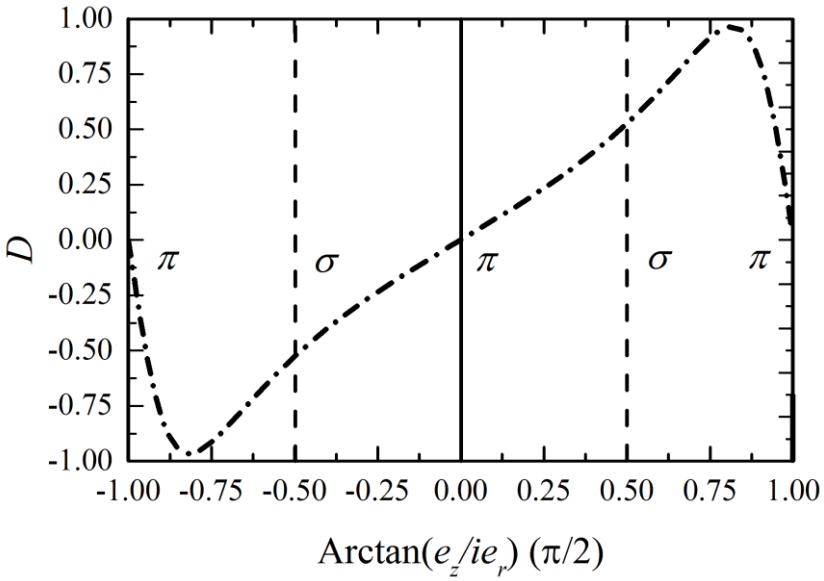

Fig. 4. Directionality of emitted light (dash line) as a function of the ellipticity of polarization of the QD emission. Vertical lines mark the limiting cases of linear and circular polarization.

The maximum directionality of D = 0.97 is obtained for elliptical polarization, which corresponds to a ratio of 33:1 between the photons emitted to the left and right.

4. SUMMARY

In this work, we have studied spontaneous emission from a QD into the fundamental mode of an optical fiber. We employed spin-orbit interaction of light to realize a directional emission in a system containing nanophotonic waveguide and quantum emitter. We have shown that the directionality factor can be controlled via the polarization of emitted light by QD and that the linear polarized photon emitted by QD always couple symmetric with respect to the propagation directions. To conclude, we demonstrate theoretically chiral effects in a simple nanophotonic system. The maximum directionality in our system is 0.97 obtained for elliptically polarized photon emitted by QD.

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Key words:
strategy planning, strategies topology

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ENTERPRISE STRATEGIES IN A COMPETITIVE ENVIRONMENT*

In the current world it seems to be no space for more companies. Despite this, new enterprises are constantly being created and are often successful on the market. This market is constantly changing, it is a place, where every enterprise has a chance to appear on it. In all markets there are numerous factors changing the type of demand and supply. All market players strive to achieve the greatest benefits. The multitude of existing enterprises means that companies must compete with each other. The necessity of competition requires the organization to acquire knowledge and introduce constant changes - innovative ventures in marketing, innovation in finances, conducting various research and development works in order to improve production and educate employees. Business management requires interdisciplinary activities to create the desired value. The aim of this chapter is to analyze various approaches of enterprises to coexist with the environment and strategies of enterprises in the competitive environment. The process of creating a competitive advantage over other companies operating in the same sector is primarily to design a management style. The multitude of points of view from which strategies can be observed, have resulted in countless types of strategies and criteria for their description. The chapter includes analysis only of those strategies that appear to be relevant from the point of view of enterprises in a competitive environment.

1. INTRODUCTION

In the current turbulent economy, complexity of the relationships [1] between entities and their number can indicate that there is a lack of space for more enterprises [2], and even that everything has already been thought up, because there was the so-called “end of the history” [3]. One can even state, that there is nothing more to discover and invent but capitalism and the world as we know it [4]. This end means that we function in the "last phase of the ideological evolution of humanity" [4]. What is more, one can get the apparent impression that in certain sectors of the economy there are

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countless companies that are already engaged [5] in the provision of a given service or the production of goods, so competing with them is pointless [6]. Although apparently there is no further development of basic principles and social institutions [7], all important problems find their final solution [3]. Nevertheless, new enterprises are created and some of them are successful on the market [8]. The market is constantly changing [7], which paradoxically gives every enterprise a chance to enter this market [1]. Therefore, in all markets there are factors changing the type of demand and supply [9]. Moreover, all market players strive to achieve the greatest possible benefits. The multitude of existing enterprises means that companies must compete with each other [1]. On the other hand, the need for competition requires organizations to acquire knowledge [8] and introduce continuous changes - innovative marketing ventures, financial innovations, and various research [10] and development works to improve production and educate employees [11]. Therefore, enterprise management requires interdisciplinary actions [12] to be able to create the desired value, which are formulated in the strategies of enterprises [13].

The aim of this paper is to join a scientific discussion about enterprise strategies in a competitive environment, which is also a title of this chapter, with the simple example of an event company. The strategic management theory in modern world is in its important and sensitive, almost vulnerable phase of development [14]. Fundamental doubts are multiplying about the possibility of predicting and shaping the future in an unstable and less predictable environment [15]. Furthermore, the importance of strategic management as applied science is being questioned [16]. This chapter considers various approaches of enterprises to coexist with the environment and strategies of enterprises in the competitive environment. The final element of the work is to analyze an exemplary process of creating a detailed strategy based on SWOT analysis - in a presented case study – event company which create the artificial beach in Krakow.

The process of creating competitive advantage over other companies operating in the same sector is primarily based on analyzing and designing management style. The multitude of points of view from which companies' strategies are looked at have created countless types of strategies and criteria for their isolation [17]. This chapter includes only those that appear to be relevant from the point of view of enterprises in a competitive environment [18].

1.1. ANALYSIS OF THE ORGANIZATION’S ENVIRONMENT

The consequence of various descriptions of the organization's environment [1] and the divisions that characterize them are the multitude of types of these descriptions in different dimensions [19]. Therefore, many of them are very similar, others differ significantly. For the purposes of this work, we will adopt a division of the organization's environment in the way we discussed in the introduction to this paper and which is mostly adopted in Polish school of strategic management [14, 20].

The organization is defined as a socio-technical system that includes people (i.e. management, organization structure, technology and goals). Environment (or rather the surrounding) can be divided into closer and further [21]. Closer are, e.g. suppliers, competitors. Further: it is e.g. legal, economic or other (socio-economic). The organization can be understood as set of internal elements, i.e. the components of the enterprise within it, such as the management board, organizational structure and culture or processes and external elements that do not fall into the set of enterprise components, but exert a significant impact on its behavior [22]. However, the company also has an impact on the external environment.

The external environment can be additionally divided into targeted and general surroundings [23]. The first of these are specific organizations with which the company has almost direct contact. These include markets in which the company competes and the industries in which it operates, their direct suppliers, customers and all kinds of stakeholders close to the company. The general environment is an unspecified dimension in which the organization operates, but these areas can also influence its decisions. However, the enterprise itself does not have such a large impact on its further environment [1, 11].

An almost identical division of the environment was presented by J. Brilman [25]. He divided the enterprise environment into a general and operational environment which respectively relate to the general and purposeful environment. Then, Brilman additionally identified an internal environment that is contained within the organization and includes organizational, marketing, financial, personnel and production aspects [25].

A similar division of the organization's environment is presented by G. Gierszowska and M. Romanowska [26], however, this concept put lighter accent to the environment inside the organization. In their book "Strategic analysis of the enterprise" [26] they separate the organization's environment into two dimensions: macro environment and competitive environment. The competitive environment includes all economic entities that are cooperatively associated with the enterprise (e.g. suppliers, buyers) or competitively (e.g. potential competitors). However, the macro environment (further macroeconomic surrounding) includes the areas: economical, technological, social, demographic, political and legal, international.

K. Bolesta-Kukuła [27] presented a completely different view on the organization's environment, assuming the existence of four segments of the organization's environment. The "power" sector is characterized as one to which all state institutions and owners belong. The "nature" sector, is this which covers global trends, demographic, cultural and awareness processes, as well as nature. The "game" sector, then is described as this where clients of the organization, banks or all kinds of companies that cooperate with the organization in some way, e.g. providing its services like suppliers, service companies and insurance companies, belong to [28–30]. The last sector, the "fight", includes all competitors and opponents of the organization [27].

The analysis of the environment can significantly differ from one another in different enterprises as it is visible on the examples [27]. The choice of the appropriate classification of the environment should be tailored to the needs of the company. The choice of strategy lies with the management of the organization and it is the management board's responsibility to choose the best tools for observing changes in order to be able to make the best decisions, one of these tools is the analysis of the company's environment.

1.2. STRATEGY DEFINITION

The strategy from the times of ancient Greece means leading the army from the position of commander-in-chief, and he was expected to prepare and wage war as a whole. However, with the time and the emergence of new categories of interest in human life, the term "strategy" began to be used at times completely different from the initial meaning of the word meanings. After World War II, the term was incorporated into a dictionary related to game theory [15, 16]. Then in the 1950s it began to be used in the United States as part of the "Long Range Planning" trend as a strategic planning concept, so that it could be used in the "strategic management" collocation during the oil shock in the 1970s [24]. All this has led to the fact that nowadays it is very difficult to talk about uniform interpretation of management and strategy. Increased terminological chaos has led to many attempts to unify the dictionary of the scientific discipline which is management science [6, 8].

Strategy definitions can be very general, usually presented as the classic content of a plan which assumes setting goals, methods of achieving them and measures that can help in the implementation of the undertaking. Other definitions are when the author tried to find some substantive distinction between them, in many cases such a distinction is the position of the organization in its environment, interaction or even struggle with the environment.

Examples confirming the first statement are theories of R. Ackoff, who wrote that the strategy relates to long-term goals and methods of achieving them, or A.D. Chandler, according to which the strategy is to define the main goals and choose such courses of action as well as to allocate resources that will allow to achieve the set goals.

The second approach was applied by M. Koontz and C. O'Donnell, according to which the strategy is planning developed in the face of competition plans. H. Mintzberg, talked about strategy as a way to shape the relationship between the organization and its environment [33].

The strategy is also presented as a general set of rules that it follows and makes decisions. Such definitions were implemented by H.A. Simon or B. Hedberg, saying that strategy is a set of ideas that results in a series of decisions that an organization makes.

T.J Peters and R.H. Waterman combine ways of thinking about strategy as a plan and about rules of conduct. They argue, that the strategy is described in the functioning organization in the long term, and is combined with specific long-term goals, methods of achieving them, but also strategy characterizes how the organization operates and rules in specific situations [6, 8, 20].

In the scientific literature most significant contribution to management science in field of strategic management had R. Krupski [6]. He formulated two ways of functioning of the organization. The first one is this, in which the organization adapts to the environment based on the rules of behavior it sets and the second way occurs when the strategy is a rigidly set action plan with goals, methods and tools. In the first case, the author agrees that the survival of the organization should be the main driving force behind changes in management. However, the question is whether the company changing its structure and functioning in terms of changes in the environment will still be the same company or each time a new organization appears after the changes. Leaving this question unanswered, R. Krupski then mentions the pros of the strategy as a plan, ending by considering that they do not think that such a plan is only a resultant nature, not referring in any way to the rules of conduct.

Continuing the considerations of R. Krupski, for the purposes of this work, the most general definition of strategy according to T.J Peters and R.H. Waterman is this that define strategy as a solution is to keep the organization in relation to its environment and to keep the organization inside. The most important is adopted strategy is included in both action plans and rules of conduct.

2. STRATEGIES IN A COMPETITIVE ENVIRONMENT

From the organization's point of view, the market is mainly customers and consumers, and one of the most important tasks of an organization should be seeking customers. When their number is limited, as well as the number of enterprise resources, in a given time horizon ordinary market activities of each enterprise can lead to confrontation between organizations. The strategies that organizations adopt when they clash with other units are called competition strategies, and such an environment can be called a competitive environment.

It is possible that the company operates on the market with a potentially large number of competitors, yet it creates relationships with a certain group of privileged partners. Such a strategy is called a relational strategy and is based on voluntary agreements that, from a logical point of view, do not comply with the principles of competitiveness. Establishing such contacts and relationships by an individual allows a certain niche of security around them that limits the risk of an enterprise operating on the market.

The literature gives one more type of strategy - dodging strategy. It is a solution used by enterprises that are unable to beat their competitors or form a coalition with them. The strategy of dodging remains the only solution. An enterprise using such a strategy

usually gives way to all competitors and is looking for e.g. a certain market niche in which it could operate. A niche market allows the company to survive because it operates in a market that is often unattractive to a potential competitor. Another way is to find a niche in the form of producing a highly specialized product, or providing services in a very narrow, specialty scope. Often, strong competitors look for opportunities in industries with a much larger field of activity, which can protect a company against a confrontation doomed to failure. However, there is always a risk associated with the increasingly frequent disappearance of various types of market niches caused by market changes. Also, the large companies are becoming more flexible and aggressive, conquering new, previously uninteresting markets, eliminating them from existing leaders.

There is the concept of a three-dimensional strategy model. It is a composite matrix of three dimensions in which the current position of the enterprise and the situation in which it finds itself are analyzed. The first two dimensions are very characteristic in the analysis of the competitive strategy. They are the attractiveness of the enterprise field and the competence of the staff. The third dimension, however, comes from a relational view on the choice of strategy and concerns a non-market security system understood as a restriction of competition. The ideas of this model are presented in Table 1.

Table 1. Three-dimension enterprises' general strategy model

Strategy name	Dimensions and positions					
	Area attractiveness		Staff competence		Security	
	strong	weak	strong	weak	strong	weak
Champion	x		x		x	
Independence	x		x			x
Adventurous	x			x		x
Sonship	x			x	x	
Ward		x		x	x	
Philanthropist		x	x		x	
Engineering		x	x			x
Suicide		x		x		x

Source: KRUPSKI R, (editor). Zarządzanie strategiczne, koncepcje - metody. Wrocław: Wydawnictwo Akademii Ekonomicznej im. Oskara Langego we Wrocławiu; 2007.

The champion's strategy is possible to fulfill in a situation when the company operates in an attractive industry, has a highly qualified staff and high confidence in relations with partners. The independence strategy ignores the sense of security and is fully based on the attractiveness of the industry and the professionalism of its staff. Adventurous can be called the strategy of a company that does not need a sense of security and has no qualified staff, and profits from participation in an attractive market. The strategy of alignment is based on good relations with trading partners and public authorities. The mentee's strategy is the strategy of a company that operates in an unattractive sector, without well-educated staff, but with a large background on the side of the state and its contractors. Just like the philanthropist strategy, which, however, is characteristic of a company with better qualified staff. Engineering strategy is used by companies in uninteresting industries, without the need for security, but with enormous competence on the part of the staff. At a time when the company has no advantage in any of these dimensions, we are dealing with a suicide strategy.
The above examples of strategies refer to general models of the approach to organization management. In the remainder of the work, we will focus on detailed strategy selection tools on the example of SWOT analysis.

2.1. SWOT ANALYSIS AS A METHOD OF STRATEGIC PLANNING

SWOT analysis is a method of strategic planning, which is evidenced by the fact that after conducting this analysis we are able to choose a strategy for the enterprise in which the analysis was carried out. It uses many universal and detailed analysis and planning procedures. The name SWOT is an acronym for words that specify the dimensions that are collected during this analysis, they are:

Strengths (as results of the internal environment of the organization),

Weakness (as results of the internal environment of the organization),

Opportunities (as results the external environment of the organization),

Threats (as results the external environment of the organization).

The method is extremely popular due to the possibility of using it in a wide range of different types of organizations. It allows for solving of both general and specific problems. The analysis process looks as follows:

1. Learning the specifics of the enterprise,
2. Analysis of the environment,
3. Surrounding forecast,
4. Determining the strengths and weaknesses of the enterprise,
5. Formulation of strategy options,
6. Selection of the final variant of the strategic plan.

Based on the analysis of the matrix of strengths, weaknesses, opportunities and threats, it is possible to identify four potential strategic situations:

SO - maxi-maxi strategy - using strengths and opportunities, aggressive strategies, development and expansion strategies;

WO - mini-maxi strategy - using upcoming opportunities to overcome the company's weaknesses, competitive strategies consisting of overcoming personal weaknesses;

ST - maxi-mini strategy - using the organization's strengths to overcome threats, conservative strategies are designed to wait;

WT - mini-mini strategy - leading to survival strategy or liquidation of the company, defense strategies, focus on staying on the market and bankruptcy.

Further consideration was given to the example of the SWOT analysis of the city beach in Krakow. There is only one such beach in the center of Krakow. The following analysis is about a competitive beach that has not yet been created. The emerging city beach will definitely fit into the current market niche. One currently existing beach does not meet the demand for this type of service. It is predicted that in the near future there will be similar places of rest and entertainment due to the reconstruction of the Zakrzówek district in Krakow. After the renovation of abandoned quarries, a large area of land will be created, which will be ideally suited to such projects. The SWOT analysis of the new city beach may look like as presented in Table 2.

Table 2 The artificial city beach in Krakow SWOT analysis

Strength	Weakness
High quality of products and services Effective advertising and promotion Favourable location Poor competition Modern equipment	Small capital and reserves Unknown brand Lack of experience
Opportunities	**Threats**
Filling a market niche Fashion for this type of bars Increasing demand for rest areas different from urban infrastructure	High rent for the city for renting land; Seasonality A strong competitive beach brand High probability of emerging competitors' beaches

Source: authors' own elaboration

The above analysis shows that the main problem caused by the high rent and seasonality of the service may be the financial liquidity of the city beach. In addition, the appearance of potential clients in the awareness will be problematic. At present, everyone knows only one such place in Krakow and they are used to it. However,

frequent queues appearing on the old city beach may indicate the need for something new.

The analysis of strengths and opportunities shows that the company is in a convenient location and provides services at the desired level. Adding to this the growing demand for these types of places and very weak competition at the moment, it seems that the best strategy of such an enterprise will be a bold aggressive strategy [21]. It will help, thanks to high-profile advertising, to inform all residents about the newly created place, thus acquiring new clients ensuring financial liquidity. The convenient location will provide an advantage over the existing city beach and the newly created competition beaches. Fresh and clean outdoor beach equipment will attract a large number of customers, and thus employees and staff will have the chance to gain experience in dealing with customers and organizing events.

3. CONCLUSIONS

An organization in a competitive environment is almost forced to prepare strategies and make decisions in line with its assumptions. An enterprise, wishing to survive, involuntarily, must know what competitors it has and in what environment it operates. By not analyzing this information, the company is doomed to management by cases that can quickly lead to bankruptcy.

The initial part of the work presents a multitude of strategies depending on the style of the organization and its current internal situation and position in the environment. However, it should be noted that each strategy selected for a given company should be selected on an individual basis. The presented strategies are only a general, theoretical view on the subject of company management. The analyzed case allowed for a detailed strategy to be developed. However, this required a thorough knowledge of the undertaking and many details of its functioning. A similar situation will occur each time using SWOT analysis even for huge enterprises. This analysis can be safely used in any situation when there is a need to make short- or long-term decisions

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Key words:
attitude towards organization, identification, knowledge sharing, organizational behavior

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KNOWLEDGE SHARING AND EMPLOYEES' ATTITUDES TOWARDS ORGANIZATION*

This article presents the corpus of organizational behaviour regarding the relationship between the type and the intensity of employees' attitudes towards organization and presence of knowledge sharing processes in a workplace. This paper shows the significance of employees' attitudes towards organization in terms of knowledge sharing and provides general overview of knowledge sharing phenomenon between employees in organization. Author suggests behaviours facilitating knowledge sharing processes, as well as actions hindering such processes. The intention of this article is to open new paths for future research and guide managerial practices which aim to improve knowledge sharing awareness in the context of organizational identification and organizational commitment.

1. INTRODUCTION

Nowadays companies are becoming more and more aware of the potential value of organizational information and data. Moreover, reasonable transformation of raw facts into the applicable form creates knowledge [1], which represents the priceless and promising asset in every organization, which is hard to imitate and substitute by third parties [2]. Knowledge sharing process may constitute the base for the effective development of the company stimulating its performance, competitive advantage, knowledge application and innovation [3]. Movement of knowledge in organization depends on specific knowledge sharing attitudes [4]. Individual knowledge possessed by an employee, to be widespread, should be transferred into organizational one. Once properly shared, knowledge may be reasonably and profitably used within organizational structures. Intelligent implementing of valuable knowledge may effectively enhance competitive advantage of the firm, as it presents one of the most

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significant intangible resources [5] [6]. Recently many things support knowledge sharing ability: Internet, virtual reality, groupware and many other intelligent tools [7]. Next to mentioned matters enhancing knowledge movement, there may be recognized soft elements which correspond to personal issues. Especially in organizations relying on creativity, managers usually appreciate useful knowledge embedded in people's minds. Information could be transferred and used more or less efficiently depending on people's abilities, approach and demeanour [8].

According to Burt, human capital is useless without the presence of social capital [9]. The significance of both tangible and intangible resources is widely discussed in social capital theory that assigns an importance to relations between entities [10]. Cooperation of individuals leads to achieving common goals. According to Coleman, an individual collaborates with others in order to benefit from joint effort [11]. Differently, Putnam examined the collective dimension of social capital discussing the significance of group commitment, reciprocity and common trust [12]. Podsakoff *et. al* noticed the benefits coming from performing organizational citizenship behaviour in the context of social capital sharing (including knowledge) [13].

In this literature review the author of this article is particularly interested in establishing whether positive attitude towards organization influences remarkably the willingness to share knowledge. The aim of this paper is to draft the possible research areas and designate interesting directions for future studies.

2. BASE ASSUMPTIONS OF KNOWLEDGE SHARING

Knowledge presents unique organizational asset; which value grows when it is shared [14]. It constitutes the foundation for firm's competitive advantage according to knowledge-based view of the firm [15] [16] [17] [18]. Knowledge sharing issue has been discussed widely in many significant publications in past decades [19] [20] [21], as well as in recently posted papers [22] [23]. Most authors perceive knowledge as a medium improving work performance [24], creating new ideas and innovations [20] and accelerating organizational competitiveness [25]. Quinn, Anderson and Finkelstein noticed the following: *As one shares knowledge with other units, not only do those units gain information (linear growth) they share it with others and feedback questions, amplifications, and modifications that add further value for the original sender, creating exponential total growth* [26]. Knowledge used to be perceived as a power, but nowadays it seems that knowledge sharing is even more prospective.

The core of knowledge is not easy to catch and define, as intangible asset. Valuable content often stays in people's heads where cannot be effectively used; it is also stored in various places and formats such as databases, intranets and file cabinets [23]. In organizations we can come across various knowledge sources: persons, notes, reports,

manuals, guides, drawings, documents etc. [27]. Lots of mentioned information may be useless by the time it is rediscovered and shared. Smart adapting and processing of the information may enrich it significantly and make it easily usable for the possible receivers [28] [29].

In the organizational context, individual's knowledge should be transferred into organizational one to be particularly useful for organization as a whole. The mutual knowledge exchange drives to creating a new, often enriched one. Process of exchange involves an engagement of both sides: knowledge source and knowledge receiver [34]; one of them supplies new knowledge, the other one demands for new knowledge [35]. Both should act voluntarily [36].

The knowledge sharing process is a dual action consisting of:

Knowledge donating, informing the others about one's intellectual capital.

Knowledge collecting, asking fellows and co-workers for sharing their intellectual capital [23].

The above requires particular activities from the entities. There are many conditions that lead to this mutual exchange. Knowledge exchange is a holistic issue, combining soft, hard and abstract concepts [37]. In the process of knowledge sharing, new knowledge may be created. It may be either tacit knowledge, or explicit one, depending on its conversion.

The researches done by Nonaka and Takeuchi helped distinguish tacit and explicit knowledge, claiming that the first one cannot be shared through manuals or theories, but using people's experience. Tacit knowledge is a distinctly personal concept, which is difficult to articulate and problematic to transfer. Dealing with tacit knowledge demands deep understanding and being aware of discussed concept [38] [39] [30] Personal beliefs and attitudes are usually connected to people's mental schemes related to their experience and subjective opinions.

On the other hand, explicit knowledge is considered as the objective and rational one [27]. It can be easily stored in paper-based or electronic documents and then used and transformed or converted by the specific person or organization. Explicit knowledge may be simply reused. Explicit knowledge sharing is influenced by project commitment and trust [40]. It is also easily adaptable and applicable in similar situations if it is properly codified [28].

According to the theory of organizational knowledge creation of Nonaka and Takeuchi, converting tacit into explicit knowledge is a process of its externalization. [18] Direct face-to-face interactions facilitate dealing with tacit knowledge. Likewise, mutual trust as a fundamental factor mitigates the sense of uncertainty and suspense between collaborators [33]. Knowledge externalization is a useful ability, but it demands mutual understanding between the entities. Tacit knowledge must be correctly and clearly articulated before it gets transferred. Nonaka suggests, that common perspectives and shared experience support knowledge externalization in teams [34].

Sense of mutual respect, commitment and cooperative ambience create convenient conditions to externalize one's know-how [35].

Explicit knowledge is easily adaptable and applicable if it is properly codified [28]. Conversion of explicit knowledge into tacit knowledge is called knowledge internalization. Nonaka suggests its similarity to the process of learning. Learning by doing may be performed gradually through trial-and-error thanks to interactions, relevant communication and experimentation [34].

Knowledge creation scheme represents also knowledge socialization (transferring it from tacit to tacit knowledge between subgroups, departments or individuals), which can be performed by observation, imitation, and practice, even without using common language. The last mode of knowledge conversion is transferring it from explicit to explicit knowledge between people (knowledge combination). It can be initiated by meetings and conversations, when people exchange and collect ideas and information, then edit, adapt or process it and finally disseminate among organizational structures. [34].

2.1. KNOWLEDGE SHARING TRIGGERS

Organizational behavior studies are very diverse and complex. There are many factors influencing each other, so that it could be complicated to determine unambiguously the elements shaping knowledge sharing processes. The literature on organizational behavior and knowledge transfer addresses a common phenomenon: knowledge sharing process is dependent on personal motivation [40], self-interest, quality of organizational climate [41], organizational commitment, trust among colleagues [4], etc. We can take an effort to try to group the elements into subgroups: individual, social, and organizational factors [41] or into: anticipated extrinsic rewards [42] (promotion, signaling one's competence. getting future support) and intrinsic motivations (enjoyment of helping, need for affiliation, self-learning) [43][44].

Based on basic assumptions, Simon and March presented group identification phenomenon as motivator that enables people to experience satisfaction when achieving common goals [45]. From the psychological point of view, there has been noticed the link between individual's psychological attachment to the organization and organizational identity [46] [47]. According to Mayhev, Gardner and Ashkanasy, the need to belong builds self-esteem and enables self-enhancement. Being a satisfied group member reinforces one's, self-worth. Significant level of group identity makes employees work instinctively to bring the profits to organization [48] [49]. The concept of organizational identity is tightly linked to group cohesiveness, solidarity, common characteristics and values with other employees [50].

Knowledge sharing in heterogenous groups may be complicated in order to possibly different values, vocabularies, experiences or habits. An experienced leader may be

helpful in order to develop common goals, implement the atmosphere of collaboration or mitigate the conflict [51] [52].

Based on scientific research, communicator's credibility (including reputation and trustworthiness) constitutes a significant factor supporting knowledge transfer. When a communicator is observed to be dishonest and fraudulent, the receiver is less likely to use or internalize the knowledge forwarded by the source [53][54][52]. Communicator's reputation helps to select and isolate possibly the most valuable information from the magnitude of data present everywhere [55].

Organizational justice is another important factor influencing knowledge sharing process. Both procedural and distributive justice reduce knowledge withhold. Employees who don't get equitable rewards for their contributions, may reduce their knowledge sharing intentions. On the other hand, workers who feel appreciated for knowledge sharing intentions, tend to share knowledge in the future in order to be awarded again [56].

2.2. KNOWLEDGE SHARING AND ORGANIZATIONAL TIES

Strong identification and commitment to the company may have the positive effect on knowledge management issues but attitude and action of an individual toward knowledge sharing is also significant [57]. Following the Kelman's social influence theory, the other people's attitudes may consequentially influence their behavior [58]. Considering also the compliance and internalization concept, employees may tend to share knowledge in the same intensity, as the other group members do. Personal norms are often influenced by social norms [59]. The above concept may suggest the need of empirical studies over possible correlation between group and individual's attitude to knowledge sharing aspect.

Finkelstein discusses broadly the phenomenon of extreme identification with the company that displays through the lack of explicit boundary between personal and corporation's interests. His research showed that executives rather do not identify too little with the company but too much. CEOs perceiving themselves as the core of the company often tend to refuse to accept suggestions and advice from the employees [60]. The above should definitely attract the workers' attention as it handicaps knowledge transfers among the staff members. The phenomena of rejecting external knowledge and presenting hostile attitude towards external ideas, solutions, products is named non-invented-here syndrome (NIH) [61].

Burcharth and Fosfuri explained that excessively strong organizational identification sometimes causes a biased perception of the external world (they compare it to a mental prison) when employees do not respect external knowledge, but they overestimate the internal one [61] [62] [63]. Quinn, Anderson and Finkelstein noticed: *Proper leveraging through external knowledge bases—especially those of specialized firms, customers,*

and suppliers—can create even steeper exponentials [26]. Contemporary organizations should rely on various sources of knowledge to be more independent and reliable. Innovative potential of the organization may be expressed by firm's openness to interaction with external companies and using extrinsic knowledge and experience [64]. In Quinn's *et al*. article it was mentioned: *There are, however, some inherent risks and saturation potentials in this process. The choices about what knowledge is to be protected, what knowledge is to be shared, and how, are critical elements in intellectual strategies* [26]. Even if firms collaborate tightly, their managers often do not tend to share the whole precious knowledge and all the innovative ideas they have.

On the other hand, the companies that intend to share their own knowledge more intensively, are supposed to get more knowledge from the collaborator. Relying on *quid pro quo* and the concept of reciprocity – organizations donating worthful knowledge, get the opportunity to get back an interesting content as well [65] [38]. Research showed that knowledge sharing behavior may be significantly affected by reciprocal benefits [66]. Moreover, enjoyment in helping others and knowledge self-efficacy are also important in enhancing knowledge sharing intentions [67]. Furthermore, according to commitment-trust theory described by Morgan and Hunt, both commitment and trust truly support relations between people participating in a community [68] [69]. Reinforced relations linking people appreciably influence willingness to share knowledge. Employees satisfied with being a part of the organization, are supposed to share knowledge readily. Even though satisfaction is important in intraorganizational relationships, it only enforces the intention to share. On the other hand - experiencing trust has a direct influence on knowledge sharing intentions [70] [71]. The same, sense of self-efficacy and perceived organizational support are significant [37]. As Kim *et al.* noticed, sense of group belongingness, cohesiveness and organizational commitment are especially important in shared information-based communities (i.e. online organizations) [42]. Employees' identification with other workers prevents from unjustified leaving the community and finding a new one. The sense of group belongingness may mitigate response to tense interpersonal relations [71].

2.3. KNOWLEDGE SHARING BARRIERS

Intense knowledge exchange may increase the possibility of knowledge leakage, but common trust and moral codes may mitigate fear, fraud or cheat [72]. The atmosphere of common trust, reliability and commitment supports effective knowledge sharing phenomena [73]. People who do not concentrate too much about possible deception, may invest more efforts in effective and genuine knowledge sharing act.

According to Hussinger and Wastyn, there is a relationship between *firm's success and the occurrence of the NIH syndrome. The extent to which individuals identify themselves with their company increases with group success because success increases*

the group's distinctiveness and attractiveness [74] [75]. Group members who are exceptionally bonded to their organization or to company ideas and patents, may overlook and omit new solutions created by outer organizations. According to Kathoefer and Leker, *the integration of external knowledge may injure a research group's pride. People may feel affronted when external ideas are regarded as superior to their own* [76]. Empirical research showed the trend that too strong identification with the company may lead to rejection of external ideas even if they are useful and valuable [77]. According to already mentioned in this paper NIH syndrome – underestimating external input may be harmful for an organization [76]. Fear of learning from foreign solutions hinders creating new innovative approaches and disallows organizational progress.

3. CONCLUSIONS

Increasing number of authors concentrate on knowledge sharing as a source of a great value. Knowledge sharing phenomenon is a complex structure uneasy to interpret and comment without preparing elaborated analysis or exact research. Knowledge sharing behavior should be examined holistically considering organizational sector, group specific, number of engaged members, type of common ties between employees and other significant factors [36] [78] [79] [80].

Knowledge exchange takes place in every kind of organization. Relations and bonds between group members constitute inseparable elements in sharing processes. Intrinsic elements such as motivation, engagement, satisfaction are important to perform an efficient exchange between employees. Employees tend to share knowledge in order to be respected, positively perceived or financially praised. However social ties, group identification and organizational commitment may decisively determine employees' attitude towards knowledge sharing intentions. Moreover, sense of belongingness prevents group members from voluntarily getting involved into foreign group. On the other hand, excessive engagement in organizational affairs may harm organizational businesses. Namely, people protecting group from extrinsic influence (even if they want to guard it against enemies), may disadvantage it. For example, blocking external (and useful) ideas, being afraid of using foreign (and correct) solutions or even consistently holding their opinions, may slow down organizational progress. Only conscientious way of provoking knowledge sharing behaviors may bring benefits to one's group. Reasonable balance in every relation and members' approach to ones' organization may truly support exchange processes [64].

The literature review presented in this paper depicts the phenomenon of knowledge sharing in the context of employees' attitude towards organization. The article highlights the significance of people's mindset regarding knowledge sharing practices.

Delivered theoretical background may suggest possible facilitations and obstacles in reviewed aspect.

Where is the limit between proper and excessive group identification? Does sense of belongingness really bring more benefits than harms to an organization? Does NIH may be considered exclusively as negative phenomenon? This paper suggests possible research directions and indicates inquiring problems in organizational behaviour.

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Students'
Science
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II

NEW MATERIALS AND TECHNOLOGIES

Key words:
concrete, cenospheres, compression strength, disintegrator

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EFFECTS OF CENOSPHERES ON DIFFERENT COMPOSITIONS OF CONCRETE*

Cenospheres are light, waterproof alum-silicate spheres. The direction of the research is the cenospheres as component of various concrete 0%, 30%, 40%, 50% by volume. Depending on the properties of the desired cement type and mixing ingredients with water and superplasticizer - concrete properties are experimentally researched immediately or after 3 days. To determine how much the increase of surface adhesion area after grinding the particles of the cenospheres affects the resulting samples, grinding mill or disintegrator were used to grind the particles. The aim of the research is to obtain scientifically based data about the crushed cenospheres, depending on the time of mixing (right after the milling process or after 3 days of delay) for the impact on quality of concrete by different composition of cement – CEM II, Aalborg White and Gorkal 70. It is predictable that the cenosphere additive increases concrete porosity, reduce compressive strength and density. An optical microscope examines compressed samples that shows adhesion properties of spheres and concrete. These concrete materials can be used as a lightweight concrete material for thermal insulation as slabs or special walls.

1. INTRODUCTION

1.1. MATERIALS AND METHODS

Cenospheres are light, inert, waterproof alum-silicate spheres. Due to its low density, it is used in lightweight concrete as a bulk fill to increase porosity. [1]

Three types of cement were used as ingredients in the test mixture: CEM II A-LL 42.5 N, Aalborg White and Gorkal 70. They differ in price, strength and thermal resistance. Portland cement CEM II A-LL 42.5 N is widely known, easily available, and therefore relatively inexpensive. Aalborg White has very high strength, white cement. Refractory aluminum cement Gorkal 70 provides fire resistance up to 1700 °C.

Grinding mill or disintegrator DSL-175 (Tallinn University of Technology, Estonia) was used for grinding the mixture of cenospheres, sand and cement for maximum smooth shuffle [2-4]. Its principle of operation is shown in Figure 1 a, b, c. Two rotors

[1] Riga Technical University.

* Paper awarded in the Best Paper Contest.

with diameter 175 mm are rotating with the speed up to 12000 rpm. Disintegrator teeth crush the material particles to the size of micrometers.

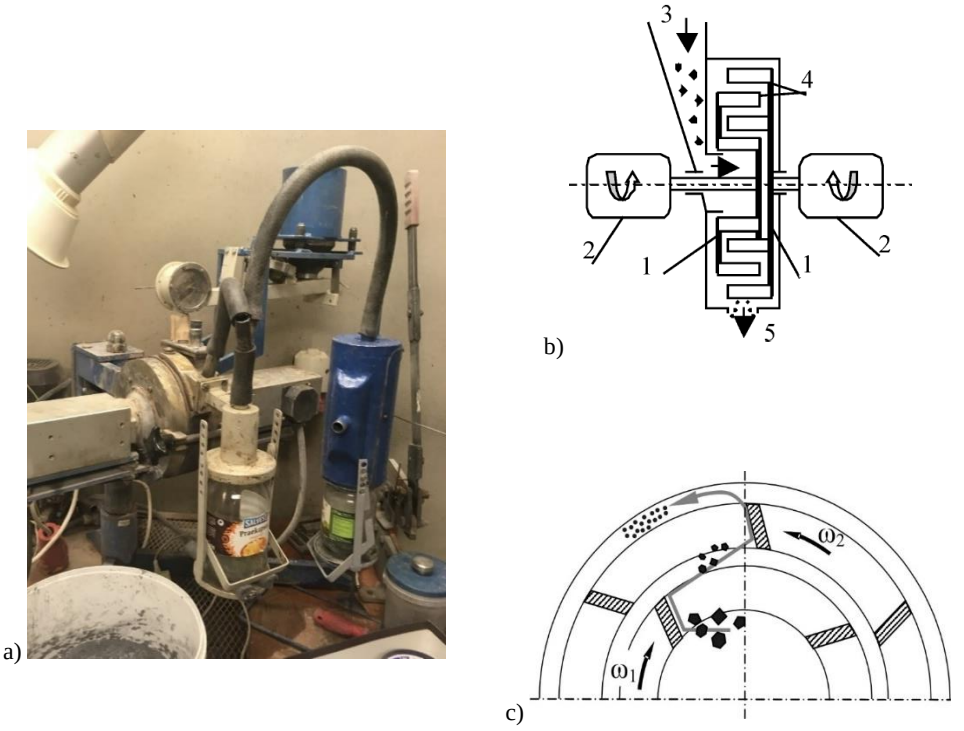

Fig.1. Disintegrator system DSL-175; a) Disintegrator system DSL-175 in a lab of Tallinn Technology University, Estonia; b) Schematic representation of the disintegrator equipment: [2] 1 – rotors; 2 – electric drives; 3 – material supply; 4 – grinding elements; 5 – output; c) Principal scheme of the process of raw material milling (longitudinal section) [2], where ω_1, ω_2 – radial velocity of disintegrator wheels.

After the samples were kept in distilled water for 3 days, the sample weight and density were determined, as well as the number of pores according to the Archimedes method.

The microstructure of cracks' surface surfaces was examined by the optical microscope KAYENCE VH-Z500W - how cleaved and unshackled are the cenospheres, as well as visually evaluated pores in open spaces.

2. EXPERIMENTAL PART

Concrete with 3 types of cement CEM II A-LL 42.5 N, Aalborg White and Gorkal 70 composition were mixed. The next step was adding 30%, 40% and 50% additive to the mixture, mixed with cement and sand and milled in a disintegrator, then added to the water and superplasticizer SuperPlast Sikament 56 in two recipes - immediately and after 3 days of waiting – to find out if this waiting gives any reasonable results.

Hardened concrete samples first in bars 3x3x45 cm (see Fig. 2 a) and then cut into cubes of 3x3x3 cm (see Fig. 2 b) were pressed after 3, 7, 28 and 56 days under compression force with 2 types of compression machines Zwick Roell and Automax 5. The test speed of the samples was 0.5 mm/s. By measuring the sample dimensions compressive plane, stress values were obtained.

a)  b) 

Fig.2 a) Sample lanes in molds, dimensions 30x30x450 mm; b) Specimens, dimensions 30x30x30 mm.

3. RESULTS AND DISCUSSION

3.1. COMPRESION TESTS

As one of the scopes of the experiment, the compression stresses of hard concrete specimens after 3, 7, 28 and 56 days were obtained. As an example, the results of the refractory Gorkal 70 specimens (shown in Figures 3 and 4) are shown after 28 days for four different sample types of cenospheres. 5 sample cubes were pressed. As it is seen the upper curve of the G00 (with 0% cenosphere) has the highest strength - an average of 60.97 MPa. In the G03 samples, or 30% cenospheres, the compression resistance is reduced to an average of 27.14 MPa, G04 to 18.17 MPa and G05 to 10.58 MPa,

respectively. Here it can be estimated the compressive test efficiency, most possible cenospheres are not applicable in the high-strength structures. Similar results are also for the 3-day settler material. The compression strength is decreasing, but for the specimens without cenospheres - G30 increases.

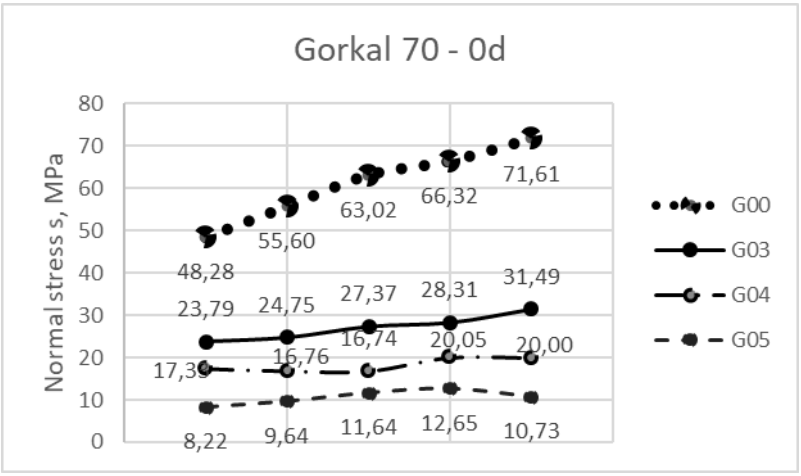

Fig. 3 Normal stress of Gorkal 70 samples after 28 days of hardening (they were mixed with water and superplasticizer immediately after grinding - 0d)

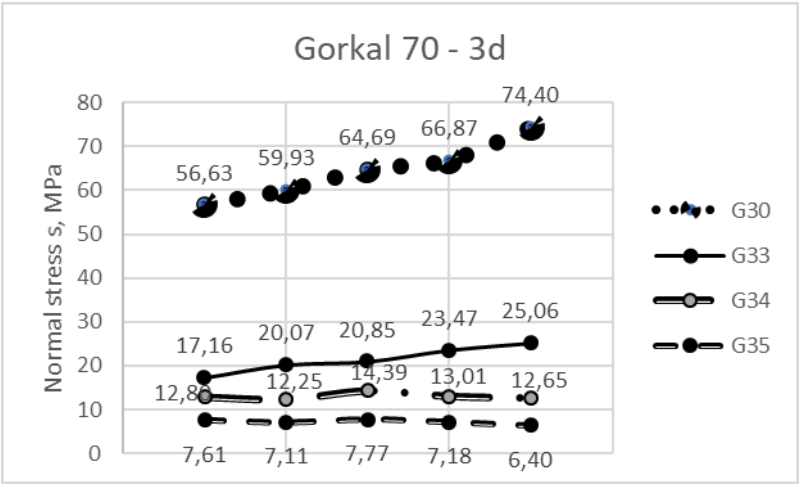

Fig. 4 Normal stress of Gorkal 70 samples after 28 days of hardening (they were mixed with water and superplasticizer 3 days after grinding - 3d)

4. OPTICAL MICROSCOPY

Visual inspection of broken surfaces with optical microscope displays the adhesion properties of cenosphere and concrete. After the observation, it is concluded that the adhesion is poor, because after the applied compression the forces in the material were not strong enough for the cenospheric particles to remain on the concrete, but they kept or tended to keep the shape of the sphere. Visually it is seen in Figure 5 – there are still spheres or spheres' imprints from the other side of the crack.

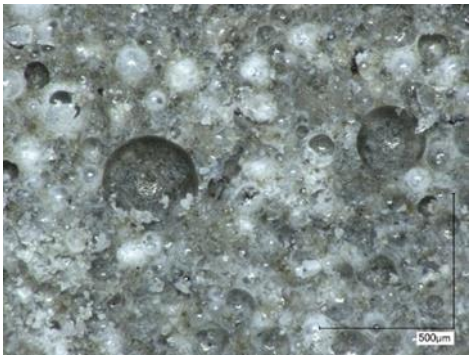

Fig.5 Surface research with the optical microscope. White spheres are cenospheres. Big dark spheres are pores. Small dark spheres are cenospheres' adhesion result with cement.

5. CONCLUSION

Engaging the disintegrator and waiting for 3 days without cenospheres increases the compressive strength of CEM II and Gorkal 70, while Aalborg White decreases.

For high-strength concrete like Aalborg White, it is not appropriate to use cenospheres because the more cenosphere, less normal stress.

If cenospheres are blended immediately instead of 3 days, the average compression strength is larger than 20%.

Waiting for 3 days increases the average stress on the cement by 3.7 MPa but samples with the cenospheres' participation are significantly reduced.

Inspection of the material's broken surface with an optical microscope showed low properties of the cenosphere and concrete adhesion.

These concrete materials can be used as a lightweight concrete material for thermal insulation as slabs or special walls where compression strength is not a priority.

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Key words:
material, composite, fiber, lamination, airplane

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TYPES AND LAMINATION OF MATERIALS USED IN AN AEROMODELING OF AN AIRPLANE

In this paper we present types of materials being used in an aeromodeling of an airplane. This wisdom is not only a theoretical intellectualization, but primary practical knowledge. This thesis is divided into two parts. The very first one is primary theoretical. It focuses on types of materials being used by Academic Flight Club members during their work on an airplane. The second one depicts practical knowledge we learned during our work in the workshop. It presents lamination as one the most common processes to create a part of an airplane from the ground. It describes preparation to lamination, putting an emphasis, that not only the action but also careful planning makes a difference. This part also shows the structure of our sandwich composite as well as the mold used during process, using visual aid.

1. INTRODUCTION

The inspiration to this thesis is a real need of an Academic Flight Club*. The main goal of this work is to characterize and set in order all information the Academic Flight Club possesses about materials being used by them. Discussed materials and processes are not only a theoretical intellectualization, but primary practical knowledge.

The first part of this job is theoretical one. It depicts types of every single material, the Academic Flight Club uses in their workshop, also describes purpose of using them and their characterization. The second part focuses on processes in which we use the materials.

The materials' desired properties are not the only one factor which determined their application. Even more important is its cost and availability on the local market. Usual

[1] Wrocław University of Science and Technology, Faculty of Machine Building and Power Engineering.

* Academic Flight Club is a students' association which works on a ground of Wroclaw University of Science.

restriction by time and lack of funds from independent funders is the motivation of using cheaper substitutes of high-end materials.

2. DESCRIPTION OF MATERIALS

2.1. BACKGROUND INFORMATION ON MATERIALS

Usually, at the beginning of the design process team seeks the perfect balance between its endurance properties and the weight of the entire structure which is supposed to be the smallest possible.

The materials we use mostly in our workspace are aluminum, herex foam, rohacell foam, carbon-epoxy composite, balsa, kevlar fiber, glass fiber, steel, plywood, felt, ASA polymer, Polylactide, cyanoacrylate glue, wikol glue.

2.2. PROPERTIES OF MATERIALS

The first mentioned material is an aluminum. It's strength equals 10150 psi. It is easy to process by Academic Flight Club's team members. It also possesses good specific strength and is highly available in our region. We usually use this material in tendons of our aircraft.

Herex (specific strength 100 psi) and Rohacell (specific strength 102 psi) foams will be considered together because of their similar structure and purpose of using them. It possesses low flexibility, high impact strength. It is usually used in sandwich composites. Herex is mostly used in ribs, cargo bay and lower section of an airplane. Rohacell foam posseses almost the same physical properties, with an exception of lighter weight, what also makes it more fragile at the same time. Rohacell foam is usually used by us in wings of an airplane.

Carbon epoxy composite is without doubt the very best material we possess. Not only it extremely strong (specific strength 145000 psi), but also light as well. It is used almost every part of an airplane like cargo bay, fuselage pipes, wings and spar links. We also possess carbon rowing, which is usually used in order to carry longitudinal stresses in our constructions.

Balsa is an usual material, because of its structure. Its specific strength equals 1015 psi. It is extremely easy to work with. Balsa is very light and anisotropic. It is usually used in ribs, wing spars, wing cover as well as the tail cover of an aircraft.

Kevlar fiber is poly(*p*-phenylene terephthalamide). It is a fiber, which is stronger than carbon one. It is used primary on those parts of construction, where the maximum concentration of pressure on it occurs.

Glass fiber is one of essential materials we possess in our workspace. It has specific strength of 52200 psi. It possesses low elongation and high Young's modulus. It is mostly used in wings of an airplane. Engineers also use it in order to experiment with new techniques of lamination, in replacement of carbon epoxy composite because this is much cheaper and easier to find.

The next enlisted material is steel. Its specific strength equals 58000 psi. This material possesses high density and strength as well as high impact strength. In our workplace we have only small pieces of it, which we use in an airplane, such like screws. This material has too big density in order to use it in great amount. This would make an airplane heavy, which is the exact opposite of what engineers desire in their materials to be. Also steel is difficult to process what makes it even less suitable material to use in workshop.

The next material which is necessary is a plywood. It has specific strength of 4350 psi. This material possesses high specific strength and also very elastic at the same time. In our designs it is usually used in fuselage fixing, payload fixing and ribs as well.

Felt is quite different material. It is light and elastic. The properties of it that make it so special is it is absorption of deformation and energy as well. It is primary used as a payload fixing.

ASA polymer and Polylactide (PLA) are not the materials with the biggest impact on an airplane. Specific strength of ASA polymer equals 6380 psi, and Polylactide's specific strength equals 7250. ASA is used on a clips. Polylactide is a material for 3D printed element, which usually serves as motor mount.

Cyanoacrylate and wikol glue are only a tool to bond few pieces together. Cyanoacrylate glue has specific strength of 2170 psi, while wikol glue's strength equals 1550 psi. Cyanoacrylate glue is quick-drying, brittle and durable bond. Wikol glue is more elastic than cyanoacrylate and perfectly fills the gasps between materials. Both of the glues are primary used in wing gluing.

3. LAMINATION AS A PROCESS, WHICH USES MENTIONED MATERIALS

3.1. BACKGROUND INFORMATION ON LAMINATION

The most popular process used on a workshop of Academic Flight Club is lamination. The materials, which are used during this process are usually carbon-epoxy composite, glass fiber, carbon fiber fabric entwined with glass yarn, herex foam, kevlar fiber and carbon rowing.

This example is an example of lamination of an undercarriage. The process starts with cutting the materials into the desired shapes. Then the materials are displayed nest

to the mold in the order they will be used. This is necessary in order to save time during the process.

3.2. DESCRIPTION OF A PROCESS OF LAMINATION

The next step is careful cleaning of the mold and preparing it with precise greasing it with wax, in the part where material will touch the mold. This part is very important, because cleaning mold reduces possibility of causing irregularities on the fiber, which decreases its mechanical properties, which is not desired. When it comes to waxing, this process is the only one possible prevention of material sticking to the mold. Thanks to it we can easily take of the laminated material. Neglect of such thing might bring destruction of laminated undercarriage or even the bond itself.

Following part consists of weighting all of the materials which will be used during lamination. We do it in order to measure the amount of resin which is necessary for the process. The prefect proportions is when the weight of resin equals half of the weight of all materials used. When the amount of resin is measured, we add hardener mixture. We do it in the proportions, where for every tenth part of resin we put inside four parts of hardener mixture. After mixing those two ingredients together, the resin starts hardening after 45 minutes. Up to this time the whole lamination process must be ended.

Next step is careful reinforcement of previously prepared materials. We reinforce materials using small painting roller and rolling material in the direction of fabric's weave. It is important in order to preserve all properties of the material. Engineers are supposed to be extremely careful while operating with carbon fiber, because before lamination it is fragile.

At this moment in the lamination process take part from three to four people. Two people are carefully laying reinforced material in the mold. They do it using small painting brushes. It is important to be gentle with the structure of materials while doing it, especially while sticking materials into the grooves of the mold. When the material does not want to stick to the surface, it is recommended to moisten painting brush into the mixture of resin an hardener.

3.3. MOLD AND MATERIALS

This sandwich composite has carbon fiber fabric as the first one- which will be outside, because of its strength. The next one is kevlar fabric, followed by two more carbon fabrics, but this time entwined with glass yarn, then rowing. We add rowing not only because of their abilities, but also because of their impact on how they pressure the material to the grooves of the mold. They minimize the amount of air which stays between mold and the fabric, which makes uneven structure of it.

Fig. 1. This picture shows mold (the first one from the bottom) and materials in order they are used starting from the bottom of the picture.

Later we put herex foam inside and again carbon fiber fabric entwined with glass yarn, but only on the curves of the mold. We end the process with another part of rowing and carbon fiber fabric entwined with glass yarn . The last part when it comes to materials is curving the first material put inside - carbon fiber fabric, so it covers all the materials from outside. We cover the outside with one fabric in order to guarantee fiber weave continuity.

Later the mold is covered from the top with hard material which puts pressure on our laminated composite inside and prevents it from moving inside mold. Later this mold is compressed with clamps from different sides.

This process ends with putting laminated material into the heating chamber and is left to be there for 5 to 7 hours.

4. CONCLUSIONS

In this paper we presented the materials as well as the lamination of an undercarriage. In Academic Flight Club we also laminate straws, using only carbon and glass fiber. Moreover we use this process to make cargo bay as well. In some examples we do not use weight to keep material in place after lamination and exchange it with vacuum, which removes air between laminated material and foil. This substitute is as efficient as weight. Lamination is a process which is used frequently in Academic Flight Club's workspace. All presented parts are the result of years of experimenting and working in the workspace.

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Key words:
microwave assisted extraction, solvents, microwave field, barodiffusion, energy efficiency, food extracts, phytopreparations, extraction kinetics

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APPLICATIONS OF MICROWAVE FIELDS IN FOOD TECHNOLOGY: PROCESSING, PRESERVATION AND EXTRACTION*

Microwave radiation, as a method of heat supplying, is not so far widely used in food industry. However, this method is promising because of the moisture present in food products, which is heated extremely intense. A number of scientific studies confirm that microwave radiation significantly intensifies processes of dehydration and extraction. This study presents the results of using MWAE – the microwave assisted extraction, – in the production of coffee, rosehips, medicinal herbs and other extracts. The dependencies of the extraction kinetics, thermograms and results of the study of obtained extracts qualitative parameters are presented. Different types of extraction units were used for different products: open vessel type, closed vessel type, operating at atmospheric and at reduced pressure. The extracting from ground coffee shows high values of mass transfer coefficients: [5.8, ... 8,8·10-8] m/s, which indicates a high degree of the process intensification in comparison with methods of battery extraction. The process temperature did not exceed 100 °C, so there are no cellulose hydrolysis processes, which reduce the quality of the coffee extract. An extractor of a closed type was used for extracting from rose hips. The extraction was carried out under reduced pressure. Analysis of the obtained extract showed a high content of vitamin C and beta-carotene, compared with the extracts obtained in the thermostat.

1. ANALYSIS OF THE EXPERIENCE OF THE MICROWAVE FIELD USAGE IN FOOD TECHNOLOGIES

As known, microwave (MW) radiation is the frequency range between 300 GHz ... 300 MHz, which takes place between infrared radiation and radio frequencies in the electromagnetic spectrum. Most microwave heating systems use frequency of

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* Invited paper.

2450 MHz, which is used by home microwave ovens. In Ukraine, the following frequency ranges are permitted for industrial use: 1 915 ± 13 MHz; 2 2450 ± 50 MHz; 3 5800 ± 75 MHz; 4 24125 ± 125 MHz.

Of the four microwave ranges, the first two, mostly, are used in the food industry. The second frequency range is used in home microwave ovens and both are used for industrial heating [1].

The main difference between microwave heating and convective heating methods is the absence of intermediate heat carriers. Energy in this case is transferred not according to classical scheme "generator - environment - product", but directly from generator to product "generator - product", and only then heat is distributed convectively and conductively to the product and environment.

When MW energy enters the sample, it is absorbed depending on the scattering factor. It is believed that penetration depth is almost infinite for materials that conduct microwave energy and zero for materials with high reflectivity, such as metals. The scattering factor is of great importance for processed samples. Since, energy is rapidly absorbed and dissipated when MW pass through the sample, the greater the scattering factor, the less the MW energy of a given frequency will penetrate into sample [2].

Recent studies confirm high intensification of mass transfer processes in the MW field. However, despite the large number of MW extraction studies, industrial MW extractors are not commercially available today. MW extraction devices have been used in research and experiments in the field of pharmaceuticals and organic chemistry. Their characteristics are shown in table 1 [3-5]. Descriptions of high-performance product that could be used in food production were not found or produced.

The MW extractor designs are being refined. In parallel MW extractors are developed in different countries, experiments are conducted for different types of raw materials, depending on production needs. For the extraction of cocoa leaves in the research of the Department of Chemical Engineering, University of Malaysia (Malaysia), an apparatus based on a household MW oven (Samsung MW718), equipped with additional regulators for implementation of two-stage and discrete extraction modes were used [6]. In this case, only microwave field was used, but with the help of an advanced control system different operating modes were implemented: a step change of the power of microwave field, a mode with interruptions of the field influence, a saw-like change of the power of microwave field.

A combined technique for extracting polysaccharides from *Fortunella margarita* (kumquat) was used in research by the Tagalog Science Center, in collaboration with the College of Food Sciences, Fujian University of Agriculture and Forestry (China) [7]. In combination with MW and ultrasonic extraction techniques, it is possible to significantly accelerate the process and purity of isolated polysaccharides. The technique of ultrasonic microwave synergistic extraction (UMSE) uses cavitations vibration and high energy potential of MW energy.

The combined extraction technique was also used in the research of Sun Yatsen University (China). They call their method of extraction "a technique of hybrid field dispersive extraction in a solid-liquid-solid system". Target components were organochlorine pesticides contained in tobacco [8].

Also, combined extraction techniques are used in their research by the experts of Chin-Yi National University of Technology (Taichung, Taiwan). The technique of hybrid MW thermal extraction is used to obtain biologically active components from mulberry root [9].

Table 1. The overview of modern microwave devices and their main features [3-5].

Device	Notes
CEM Corporation; MARS (open (OTC) and closed type (CTC) of construction)	Adjustable power up to 1600 W; possibilities to adjust the reflux condensers, use of additional reagents, additional mixing, etc.; capacity up to 40 containers (75 ml) in closed system and one container in 5 ml in open mode. [50, … 300] ° C, depending on capacity and pressure rise up to 34 bar
CEM Corporation; Discover series (OTC and CTC)	Focusing microwaves up to 300 W with high efficiency; single camera mode with capacity up to 300 ml; interaction with autosampler from 12 to 96 points; [80, … 300] ° C at pressures up to 21 bar; dynamic mode of operation during continuous operation or in the flow stop mode
Milestone; Ethos EX Lab; (OTC and CTC)	From 1 to 100 g; adjustable power up to 1600 W; adjustable motors for normal operation, high throughput and large sample analysis; a magnetic stirrer to ensure uniform mixing, solvent evaporation and recovery after treatment; pressure control up to 35 bar
Milestone; Ethos Digestion Lab series (OTC and CTC)	Convenience for welding procedures; maximum working pressure is 100 bar; different configurations of agitator motors.
Anton Paar; Multiwave 3000; (CTC)	Adjustable power up to 1400 W; mixing device and rapid cooling system; processing up to 48 samples at a time; controlled evaporation of the solvent to dry the extract
Aurora; Biomed; Transform 800; (CTC)	Processing up to 10 samples; maximum modes are 250 ° C and 55 bar; centralized control of pressure and temperature
Sineo; MDS-8; (CTC)	Adjustable power up to 1200 W; processing up to 10 samples; maximum modes are 300 ° C and 80 bar
Sineo; MDS-10; (CTC)	Adjustable power up to 1800 W; processing up to 15 samples; maximum modes are 300 ° C to 15 bar

In general, it can be noted that MW field using gives a positive result for extraction from plants and vegetable raw materials.

Literature does not give a clear explanation of the causes of intensification precisely when applying a microwave field, a clear mathematical description of the process and transition to a meaningful mathematical model of extraction processes under the influence of microwave field on plant structures.

When extracted from plant raw materials, the main barrier to extractive substances in the extract is the cell membrane. In the works of scientists of Ukrainian scientific centres [10] it is emphasized that the destruction of cell walls can intensify the process of extraction. Different methods can be used for this: chemical, mechanical or electro physical, to which MW extraction applies.

In the research of the Department of Processes, Equipment and Energy Management MW technologies for process intensification have been used since late 90's. Positive results have been achieved in coffee and coffee raw materials extraction [10-11], cognac production, flax and amaranth oil extraction. In study of extraction processes, it is determined that the phenomenon of barodiffusion occurs under the action of MW field [10]. Barodiffusion phenomena and its in-depth study became the basis for development of the direction of extraction with involvement of MW radiation.

Next step in the development of microwave assisted extraction (MWAE) apparatus is to implement continuous operating modes and increase productivity. Work in this area has begun relatively recently mode of continuous movement of the solvent through the raw material layer was implemented in the works of O.G. Burdo, S.G. Terziyev and T.L. Makeevskaya when working with coffee sludge [11].

2. RESEARCH MATERIALS AND METHODS

2.1. EXPERIMENTAL BENCH AND EQUIPMENT

The most of studies were conducted on laboratory plants, developed by the authors of this article. The power supply in MW extractors was carried out by means of impulse control. There was specified the total time of electro physical exposure and the frequency of magnetron activation. The MW unit was connected to the mains via a combined K-50 type measuring kit.

Using the wattmeter of this device was determined by power consumption of the plant. Accuracy of MW timer operation was checked with stopwatch. Portable MW radiation leakage tester EM0328 indicates intensity of the electromagnetic field in range [0, ... 10] mw/sm. Power consumption of 230 VAC, 50 Hz, 1,450 W, in magnetron mode output power was 900 W, frequency 2,450 MHz. The error of the timer cycles is near the 0.3%.

2.2 ANALYTICAL INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

During the processing of results of the experiments, there is a need to calculate the thermo physical and physicochemical properties of the extracts. Temperatures ($t_к$, $t_н$) were measured at inlet and outlet of the extractor solution using a chromel alumel

thermocouple and a Fluke 561 HVA CPro digital measuring instrument, and by the DAN -1000 contact thermometer.

Diffusion coefficients D for "coffee bean - water" system have been identified in the literature [10] and average values of diffusion coefficient for the "solid phase - water" system have been established at 25 °C. Influence of ambient temperature (*t*, ºC) on average values of the diffusion coefficient for processing experimental data was taken into account by the ratio 1 [11]:

$$D(t) = (1.97 \cdot 10^{-8} \cdot t^3 + 3.71 \cdot 10^{-5} \cdot t^2 + 3.76 \cdot 10^{-3} \cdot t + 0.09) \cdot 10^{-9} \quad (1)$$

Since in case of the phenomenon of barodiffusion partial destruction of the plant cells walls and the capillaries and turbulence of the boundary layer occur, traditional model of mass transfer is changing. A common barodiffusion flow JM occurs, in which it is impossible to distinguish the internal and external diffusion components. Thus, the intensity of mass transfer can be characterized by the effective mass coefficient βE, which is calculated by the classic formula (2).

$$\beta_E = \frac{V_E \cdot 100}{F_K \cdot \tau \cdot (C_n - C_p)}, m/s \quad (2)$$

where V_E – volume of the extract, m^3; F_K – phase contact area, m^2; C_n – current concentration in raw materials; C_p – equilibrium concentration in raw materials; τ – extraction time, s.

During the generalizing of the experimental studies, parameters of the criterion equation (3) and dependences for the calculation of the phase equilibrium conditions were determined.

$$St_m = A(Re)^m \cdot (Sc)^n (\Pi)^b \cdot (Bu)^p \cdot (D)^y \quad (3)$$

where St_m Stanton number of mass-transfer; *Re* Reinolds number; *Sc* Shmidt number; Π parametrical number; *Bu* Burdo number; *D* diffusion coefficient; *A, m, n, p, b, y* – experimentally defined constants

Error in estimating these parameters depends on accuracy of the calculations of similarity numbers: Stanton *(St_m)*, Schmidt (*Sc)*, Reynolds *(Re)*, Burdo *(Bu)*, which in turn are determined by errors of estimation of geometrical and mode characteristics of the extraction process obtained by means of measurements. To reduce systematic errors determined by error of the device, devices with an accuracy class of [0.5, ... 1] were used. Work with the devices was carried out in accordance with rules given in the passports and operating instructions.

2.3. THE INSTRUMENTAL ERRORS

Direct measurements give estimates of height and length of the channel, time, radiation power, changes in volume of the solvent in a measuring container, volume of the solution, its optical density and mass of coffee raw materials.

Limit of the allowable relative error of direct measurements, which are determined by accuracy class of the instrument and magnitude of the measured value, are given in table 2. Upper and lower magnitudes of the measured values were taken into account in calculation of the limit of permissible relative error. The RMS (root-mean-square) errors of the similarity numbers and dimensionless parameter Π consist an error of changes in the values (υ, ρ, D, r, c_p).

Table 2. Limits of allowable error of direct measurements

№	Measured value			Allowable error	
	Name		Marking	Absolute	Relative
1	Time, s		τ	1	1 / 300 = 0.003 1 / 1,800 = 0.0006
2	Height, mm		H	1	1 / 27 = 0.037 1 / 20 = 0.05 1 / 14 = 0.07 1 / 8 = 0.125
3	Length, мм		L	1	1/200 =0.005
4	Temperature, °C	Thermocouple DAN-1000	T	0.5	0.5/30 = 0.017 0.5/75 =0.007
4	Temperature, °C	Thermometer	T	0,1	0.1/10 = 0.01 0.1/100 = 0.001
		Pyrometer GM320		1.5	1.5/330=0.0045
		Thermal imaging pyrometer FLIR TG54		1	1/100=0.001
5	Optical density	Refractomether	E	0.001	0.001/1.3334 = 0.0007
		«SPEKOL»		1	1/15 = 0.07 1/100=0.01
6	Concentration	HI 96801, Hanna Instruments	C	0.2	0.2/100=0.002
		EC /TDS / COM-100		2	2/100=0.02
7	Weight, g		$G_з$	0.001	0.001/180 = 0.000006 0.001/335 = 0.000003
8	Volume, l		V_P	0.01	0.001/5 = 0.002 0.001/20 = 0.00005

It should be noted that even with increased values of input parameter errors (δRe = ± 2.3%, δSc = ± 1.13%, δBu = ± 5.8%), the final error δSt_m of the criterion equation does

not exceed 7%. That is, the standard error of the mathematical model contains an experimental error, not exceeding 7%.

3. RESEARCH RESULTS AND DISCUSSION

3.1. RESEARCH RESULTS

The results of studies of hydraulic processes in MW modules of the apparatus of continuous action should to determine the maximum concentration in solid phase, the kinetics of extraction under conditions of change of mode parameters are necessary to determine modes of operation, in particular to avoid removal of the product from the extractor or loss of solvent. Main factors affecting the extraction process are temperature (T, °C) and power (N, W) of MW radiation and hydraulic module (ζ), volume consumption of solvent (V_p, kg/s), equivalent particle size (d_e, mm), thickness of product layer (σ, mm) (table 3).

Experiments were conducted using coffee beans of different grinding tonnage and whole grains. Separation of coffee into fractions was performed using a set of laboratory sieves. The mass exchange module was filled with 10 mm product.

Table 3. Range of experimental studies of hydraulic processes

Parameters	ΔP, Pa	$V \cdot 10^6$, m^3/s	$\delta \cdot 10^3$, m	d, mm	τ, s
min	80	1.2	8	0.63	60
max	310	5.3	27	7	720

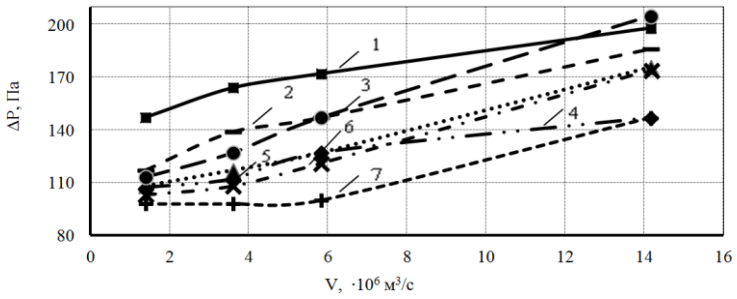

Fig. 1. Hydrodynamic situation in the module depending on change in the speed of solvent and the particle size: 1 – less than 0,8 mm; 2 – [1, … 2] mm; 3 – 1/2 of coffee bean; 4 – [2, … 2,5] mm; 5 –1/4 of coffee bean; 6 – [2,5, … 3] mm; 7 – whole coffee bean.

As consumption of the solvent changed, product level in the module varied accordingly. Different grinding modes of solvent are characteristic for coffee of different grinding tone (fig. 1).

Porosity of the raw material layer was experimentally determined depending on change in the equivalent particle diameter of product (table 4).

Table 4. Porosity change depending on the particle size of ground coffee beans

d, mm	> 0.8	[1,…2]	[2, …2.5]	[2.5, …3]
ε	0.441	0.458	0.475	0.491

Experimental data determined Reynolds and Euler numbers, equivalent dimensionless particle diameter *D*. Mathematical model of hydraulic processes in the extractor is specified:

$$Eu = 6.836 \cdot Re^{-1.06} D^{1.2} \quad (4)$$

Equation (4) can be used to estimate the hydrodynamic situation in mass transfer modules and to design MW extractors.

To adequately evaluate results of the experiment, calibration of the energy supply system under conditions of movement of the solvent through one module and a block of mass exchange modules was carried out.

Most of the experiments were aimed at studying the kinetics of extraction from coffee. Dispersion of the milled coffee particles varied in the range $[0.63 \cdot 10^{-3}, \ldots 3 \cdot 10^{-3}]$ m. Experimental studies of process of mass transfer in the system "raw material - solvent" under the conditions of MW energy supply were carried out in range of parameters, which are shown in table 5.

Table 5. Range of experimental studies

Weight of coffee in 1 module $G_к$, kg	Layer thickness $\delta \cdot 10^3$, m	Solvent consumption $V \cdot 10^6$, m^3/s	Temperature *t*, ºC	Specific microwave power *N*, W/kg
[0.02, … 0.35]	[4, … 27]	[1, … 4]	[20, … 90]	[270, … 900]

From the dependencies (fig. 2) dynamics of the depletion of water-soluble extractive solids from grains is noticeable.

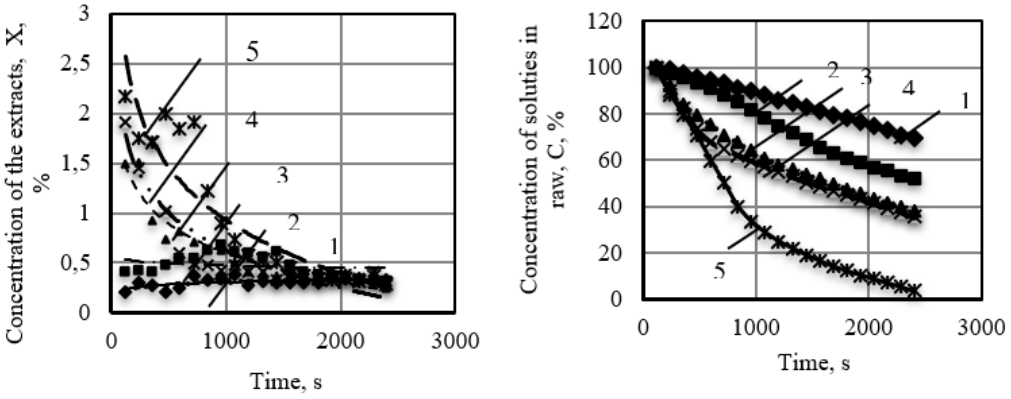

Fig. 2. Exhaustion of dry water-soluble substances (d.s.) in extract and in the raw material depending on intensity of the action of MW field: 1 – 90 W; 2 – 270 W; 3 – 450 W; 4 – 630 W; 5 – 900 W.

Studies have shown (fig. 2) that increasing the specific power of MW energy from 90 to 900 watts can increase the output of extractives from coffee beans more than twice and significantly reduce duration of the extraction process, and, consequently, reduce energy intensity of the coffee extract production process. In order to study completeness of the exhaustion of solids from coffee at different costs of the solvent, study at a specific power of 270 W was conducted (m=50 g, δ=[1, … 2] mm). Results of the experiment are shown in fig. 3. From the dependencies obtained, it is seen that with increasing of the solvent flow we obtain an extract with a lower concentration of solids

Final concentration of the extract is also significantly affected by the "solid-solvent" ratio (hydraulic module). To evaluate its impact, a study was conducted using ground coffee (δ=[1, … 2] mm) on laboratory bench, which consisted of an MW camera with a power unit and reflux condenser, which kept a constant volume of solvent (200 ml), a specific power of 270 W.

Used ground coffee samples in 2, 10 and 50 g for 1:100, 1:20 and 1:4 hydraulic modules respectively. Analysis of the results showed that the complete extraction of solids from coffee was 20 %, 15 % and 12 %, which indicates a better extraction of water-soluble substances when using a larger hydraulic module. However, with a large hydraulic module, concentration of solids in the extract is lower.

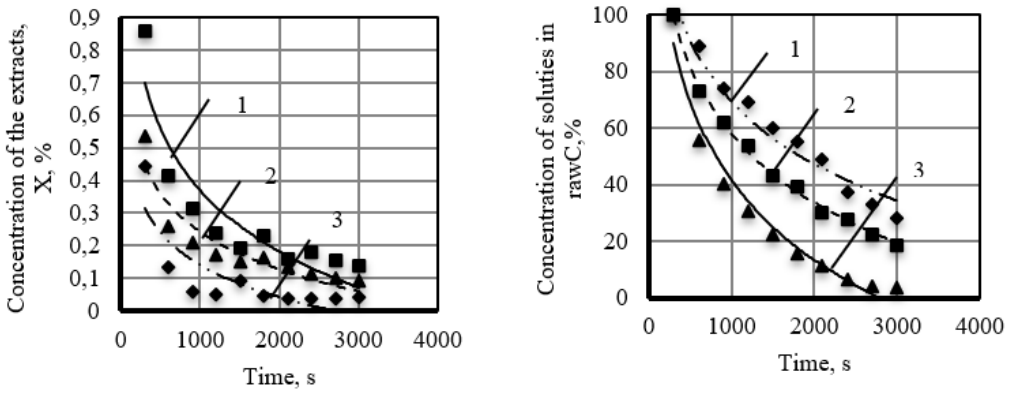

Fig. 3. Exhaustion of solids from ground coffee at different solvent consumption: 1 – $1.2 \cdot 10^{-6}$ m^3/s; 2 – $4.2 \cdot 10^{-6}$ m^3/s; 3 – $7.7 \cdot 10^{-6}$ m^3/s.

During the extraction under conditions of continuous movement of solvent it is difficult to estimate the value of hydraulic module, it is more appropriate to evaluate effect of loading the mass transfer module. A series of experiments with different thickness of product layer in the mass transfer module of the continuous action MW apparatus was carried out. With a thin layer, contact area of the phases is larger and larger volume of the solvent is in contact with the product, with larger layer of the product, movement of the solvent is complicated, which affects the efficiency of raw material use. Ground coffee with a particle size [0.63, … 1] mm was used for the experiment. Product weight in cartridges was 100, 75, 50 and 20 g. Extraction was performed at a flow rate of the solvent 6.4 kg/h ($1.66 \cdot 10^{-3}$ kg/s) and power of MW radiation of 490 W/h (50 %). Temperature of the extract at inlet is 12…14 °C. Extracted 30.3 g (30.3 % d.s.), 23.4 g (31.2 % d.s.), 16.32 g (32.6 % d.s.) and 8.96 g (35.8 % d.s.).

When choosing thickness of the product layer in the module, it should be taken into account that large layer of the product may interfere with movement of the solvent, and small one will cause a low concentration of solids in the finished extract, which will cause problems of further processing of the extract and inefficient use of energy.

Size of the particles, or dispersion of the raw material, is a factor that determines the specific surface area in contact with the solvent, respectively, it affects the rate of transition of soluble components to the extract. The experiment was carried out using 50 g of ground Arabica coffee variety of grinding. Using a set of laboratory sieves, ground coffee beans were separated by dispersion: [2.5, … 2] mm; [2, … 1] mm; [1, … 0.8] mm; [0.8, … 0.63] mm. Smaller particles were not used due to peculiarities of structure of the mass exchange modules of extractor.

As the particle size of ground coffee decreases, extraction of the extractives from the raw material to the extract increases, this is explained by the increase of contact area of the phases in the solid-solvent system, greater openness of the capillaries containing the

extractives. Large particles of crushed coffee beans are characterized by a slow transition of extractives to the extract.

After processing results obtained values of mass transfer coefficient (fig. 4), depending on speed of movement of the solvent inside the extractor.

When thickness of the ground coffee in mass exchange module is increased by [1.75, ... 4] times, mass transfer coefficient is increased by [1.2, ... 2.5] times, respectively.

Processing of the experimental data set makes it possible to recommend following relation for the calculation of mass transfer intensity during extraction from ground coffee beans under conditions of MW field:

$$St_m = 0.0027 \cdot (Re)^{-0.86}(Sc)^{0.43}(\Pi)^{0.35}(Bu)^{0.42}(D)^{1.2} \quad (5)$$

where St_m Stanton number of mass-transfer; Re Reinolds number; Sc Shmidt number; Π parametrical number; Bu Burdo number; D diffusion coefficient.

Third stage of the experimental studies was carried out on a closed stand with vacuum extraction tank. Fruits and solvent are placed in a volume that is paired with reflux condenser. After loading the volume, system is evacuated and magnetron mode is set. Temperature in the system is provided by a refrigerating machine, vacuum pump and camera magnetron. Reliability of the sealing system, consistency of the capacities of magnetron and refrigerating machine provide the opportunity to conduct the experiment without changes in evacuated system. In the first stage, a comparison of extraction efficiency in a stream without EMF and with EMF and with vacuum MW extractor was carried out. In this series of experiments, the object of research was rose hips. It is known that rose hips are rich in vitamins, in particular is thermo unstable vitamin C, which decomposes at about 60 ° C.

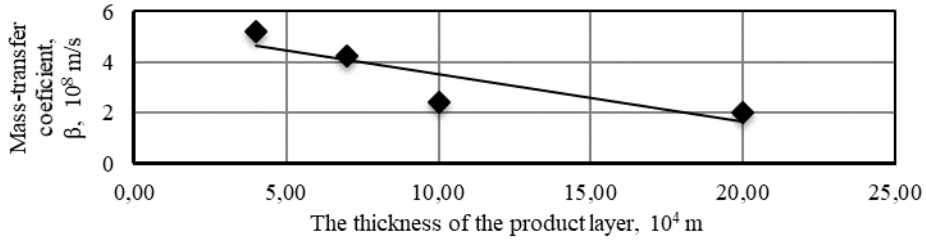

Fig. 4. The dependence of mass transfer coefficient from the product thickness layer.

Experiments were carried out with halves of rose hips under the same temperature conditions. From the dependencies (fig. 5) it can be seen that vacuum is a significant factor in the intensification of mass transfer. Effect of pressure in the chamber on the intensity of extraction was established (fig. 6). With increasing pressure from 15 kPa to 45 kPa, concentration of the extract increased by 25%.

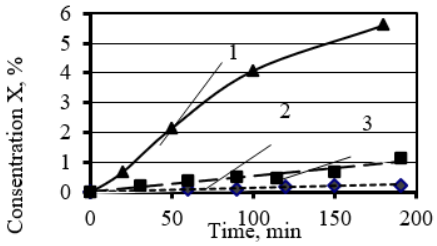

Fig. 5. The dependence of change of dry matter concentrations on extraction duration for different plants: 1 - MW vacuum extractor; 2 - MW extractor stream; 3 - no field in the stream.

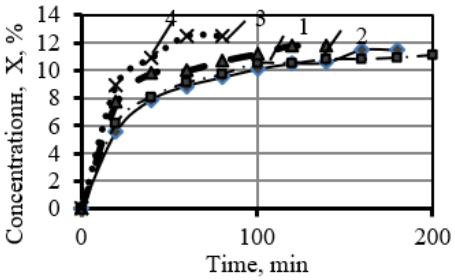

Fig. 6 Effect of pressure on extraction kinetics in vacuum microwave apparatus: 1 – 15 kPa; 2 - 25 kPa; 3 - 30 kPa; 4 - 45 kPa.

With increasing power, intensity of mass transfer increased (fig. 7), but temperature of the process is also increased (fig. 8).

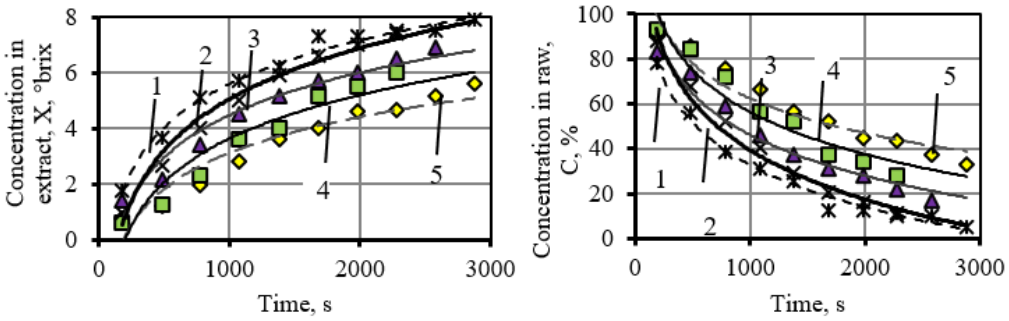

Fig.7. Influence of magnetron power to extraction kinetics: 1 - 1024 W; 2 - 682 W; 3 - 512 W; 4 - 273 W; 5 - 136 W.

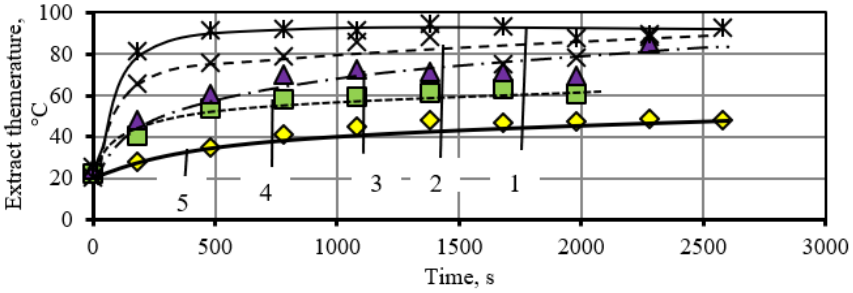

Fig.8. Process thermograms: 1 - 1024 W; 2 - 682 W; 3 - 512 W; 4 - 273 W; 5 - 136 W.

Thus, contradiction between the intensity of extraction and the preservation of vitamin C should be solved, including, on the basis of chemical analysis of samples of extracts. Results of chemical analysis of the samples of concentrated extracts are shown in table 6.

Table 6. Characteristics of extracts and concentrates

Sample	Concentration of d.s., %	Vitamin C content, mg/100 cm^3	Relative vitamin content C, %
Extract	4.,2	[430, … 550]	[10.2, … 13]
Concentrate №1	24	[3,640, … 4,050]	[9.2, … 10.2]
Cryoconcentrate №2	14	[2,120, … 2,310]	[11.2, … 12.5]

It is known that 100 g of rose hips contain an average of [470, ... 2,400] mg of vitamin C, depending on the variety and growing conditions [0.47, ... 2.4%]. *Rosa Cinnamomea* contains more vitamin C than any other species up to 2,400 mg per 100 g. It is determined that content of dry water-soluble extractives for rose hips ranges from [20, ... 25]%. Therefore, relative to the total solids content of vitamin C is [2.1, ... 11]%.

An extract volume in 500 cm^3 was selected for further concentration. When concentrated in MW device, operating temperatures varied in range of [30, … 40] °C. In 10 minutes, 412 cm^3 of moisture was removed from the extract, solids content of the extract was 24%. By cryoconcentration was treated 500 cm^3 of extract. The freezing time of the block amounted to 13 minutes. Separation of the ice block and concentrate gave 160 cm^3 of the extract with a concentration of 12%. Separation lasted 1 hour 18 minutes at temperatures close to 0 °C – phase transition temperature for water. Obtained samples proceed an organoleptic research (fig.9). There are 5 points corresponds to a rich, characteristic rose hips aroma, bright reddish-orange colour, taste without tinges of cooking, with a pronounced sour taste, and homogeneous consistency. Compared to

thermostatic processing at 60 ° C, extraction efficiency in the MW field increases approximately by 1.5 times. Increasing the specific power from 90 to 900 W/kg increases yield of solids by 3 times and significantly reduces duration of the process.

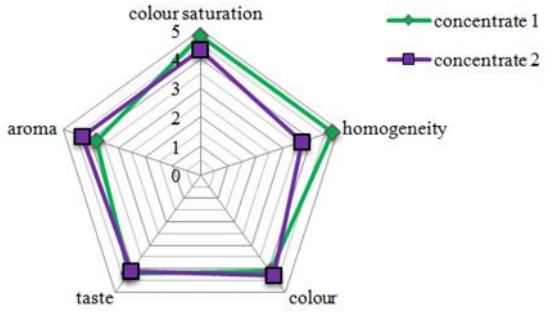

Fig. 9. Profile chart of concentrate quality assessment.

It can be concluded that cryoconcentrate (2) is better in aroma, colour and taste. But, MW treatment allows you to increase productivity without significant loss of product quality.

3. CONCLUSIONS

Influence of the solvent consumption, increase of the equivalent particle diameter, thickness of the layer on the initial concentration of solids in the extract was determined. Coefficients of mass transfer during the variation of the mode parameters are determined: when increasing power from 90 to 900 W/kg, it increases approximately by 10 times, with increasing consumption of the solvent proportionally, with increasing thickness of the layer by 5 times – decreases by about 4 times, with increasing equivalent diameter ratio of 3 to 0,8 coefficient is reduced by 2 times. Results of the experiments are summarized as mathematical models in criteria form.

Effect of temperature and concentration on the value of ascorbic acid is studied. Samples were compared in the range of concentrations from 11 to 60 ° brix and temperatures of [50, … 70] ° C. It was found that ascorbic acid content in extracts decreases with temperatures above 50 ° C. Chemical studies of the samples were carried out: extract (4.2 ° brix), concentrate obtained in MW vacuum apparatus (24 ° brix) and cryoconcentrate (14 ° brix). Content of vitamin C in these samples was, respectively, 500, 4,000 and 2,200 mg per 100 cm^3. It was found that relative to the total solids content of vitamin C in all samples was kept in range of [10.2, ... 13] %. As a result of organoleptic studies, a profile of quality indicators of samples: concentrate and

cryoconcentrate was constructed. The cryoconcentrate has slightly superior indicators in comparison with MW concentrate. But, MW treatment allows to increase productivity without significant loss of product quality.

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Students' Science Conference

III

BIODIVERESITY AND HUMAN WELL-BEING

Key words:
3D modelling technology, brain modelling, ICH, neurology, segmentation

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INTRACEREBRAL HEMORRHAGE EXTENT ASSESSMENT USING 3D MODELLING TECHNOLOGY

Intracerebral hemorrhage (ICH) is the second most common cause of stroke, accounting for 10% of hospital admissions for stroke. Risk factors for ICH include: hypertension, smoking and diabetes. People with intracerebral bleeding have symptoms that correspond to the functions controlled by the area of the brain that is damaged by the bleed. We decided to create a 3D brain models to estimate the extension of bleeding in intracerebral hemorrhage, by using CT scans of patients with this diagnosis. CT scans are performed in patients' admission to the hospital, after week and after two weeks of treatment. Moreover we checked the accuracy of our models - by comparing corresponding CT scans with transection of our 3D project of brain. The goal of our research was to examine the possibility of using 3D modelling technology to visualize intracerebral hemorrhage.

1. INTRODUCTION

Intracerebral hemorrhage (ICH) is a devastating disease refers to any bleeding within the intracranial vault, including the brain parenchyma and surrounding meningeal spaces. ICH is also the second most common cause of stroke, accounting for 10% of hospital admissions [1]. Risk factors for ICH include: hypertension, cigarette smoking, diabetes mellitus, excessive alcohol consumption, male sex, older age, and Asian ethnicity [2]. People with intracerebral bleeding have symptoms that correspond to the functions controlled by the area of the brain that is damaged by the bleed.

The location of ICH depends on the symptoms and prognosis. The CT scans allow us to estimate the extent and thus determine if patients can be treated or need surgery. ICH can be recognized on CT scans because blood appears brighter than other tissues. However, due to the fact that we have cross-sectional images, it is harder to visualize the whole hemorrhage for the medics without 3D modelling technology.

3D modeling is the process of creating representations of any surface or object by manipulating angles, edges and vertices in a simulated space. Modeling effects are

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visible in movies, animations and video games. Modeling can be obtained manually using specialized software for the production of three-dimensional graphics, which allows you to create and deform surfaces or transform real objects into a set of points [3].

2. MATERIALS AND METHODS

2.1. MATERIALS

The dataset used in this project consists of 15 CT images which belong to 5 patients (3 images for each patient. First image refers to diagnosis stage, the second one was taken after one week of treatment and the third after two weeks. The dataset was provided by Department of Neurology in Zabrze, Medical University of Silesia. All images were formatted into DICOM extension. The intracerebral bleeding can be seen on Fig. 1.

Fig. 1. Image of patient with ICH.

2.2. METHODS

The first of the project was to made a manual segmentation of: brain, ventricles and hemorrhage to create 3D brain models using 3D Slicer and then improve them in 3D Blender. Next step was to made cross-section of obtained models in Meshmixer programm and compare them with original CT scans. The last step of this research was to develop an application using Windows Presentation Foundation framework and C# programming language. Main steps of the project can be seen on Fig. 2.

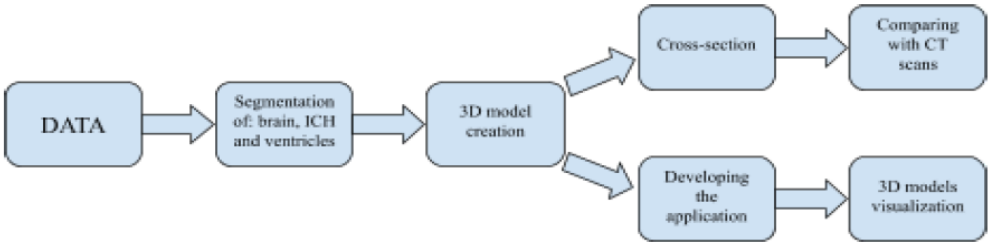

Fig. 2. Main steps of the project.

Before the segmentation step, the resolution of dataset images was checked. It was done in order to make sure that the images were based on isotropic voxels - voxel shape is the same in every dimension. The next step was to extract the region of interest (ROI) which was done manually.

Segmentation, in relation to images, is the process of separating uniform areas on the basis of a defined criterion [4]. In this work, the first stage of segmentation was the creation of empty segments referring to specific brain elements to be visible on the generated three-dimensional model (Fig. 4). Created segments: brain, ICH, ventricles.

The next step was to mark structures corresponding to specific segments, using the - Paint selection tool, thanks to which it is possible to define voxels and automatically assign them to a specific area. After selecting the segments, the Grow from seeds function was used, which causes the growth of regions, based on the labels assigned to individual anatomical structures. The Grow from seeds function uses the GrowCut method [5]. The GrowCut method divides the image into region based on similar voxels intensities in the closest neighbourhood [6].

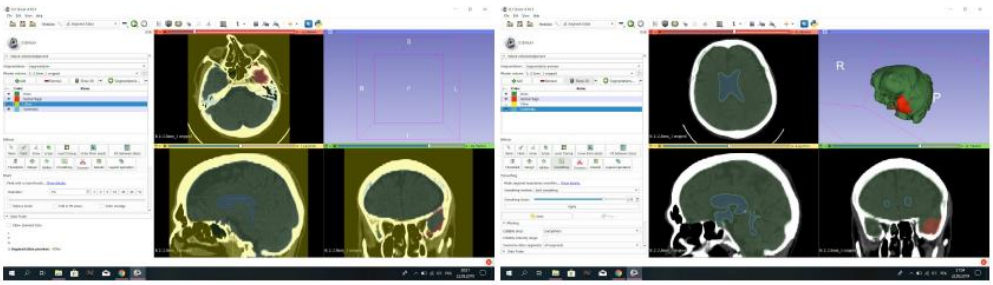

Fig. 3.Segmentation process.

After improving the selected fragments, model was smoothed using the joint smoothing method. This method ensures that the segmented structures will not overlay

in the smoothing process and is based on standard method of image filtration - convolution operation using a triangular filter [7].

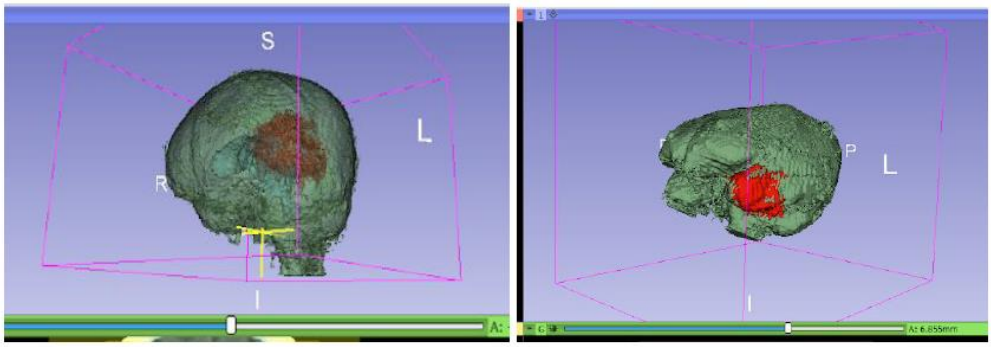

Fig. 4 .Created models.

Models were further improved using 3D graphics designer software (Blender). The noise in their structure was removed, it basically means to reject the misclassified parts in the segmentation process.

Fig. 5. Smoothed and improved 3D models.

In order to provide our project with metrics to evaluate similarity of the models, we have made a cross-section from obtained brains and compared this cross-sectional images with original CT scans. An example of the adjustment can be seen on Fig. 6.

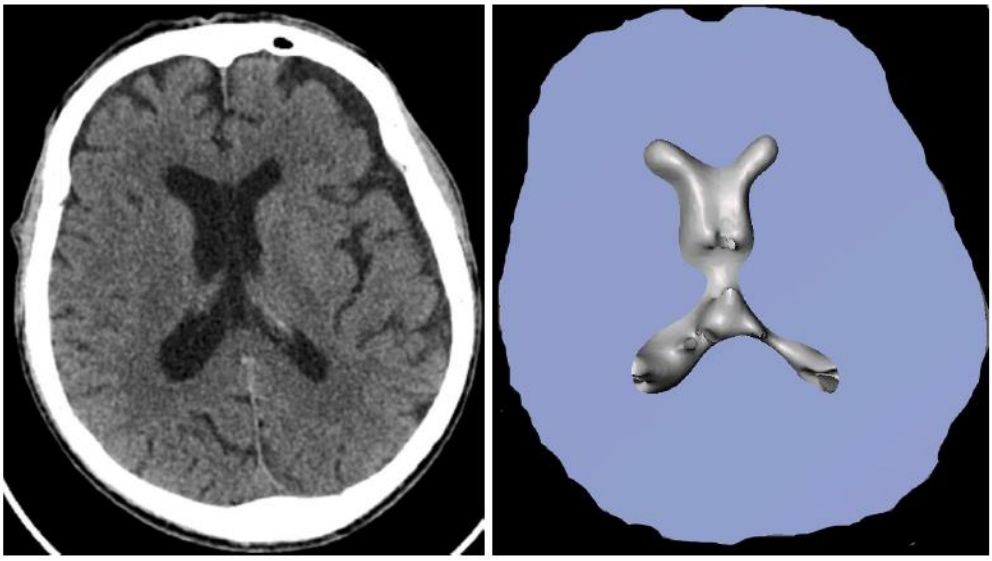

Fig. 6 Original CT scan (on the left side) and cross-section of obtained brain model (on the right side).

The last step of this research was to developed an application, that allows user to visualize and manipulate created models (Fig. 7).

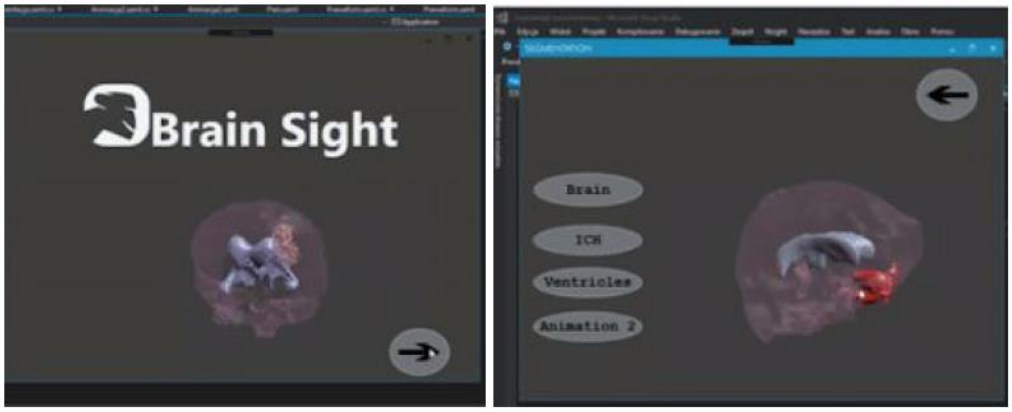

Fig. 7. Developed application.

3. RESULTS

Models were evaluated with two similarity metrics. First one is Sørensen-Dice similarity coefficient, which tells how much the segmentation mask overlapped the original scans and the second is Hausdorff distance, which measures shift between the segmentation mask and original scans. The results can be seen in Table 1.

Table 1. Sørensen-Dice similarity coefficient and Hausdorff distance results.

Iteration	Sørensen-Dice similarity coefficient [%]	Approximate result for Sørensen-Dice similarity coefficient for all models	Hausdorff distance [mm]
Model 1	91	92.8%	3.20
Model 2	92		3.23
Model 3	94		2.33
Model 4	94		2.15
Model 5	93		2.60

The volume of intracerebral hemorrhage was also calculated after first diagnosis and after treatment. After a week the volume of the ICH for most patients was reduced by half and after two weeks it was not detectable.

Table 2. Volume of intracerebral hemorrhage

	First diagnosis	After week	Approximate percentage change of ICH volume after week [%]	After 2 weeks
	ICH volume [cm3]	ICH volume [cm3]		ICH volume [cm3]
Patient 1	17.0607	7.7141	55	Not detectable intracerebral hemorrhage, visible edema of the brain
Patient 2	76.4668	33.1258	57	
Patient 3	17.5321	8.2503	53	
Patient 4	8.5965	0	100	
Patient 5	52.9358	26.0897	51	

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Key words:
metallic nanoparticles, Acinetobacter baumannii, bactericidal properties, laser light

Ewelina WANARSKA[1]

ENHANCEMENT OF BACTERICIDAL ACTIVITY OF SILVER AND GOLD NANOPARTICLES USING LASER LIGHT IRRADIATION

Bacterial infections are the main cause of diseases of 21 century. The Infectious Diseases *Society* of *America have introduced acronym ESKAPE, which describes six pathogen "escaping" from drug therapy: Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter* spp. An alternative to antibiotic therapy is the use of metal nanoparticles. It is well known that that some metallic nanoparticles have bactericidal properties. In this study bactericidal activity of biogenic silver [40 ppm] and gold [48 ppm] nanoparticles after incubation with *Acinetobacter baumannii* was tested. In next step the enhancement of bactericidal activity using laser irradiation was tested. After incubation of bactericidal suspension with biogenic nanoparticles, 92 % (in presence of Au nanoparticles) and 93% (in presence of Ag nanoparticles) lethality was observed. Using laser light irradiation caused 50% enhancement of bactericidal activity.

1. INTRODUCTION

The main cause of health and life risk in the twenty-first century are bacterial infections. Antibiotic therapy is the most popular method of treating bacterial infections. The most well-known bacteria that do not undergo drug therapy are *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumanni, Pseudomonas aeruginosa and Enterobacter spp* called "ESKAPE" bacteria [1].

In recent decades, nanotechnology products such as nanomaterials, have been of great interest [2]. Nanotechnology focuses on manipulates an object in size 10^{-9} m. These nanomaterials are characterized by special magnetic, physical and biological

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properties and can be used in many sectors of knowledge [3, 4]. Nano-biotechnology focuses on creating nano-objects with living cells or parts of them. Biosynthesis is a very desirable process due to its ease and compliance with ecological principles [5,6]. During the biosynthesis process, the main point is the manipulation and control of the properties of nanoparticles, such as size, shape and stabilization, which cause that biogenic nanoparticles can better interact with bacteria [7].
The most well-known and promising metal nanostructures are silver (Ag) and gold (Au) particles [8]. Metallic nanoparticles can exert antibacterial effects through a number of mechanisms, such as: (1) direct interaction with the bacterial cell wall; (2) inhibiting biofilm formation; (3) induction of congenital as well as adaptive host immune responses; (4) the production of reactive oxygen species (ROS); and (5) induction of intracellular effects (e.g., interaction with DNA and / or proteins) [9, 10]. One of the methods of killing bacteria using metallic nanoparticles is photo-thermal therapy (PTT). In PTT, plasmonic nanoparticles (NPs) are delivered into living cells and are irradiated with laser light, which causes the NPs' conduction band electrons to undergo synchronized oscillations that result in either the absorption or scattering of the applied light. The absorbed light is converted into heat, which irreversibly damages bacterial cells [11,12].

In this study the antibacterial activity of the biogenic gold and silver nanoparticles against *A. baumannii* was examined. Moreover, an enhancement of bactericidal properties of these particles by laser light irradiation was estimated.

2. MATERIALS AND METHODS

2.1. PREPARATION OF MICROBIOLOGICAL MATERIAL FOR TESTING

The microbiological material was Gram (-) bacterium *Acintetobacter baumannii* (Figure 1.).

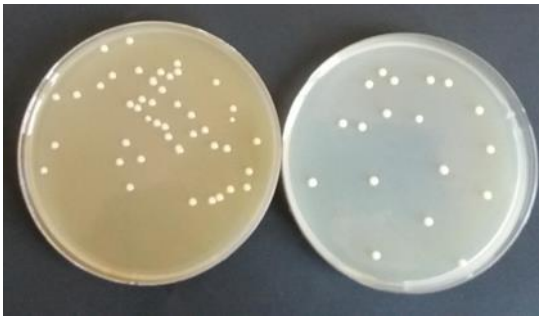

Fig. 1. Acintetobacter baumannii colonies.

The single colony of bacterium was taken from agar plate and was transferred to the 2 ml of Mueller-Hinton liquid medium. The prepared suspension was incubated for 24 hours at 37°C in dark. After 24 hours suspension was centrifuged for 5 min (600 sales per minute). The supernatant was rejected and the bacterial sediment was suspended in 2 ml deionized water and mixed.

2.2. PREPARATION OF COLLOIDAL GOLD AND SILVER NANOPARTICLES

Tested silver and gold nanoparticles were biosynthesised using Trichoderma koningii fungus extract and HAuCl4 acid or AgNO3 salt. The presence of gold and silver nanoparticles was confirmed by colour (pink and brown) and maximum absorbance peaks (511 nm and 437 nm). Figure 2. shows colour of gold and silver nanoparticles.

Fig. 2. Colloidal solutions of gold (pink solution) and silver (brown solution) nanoparticles.

2.3. BACTERICIDAL ACTIVITY OF METAL NANOPARTICLES

The 100 µl of bacterial suspension was taken to the 900 µl of deionized water making series of dilutions. The 100 µl of solutions was taken from three last control samples (10^{-7}, 10^{-8}, 10^{-9}) and seed culture was made. After 48 h the colonies were counted.

In next, step each 100 µl of colloidal solution of silver [40 ppm] or gold [48 ppm] nanoparticles was taken separately to 900 µl to bacterial suspension and samples was

incubate through 30 min in incubator in 37°C in dark. After that time 100 µl of each sample was taken to the series of dilutions using 900 µl of deionized water. The 100 µl of solutions was taken from three last samples (10^{-7}, 10^{-8}, 10^{-9}) and seed culture was made. After 48 h the colonies were counted.

2.4. ENHANCEMENT OF BACTERIDIAL ACTIVITY OF METAL NANOPARTICLES BY LASER LIGHT IRRADIATION

After 30 minutes of incubation in dark of colloidal solution of silver [40 ppm] or gold [48 ppm] nanoparticles with bactericidal suspension, each sample (200 µl) was taken to the black plate (each sample to separately hole) and irradiate by laser light (635 nm, 40 mW) for 30 min each. After irradiation, the 100 µl of each sample was taken to the series of dilutions using 900 µl of deionized water. In next step the 100 µl of solutions was taken from three last samples (10-7, 10-8, 10-9) and seed culture was made. After 48 h the colonies were counted.

3. RESULTS

3.1. DETERMINING THE NUMBER OF COLONIES (CFU/ML)

Table 1. Determining the number of colonies in colony-forming unit per milliliter (CFU/ml).

	Dilution	Number of colonies	CFU/ml
Control plate [0 ppm]	10^{-7}	600	$6.0*10^{10}$
After Au incubation [48 ppm]	10^{-7}	48	$4.8*10^{9}$
After Au incubation and laser irradiation	10^{-7}	21	$2.1*10^{9}$
After Ag incubation [40 ppm]	10^{-7}	42	$4.2*10^{9}$
After Ag incubation and laser irradiation	10^{-7}	18	$1.8*10^{9}$

3.2. DETERMINATION OF THE PERCENTAGE VITALITY OF ACINETOBACETER BAUMMANNII CELLS AFTER GOLD AND SILVER NANOPARTICLES INCUBATION

The graph below presents cells' viability after incubation with Au and Ag nanoparticles colloidal solutions. The viability of Acinetobacter baumannii cells in case of Au nanoparticles was just 8 %, which shows around 92% lethality compared to control. The viability of Acinetobacter baumannii cells in case of Ag nanoparticles was just 7 %, which shows around 93% lethality compared to control.

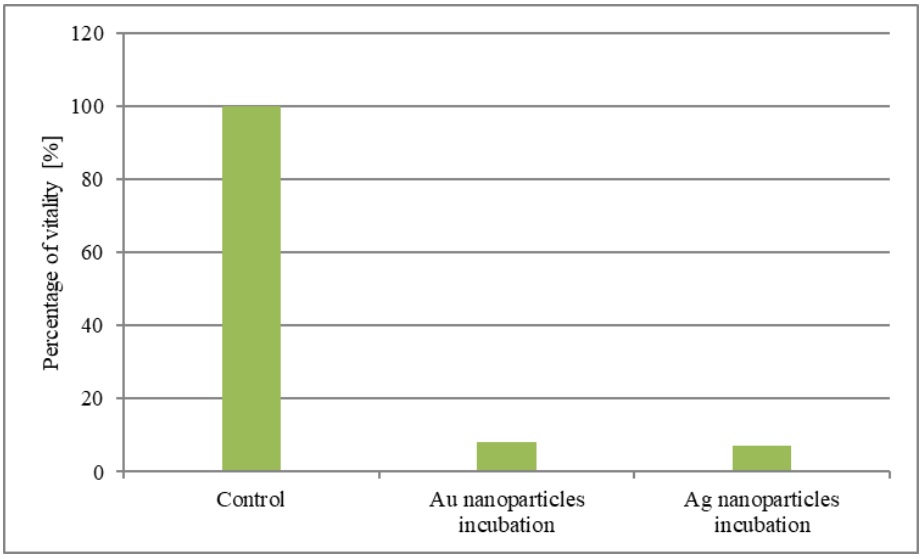

Fig. 3. Cells' viability after incubation with Au and Ag nanoparticles colloidal solutions

3.3. DETERMINATION OF THE PERCENTAGE VITALITY OF BACTERIAL CELLS AFTER LASER IRRADIATION ENHANCEMENT

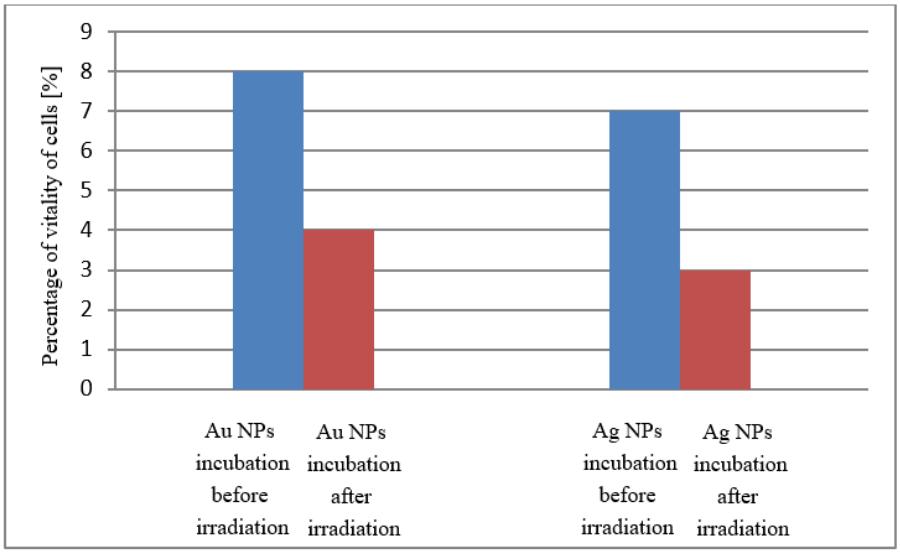

Fig. 4. Comparison cells' viability after incubation with Au and Ag nanoparticles before and after laser irradiation

The graph above presents comparison cells' viability after incubation with Au and Ag nanoparticles with laser irradiation. The viability of *Acinetobacter baumannii* cells in case of Au nanoparticles after laser irradiation was just 4 %, which shows 50 % enhancement of laser irradiation. The same results were obtained in case of Ag nanoparticles, viability of *Acinetobacter baumannii* cells in case of Au nanoparticles after laser irradiation was just 3 %, which shows 50 % enhancement of laser irradiation.

The results presented in this experiment shows high activity of gold and silver nanoparticles against Gram(-) bacteria *Acinetobacter baumannii*, while the mechanism of activity is hypothetical and still unknown. Using of laser light irradiation shows the enhancement of bactericidal effect, which in this experiment was 50 %.

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Key words:
antimetabolites, gemcitabine, phosphoramidates, phosphorylation, cytotoxic activity, human cancer cell lines: HeLa, KB, A549, U87, HepG2, normal human cell line: HDF

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SYNTHESIS OF NOVEL GEMCITABINE 5′-PHOSPHORAMIDATE DERIVATIVES WITH ANTICANCER ACTIVITY

Among antineoplastic medicaments, antimetabolites are very popular with scientists. This group includes pyrimidine and purine nucleoside analogues. They constitute the so-called false metabolites which are involved in biochemical processes. Pretending physiological biomolecules is possible due to having the same spatial structure and electron properties. A well-known example of a nucleoside analogue is gemcitabine **(2′–deoxy–2′,2′–difluorocytidine; dFdC, 1).** It is a known difluorated cytidine derivative with anticancer properties. As a cytostatic agent it is successfully used both in adjunctive and monotherapy treatment of pancreatic, breast, bladder or non-small cell lung cancer. Here, we report the synthesis of six novel gemcitabine 5'–phosphoramidate with anticancer properties. We also present results of the initial evaluation of the cytotoxic activity of the obtained derivatives in five human cancer cell lines: cervical (HeLa), nasopharyngeal (KB), lung (A549), brain (U87), liver (HepG2) and normal dermal fibroblast cell line (HDF) using the sulforhodamine B (SRB) assay. In our syntheses we used two biolabile protecting group – *tert*-butoxycarbonyl (Boc) and benzyloxycarbonyl (Cbz). Our compounds are worth of interest as in their case it is possible to eliminate the limiting step of gemcitabine activation and additionally improve the lipophilic character of the compound.

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1. INTRODUCTION

Medical chemistry has made tremendous progress over dozen years in obtaining new compounds with pharmacological activity [1]. However, despite such significant achievements, neoplastic diseases are still one of the leading factors which shows a high mortality rate. Statistical data show that 20% of deaths have their source in the incidence of malignant tumours [2]. Synthesising new chemical compounds with potential treating properties is a milestone in the process of obtaining a drug. Admission of the drug to the market is a long-term process, which caused by a series of tests, ranging from screening, biological, toxicological and finishing with clinical trials of phases I–IV [3].

Among antineoplastic medicament, antimetabolites are very popular with scientists. This group includes pyrimidine and purine nucleoside analogues. They constitute the so-called false metabolites which are involved in biochemical processes. Pretending physiological biomolecules is possible due to having the same spatial structure and electron properties [4]. A well-known example of a nucleoside analogue is gemcitabine (**2′-deoxy-2′,2′-difluorocytidine; dFdC, 1)**. It is a known difluorated cytidine derivative with anticancer properties (Fig. 1).

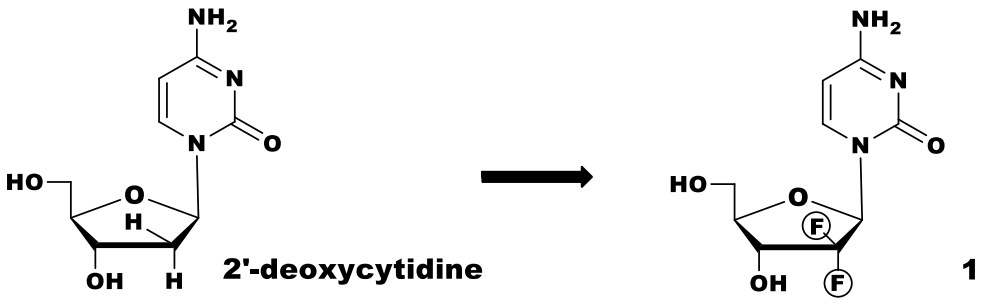


Fig. 1. Chemical structure of gemcitabine.

As a cytostatic agent it is successfully used both in adjunctive and monotherapy treatment of pancreatic, breast, bladder or non-small cell lung cancer [5–7]. Fig. 2. presents the cell metabolism of gemcitabine. Gemcitabine has to be converted into the active form of 5'-triphosphate (dFdCTP) to be cytotoxic.

Just like every nucleoside gemcitabine has hydrophilic nature. This feature prevents distribution of the drug by passive diffusion. The intracellular transport is possible thanks to the presence of integral membrane proteins, called human nucleoside transporters [8]. Nowadays two transport systems are distinguished: hENT and hCNT. They are divided into the following subtypes: hENT1, hENT2, HENT3, hENT4, hCNT1, hCNT2, hCNT3 [9,10]. Literature reports show that the main transporter of gemcitabine is hENT1. Less important are also hENT2, hCNT1 and hCNT3.

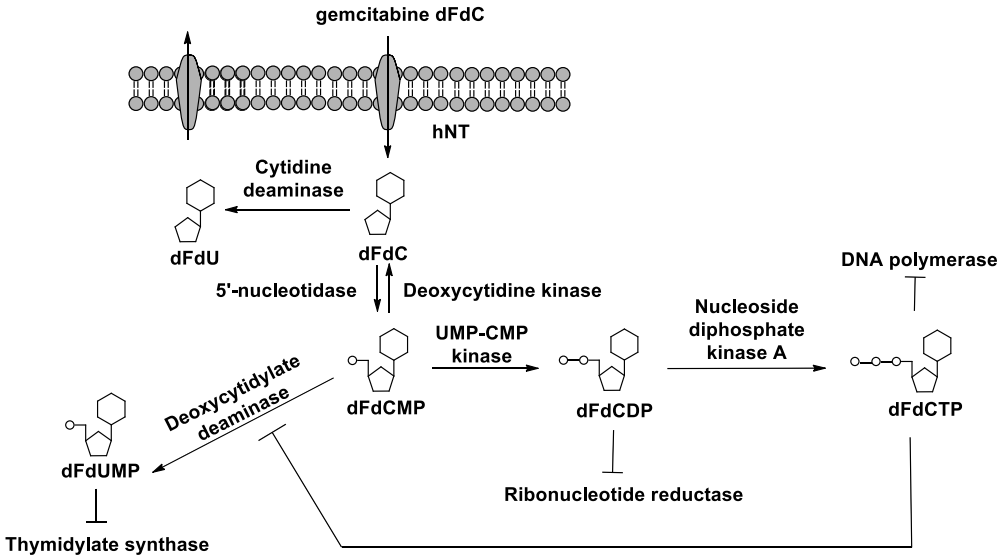


Fig. 2. The cell metabolism of gemcitabine.

In the cytoplasm, dFdC is phosphorylated to monophosphate (dFdCMP). This reaction is catalysed by deoxycytidine kinase (dCK). This stage is a limiting step for the entire metabolic pathway of gemcitabine. Diphosphate (dFdCDP) is formed by the action of nucleoside monophosphate kinase (UMP-CMP kinase). The formation of key triphosphate (dFdCTP) is not fully understood, but the role of the catalyst for this reaction is attributed to the nucleoside diphosphate kinase. Gemcitabine is susceptible to the destructive effects of three enzymes: cytidine deaminase (CDA), deoxycytidylate deaminase (dCTD) and 5'-nucleotidases (5'-NTs). CDA has two times higher affinity for dFdC comparing to dC. The dFdU as a result of CDA also shows cytotoxicity, and also regulates the transport, accumulation and activity of gemcitabine [8,11–13]. The essence of the mechanism of gemcitabine action is the induction of so-called masked termination of the DNA chain. This inhibition of deoxyribonucleotide acid synthesis occurs in the result of incorporation of dFdCTP into the DNA strand. After the incorporation of dFdCTP, the DNA polymerase is able to include only one single nucleotide. The elongation is inhibited and the cell dies. Gemcitabine is able to intensify its cytotoxicity by affecting dCTD activity. Ribonucleotide reductase (RR) is inactivated by covalent attachment of dFdCTP to its active site. This action leads to a reduction in the effective action of dCTD, and this affects the depletion of dinucleotide resources. A low level of dNTP leads to increased production of triphosphate derivatives including dFdCTP. In addition, gemcitabine induces apoptosis of tumour cells by caspase signalling [8, 14].

Interesting structures are pronucleotides which, in the form of masked 5'-*O*-phosphate allow to improve the pharmacodynamic and pharmacokinetic parameters of

the used antimetabolites. These derivatives are capable of eliminating the resistance mechanisms which are subject to the nucleoside analogy, including gemcitabine. These mechanisms include the cell transport described above, as well as biochemical processes occurring in the intracellular space. The processes are controlled by kinases (Fig. 3). The first stage of phosphorylation is the decisive stage for the speed of the entire process, hence the synthesis of pronucleotides allows to eliminate this stage. However, the physiological barrier of the lipophilic cell membrane prevents hydrophilic monophosphates from entering the cytosol. Thus, there are two conditions required for the obtained nucleoside prodrugs. The first is to have a sufficiently lipophilic substituent which facilitates passive diffusion and crossing the blood-brain barrier. The second feature is the introduction of masking groups that will not become toxic to tissues as a result of enzymatic or chemical hydrolysis. The above facts focus of today's scientists focusing on the discovery of new lipophilic carriers [15–18].

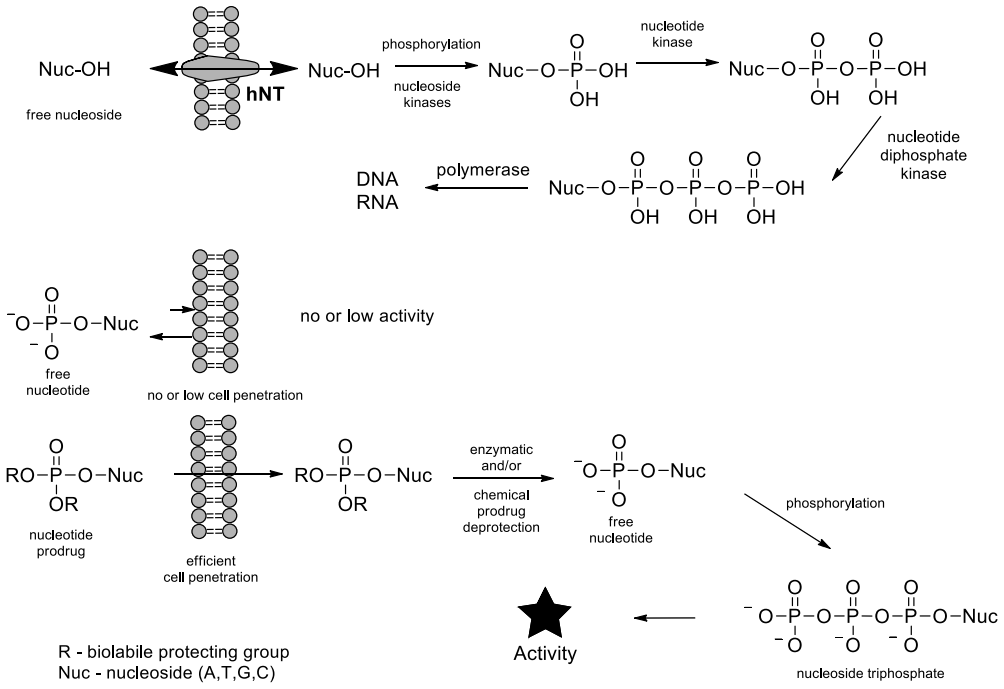


Fig. 3. The strategy of pronucleotides action.

Among the pronucleotides, there are distinguished phosphodiesters, which have one masking group and phosphotriesters with two such groups. Another interesting class of these compounds are phosphoramidates. Their masking moiety are amine or amide residues [15].

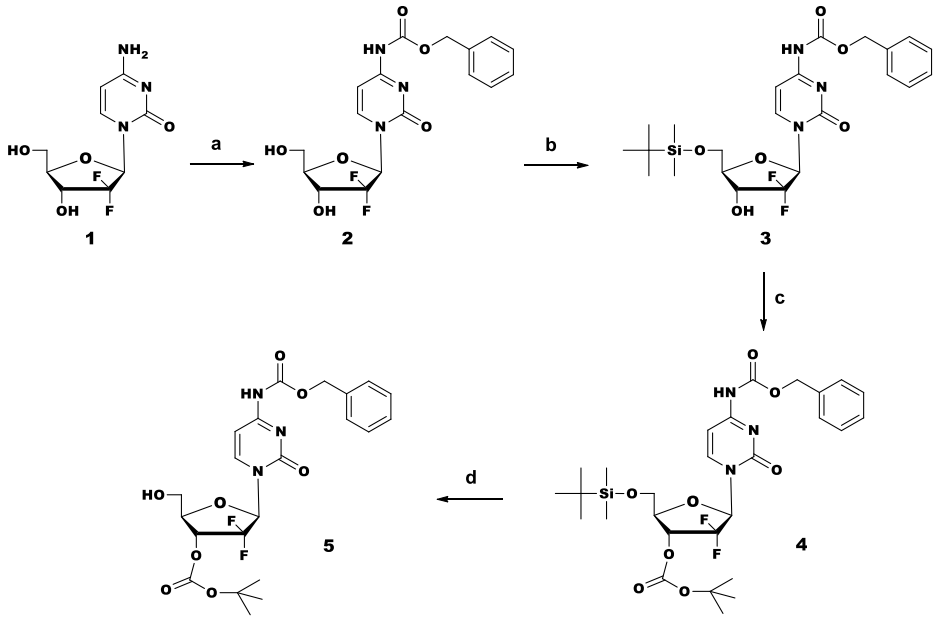
Here, we report the synthesis of six novel gemcitabine 5'-phosphoramidate with anticancer properties. We also present results of the initial evaluation of the cytotoxic activity of the obtained derivatives in five human cancer cell lines: cervical (HeLa), nasopharyngeal (KB), lung (A549), brain (U87), liver (HepG2) and normal dermal fibroblast cell line (HDF) using the sulforhodamine B (SRB) assay.

2. RESULTS AND DISCUSSION

2.1. CHEMISTRY

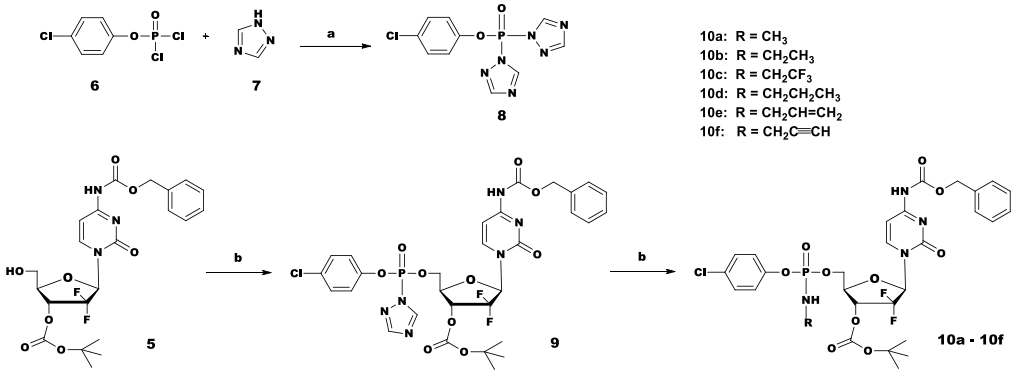
Regioselective synthesis of gemcitabine 5'-*O*-phosphate is not effortless. At the moment, when this type of synthesis is carried out, we received a mixture of mono-, di- and even gemcitabine-triphosphates. Therefore, we decided to introduce protective groups for the exoamine group and 3'-hydroxyl. We used two biolabile groups which undergo enzymatic hydrolysis *in vivo*. The first of these is the *tert*-butoxycarbonyl group (Boc) introduced into the 3' position. The second is the benzyloxycarbonyl (Cbz) group inserted on the 4-*N* position of gemcitabine. In Scheme 1, we introduce the synthesis of gemcitabine with protected groups (3'-OH and exoamine). After testing several possible ways to synthesise the component for 5'-phosphorylation, we have finally concluded that it is best to start the procedure from securing the exoamine group. The benzyloxycarbonyl (Cbz) group was introduced using the trimethylsilyl method with the benzyl chloroformate [19]. The 4-*N* acylated gemcitabine (**2**) was then substituted at the 5 'position with a *tert*-butyldimethylsilyl group [20]. A *tert*-butoxycarbonyl substituent (Boc) was introduced into the 3'-OH group, and the last step of this synthesis was deprotection of the 5'-OH group [21]. Removal of the trialkylsilyl ether was carried out using triethylamine trihydrofluoride [21].

In order to obtain new gemcitabine 5'-amidophosphates, we used the modified Rees method, which we successfully adapted for the synthesis of floxuridine phosphoramidate [22]. The course of the used method is shown in Scheme 2. The first step consisted of the in situ formation of a phosphorylating agent (**8**). This reaction was carried out in a polar aprotic solvent - acetonitrile. 4-Chlorophenyl phosphoroditriazolide (**8**) was prepared by the reaction of 4-chlorophenyl phosphorodichloridate (**6**) with 1,2,4-triazole (**7**) in the presence of triethylamine, which bounded the formed hydrogen chloride. To carry out the phosphorylation, a suitably protected nucleoside (**5**) dissolved in anhydrous pyridine was added to the formed phosphorylating agent. Without the need to isolate intermediate (**9**), a suitable amine was added to the resulting mixture.



Scheme 1. Synthesis of 4-*N*-(Benzyloxycarbonyl)- 3′-*O*-(*t*-butyloxycarbonyl)-2′-deoxy-2′,2′-difluorocytidine. Reagents and conditions: (a) (i) TMSCl, py, 0°C, under Ar, 1.5 h, rt, (ii) CbzCl, 0°C, under Ar, 12 h, rt, (iii) MeOH, 0°C, under Ar, 15 h, rt, (b) imidazole, DMAP, *tert*-butyldimethylsilyl chloride, DMF, 16 h, rt, (c) DBDC, DMAP, dioksan, TEA, 1 h,rt, (d) $Et_3N \cdot 3HF$, THF, under Ar, 12 h, rt.

When using amine hydrochlorides (amine a, b and c), an appropriate amount of triethylamine (5 eq) should also be added, which by binding HCl liberated the desired amine in situ.



Scheme 2. Synthesis of the para-chlorophenyloxy *N*-alkyl phosphoramidates of dFdC. Reagents and conditions: (a) Et_3N, CH_3CN, 30 min, rt, (b) **8**, py, 1 h, rt, (c) R-NH_2, 1 h, rt.

The newly formed gemcitabine 5'-phosporamidates have an additional stereogenic centre on the phosphorus atom. This property was confirmed basing on the obtained ^{31}P NMR spectra. The phosphorylated nucleosides are in the form of diastereoisomers, and therefore two closely located peaks were observed in the spectrum. In addition, when performing control TLC plates, the product was identified as two closely lying spots. Each of them showed the same intensity. Column chromatography on silica gel failed to separate the two diastereoisomers. Perhaps the separation would be possible if different analytical techniques were used, e.g. reversed-phase HPLC.

2.2. BIOLOGICAL ACTIVITY

In the Table 1 we present results of the evaluation of the cytotoxic activity of five out of the six obtained 5'-phosphoramidates. This parameter was determined as a result of the sulforhodamine B test. It was determined against five tumour cell lines: cervival (HeLa), nasopharyngeal (KB), lung (A549), brain (U87), liver (HepG2) and healthy dermal fibroblast cell lines (HDF). The compound **10c** is currently undergoing biological testing.

Table 1. In vitro cytotoxic activity of compounds **10a–10f** in five human cancer cell lines: cervical (HeLa), nasopharyngeal (KB), lung (A549), brain (U87), liver (HepG2) and normal human dermal fibroblast cell line (HDF)

Compound	Cytotoxicity (IC_{50}, μM)[a] ± SD[b]						Log P[c]
	HeLa	KB	A549	U87	HepG2	HDF	
10a	**9.10±0.86**	9.44±0.01	9.90±0.73	8.73±0.68	8.59±0.01	24.28±0.13	3.93
10b	**9.38±0.52**	8.54±0.18	8.84±0.24	9.69±0.39	8.84±0.56	25.79±0.26	4.30
10d	58.38±0.13	63.14±0.33	61.89±0.32	56.29±0.09	60.25±0.47	81.15±0.04	4.81
10e	49.54±0.02	50.79±0.16	42.68±0.17	45.65±0.20	46.89±0.44	65.81±0.07	4.57
10f	11.02±0.06	10.19±0.06	10.30±0.10	9.70±0.03	9.96±0.10	11.08±0.01	4.09
dFdC[d]	9.42±0.19	8.21±0.07	5.05±0.30	5.21±0.46	4.90±0.79	19.45±0.03	-1.60
Ara-C[d]	3.54±0.16	4.07±0.08	3.47±0.07	2.88±0.19	2.86±0.09	4.99±0.84	-1.93

[a]IC_{50} is the compound concentration required to inhibit cel growth by 50%
[b]SD (standard deviation) of three independent experiments
[c]logP (logarithm of partition coefficient) was calculated using '$logP_{Knowwin}$' method.
[d]Standards: gemcitabine (dFdC), cytarabine (ara-C)

The most active derivatives have methyl (**10a**) and ethyl (**10b**) substituents. They exhibit higher maximal half inhibitory concentration in case of HeLa line comparing to gemcitabine.

In Table 1 we also present another important element of the pharmacological evaluation of the compound – the partition coefficient [23]. We designated it theoretically using the Molinspiration programme. Its value indicates the lipophilic nature of the compound, the higher it is, the higher lipophilicity is. All obtained derivatives show better lipophilic properties comparing to gemcitabine. This can potentially facilitate the transport of the cell by passive diffusion. Selectivity is also very important in the characteristics of the drug. It can be assessed by determining the selectivity index (SI) (Table 2). It is the inhibitory concentration quotient of healthy cells to the inhibitory concentration of tumour cell lines. The higher the index value, the less toxic to healthy cells the compound is. In case of anticancer compound if the SI value is higher than 3 there are considered to be highly selective [24]. Compared to gemcitabine the most active 5'-phosporamidates (**10a** and **10b**) exhibit better selectivity of action in the HeLa and KB cell lines. Additionally, the ethyl derivative (**10b**) shows more than 3 Si's value. We decided to use *p*-chlorophenyl substituent in our syntheses and not phenyl substituent, as in reaction S_N2 on phosphorus it is a better leaving group. In addition, its cytotoxic activity is significantly lower comparing to the cytotoxic activity of gemcitabine, hence its contribution to the total IC_{50} value is negligible [22].

Table 2. The calculated values of the selectivity index (SI) of the gemcitabine 5′-phosphoramidates

Compound	SI				
	HeLa	KB	A549	U87	HepG2
10a	**2.67**	**2.57**	2.45	2.78	2.83
10b	**2.75**	**3.02**	2.92	2.66	2.92
10d	1.39	1.29	1.31	1.44	1.35
10e	1.33	1.30	1.54	1.30	1.40
10f	1.01	1.09	1.08	1.14	1.11
dFdC[d]	2.07	2.37	3.85	3.73	3.97
Ara-C[d]	1.41	1.23	1.44	1.73	1.75

3. CONCLUSION

In conclusion, we synthesised six new gemcitabine 5'-phosporamidates. We have determined an initial assessment of the cytotoxic activity of five out of the six obtained derivatives. Two gemcitabine 5'-phosporamidates with methyl (**10a**) and ethyl (**10b**) substituents exhibit better cytotoxicity activity in the HeLa cell line, and better

selectivity of action for the HeLa and KB cell lines. We increased the lipophilic character of all derived derivatives. The great advantage of the method we use is the ability to synthesise a series of compounds with various amino substituents without the need to modify the course of each individual reaction.

4. EXPERIMENTAL SECTION

4.1. *IN VITRO* CYTOTOXICITY ASSAY

The monolayer cell culture was trypsinized and the cell count was adjusted to 5 x 10^4 cells. After 24 hours, when a partial monolayer was formed, the supernatant was washed out and 100 μL of six different compound concentrations (0.1, 0.2, 1, 2, 10 and 20 μM) were added to the cells in microtitre plates. The tested compounds were dissolved in DMSO (containing 10% of water) (50 μL). The cells were exposed to compounds for 72 h at 37 °C in a humidified atmosphere (90% RH) containing 5% CO_2. Then, 25 μL of 50% trichloroacetic acid was added to the wells and the plates were incubated for 1 h at 4°C. The air-dried plates were stained with 100 μL of 0.4% sulforhodamine B (prepared in 1% acetic acid) and left for 30 minutes at room temperature. The unbound dye was removed by washing five times with 1% acetic acid and then the plates were air dried overnight. For determination of optical density, the protein-bound dye was dissolved in 100 μL of 10 mM unbuffered Tris base (pH 10.5) and the absorbance was read at 490 nm. All the cytotoxicity experiments were performed in triplicate. Cell survival was measured as the percentage absorbance of the treated cells compared to the absorbance of control (non-treated cells).

4.2. 4-*N*-(BENZYLOXYCARBONYL)-2′-DEOXY-2′,2′-DIFLUOROCYTIDINE (**2**)

A suspension of gemcitabine **1** (100 mg, 0.38 mmol) in dry pyridine (4.5 mL) was prepared and cooled to 4°C in an ice bath. Trimethylsilyl chloride (0.5 mL, 3.8 mmol) was added dropwise under an argon atmosphere and the mixture was left to stir at room temperature. After 1.5 h, the solution cooled to 4°C in an ice bath and benzyl chloroformate (0.3 mL, 1.9 mmol) was added dropwise to the mixture. After 12 h the solution was cooled to 4°C in an ice bath and methanol (3.3 mL) was added slowly and the reaction mixture was stirred at room temperature overnight. Then the mixture was evaporated to dryness. The residue was treated with saturated sodium bicarbonate (4 mL) and it was extracted with ethyl acetate (3 x 40 mL). The combined organic extracts were dried over anhydrous magnesium sulfate, filtered and evaporated to dryness with repeated coevaporation using toluene. The residue was dissolved in methanol and evaporated with silica gel (1 g). The crude product was purified by silica gel column

chromatography using dichloromethane-methanol (gradient from 100:1 to 10:1, v/v) as eluent to afford pure **2** (yield: 144.5 mg, 94%).

4.3. 4-*N*-(BENZYLOXYCARBONYL)-5′-*O*-(*TERT*-BUTYLDIMETHYLSILYL)-2′-DEOXY-2′,2′-DIFLUOROCYTIDINE (**3**)

Compound **2** (230.5 mg, 0.58 mmol) was dissolved in DMF (5 mL). Then imidazole (0.1185 g, 0.07 mmol), DMAP (0.0177 g, 0.15 mmol) and *tert*-butyldimethylsilyl chloride (0.1049 g, 0.7 mmol) were added and the reaction mixture was stirred at room temperature for 16 h. After that time the mixture was evaporated to dryness. The crude product was purified by silica gel column chromatography using dichloromethane-methanol (gradient from 100:1 to 20:1, v/v) as eluent to afford pure **3** (yield: 169.9 mg, 57%).

4.4 4-*N*-(BENZYLOXYCARBONYL)-3′-*O*-(*T*-BUTYLOXYCARBONYL)-5′-*O*-(*TERT*-BUTYLDIMETHYLSILYL)-2′-DEOXY-2′,2′-DIFLUOROCYTIDINE (**4**)

Compound **3** (260.3 mg, 0.51 mmol) was dissolved in dioxane (3 mL) and triethylamine (2 mL). Then DMAP (8.1 mg, 0.066 mmol) and di-*t*-butyl dicarbonate (DBDC) (144.6 mg, 1.3 mmol) were added and the reaction mixture was stirred at room temperature for 1 h. After that time the mixture was evaporated to dryness. The residue was treated with saturated sodium bicarbonate (10 mL) and it was extracted with ethyl acetate (3 x 20 mL). The combined organic extracts were dried over anhydrous magnesium sulfate, filtered and evaporated to dryness. The residue was dissolved in methanol and evaporated with silica gel (1 g). The crude product was purified by silica gel column chromatography using dichloromethane-methanol (gradient from 100:1 to 90:1, v/v) as eluent to afford pure **4** (yield: 227.4 mg, 73%).

4.5. 4-*N*-(BENZYLOXYCARBONYL)- 3′-*O*-(*T*-BUTYLOXYCARBONYL)-2′-DEOXY-2′,2′-DIFLUOROCYTIDINE (**5**)

Compound **4** (340.6 mg, 0.56 mmol) was dissolved in anhydrous THF (7 mL). Triethylamine trihydrofluride (0.28 mL, 1.68 mmol) was added dropwise under an argon atmosphere and the mixture was left to stir at room temperature. After 12 h, the mixture was evaporated to dryness. The crude product was purified by silica gel column chromatography using dichloromethane-methanol (gradient from 100:1 to 70:1, v/v) as eluent to afford pure **5** (yield: 221 mg, 80%).

4.6. GENERAL PROCEDURE FOR THE SYNTHESIS OF COMPOUND **10A**–**10F**

To a solution of 4-chlorophenyl phosphorodichloridate (**6**) (0.073 mL, 0.34 mmol) in acetonitrile (2 mL) was added 1,2,4-triazole (**7**) (80.7 mg, 0.88 mmol) followed by trimethylamine (0.13 mL, 0.7 mmol) and the reactants were stirred for 30 min at room temperature. Then to the mixture compound **5** (70 mg, 0.14 mmol) and pyridine (2 mL) were added. The reaction mixture was stirred at room temperature for a further 1 h and the appropriate amine (1.68 mmol) was added. In the case of synthesis of compounds 10a–10c amine hydrochloride (1.68 mmol) and trimethylamine (0.37 mL, 2.65 mmol) were added. After 1 h, the reaction mixture was evaporated under reduced pressure. To the residue was added saturated aqueous sodium bicarbonate (20 mL) and the mixture was extracted with chloroform (50 mL). The combined chloroform extracts were dried over anhydrous magnesium sulfate, filtered and evaporated to dryness. The residue was purified by silica column chromatography using dichloromethane-methanol (from 100:1 to 70:1, v/v) as eluent to afford products 10a–10f (yield 17–67%).

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Key words:
air pollutant, particulate matter, formaldehyde, fireplace, air cleaner, air purifier

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EVALUATION OF AIR PURIFIERS' EFFICIENCY IN THE DIRECT VICINITY OF AIR POLLUTANTS EMISSION SOURCE

The purpose of this paper was to evaluate the efficiency of air cleaning in the direct vicinity of air pollutants emission source. Air quality measurement devices for particulate matter PM10 and PM2.5 as well as formaldehyde concentrations measurement has been used. Research has been carried out in a single-family house located in the suburbs of Warsaw (Poland). The source of air pollutants emission was a fireplace fueled by dried, cut, barkless deciduous wood. Air pollution was monitored in two places: in the room with the fireplace and in the sleeping room which was about 20 meters away from room with the fireplace. Basing on the results the following conclusions has been made: air purifier shortened from 8 to 2 hours the time needed to clean air polluted by the combustion products from fireplace, reducing also the possibility of their migration to other rooms. It also allowed to clean efficiently the air from formaldehyde (representing the group of volatile organic compounds) not allowing them to be spread over the house. Thus, the air purifier allows to maintain proper air quality in the presence of an internal emission source, such as fire-place, limiting the exposure of household residents to high concentrations of air pollutants characterized by the negative health influence.

1. INTRODUCTION

Nowadays, the world's media often focus on outdoor air pollution. Air quality is monitored in many cities in Poland. Dynamic development of technology cause growing environmental awareness. In every smartphone there are numerous applications to check air quality in the nearest area.

Very important however is also indoor air quality and conditions. People spend a lot of time sleeping, cooking or doing housework in their houses and generally the inhabitants of Europe (but also North America) spend most of the time (80-90%) during

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the day indoor [7,8]. Therefore the question arises: Why we do not focus on in-door air pollution like we do on outdoor air pollution?

As World Health Organization indicates, each year, close to 4 million people die prematurely from diseases attributable to household air pollution from inefficient cooking practices or due the use of old stoves and boilers powered by solid fuels. Household air pollution increases the risk of arising some of the noncommunicable diseases and exacerbation of them, including stroke, ischaemic hearth disease, COPD or lung cancer. Approximately 17% of lung cancer deaths in adults are attributable to exposure to carcinogens from household air pollution caused by cooking with kerosene or solid fuels like wood (WHO,2017).

This article presents the results of evaluation trials of the efficiency of air cleaning in the direct vicinity of air pollutants emission source. Research has been carried out in a single-family house located in the suburbs of Warsaw. A fireplace fuelled by dried, cut, deciduous wood was the source of air pollutants emission. Similar investigations are rather not very common, but the results of the research can help to evaluate the efficiency of indoor air cleaning.

2. MATERIALS AND METHODS

As indicators of air pollution particulate matter PM_{10} and $PM_{2.5}$ as well as formaldehyde has been used. Particulate matter is a common indicator of outdoor air pollution and is a typical air pollutant emitted from individual households burning solid fuels (coal, wood) for heating purposes. Taking into account that still 4.5 million of single-family houses in Poland burn solid fuels [9] the municipal and household sector is responsible for over 50% of the total PM_{10} and $PM_{2.5}$ emission [10]. It affects more people than any other pollutants (WHO,2018). Formaldehyde concentration was measured during the experiment because of several reasons: formaldehyde sources in indoor environments include many households items (WHO,2010), formaldehyde and acetyldehyde were the predominated carbonyls in the emission from wood combustions appliances, regardless of the wood type (Reda et al. 2015).

Air pollution was monitored in two places: in the room with the fireplace and in the sleeping room located about 20 meters away from room with fireplace. First of these two points has been selected due to the fact of air pollutant emission source location and the necessity of PM measurement in the vicinity of the source. The second point has been chosen because of the desire to check how much of the indoor air pollution is able to migrate to different rooms in the building (even those distant from the direct influence of emission source) and whether the air purifier is able to reduce the exposure of people living in peripheral parts of the buildings to the impact of air pollution generated there. Concentration changes of particles and formaldehyde was divided into three phasess:

1. Fire up, when significant amount of air pollutants was emitted;
2. Formation of chimney draft, that allows effective discharge of exhaust gases into the ambient air;
3. Fireplace expiration by itself due to the lack of fuel.

Measurements were completed using four mobile PM measurement devices, two of which were supplied by the Warsaw University of Technology (PM Meter). The measurement devices use the non-reference method based on illumination of particles with a light beam and analysing the accompanying phenomena. The light source is a laser emitting a beam of light with assumed parameters (including specific wavelength) and photodiode. When the particles pass through the chamber, the laser light is dispersed on them and the photodiode detects the rays dispersed on the particles. The devices are under the process of the permanent (for over three years) calibration (due to parallel measurements carried out with the use of devices for which compliance with the reference method has been demonstrated), however in order to demonstrate this compliance in an independent manner, two mobile PM devices supplied by WUT have been calibrated by National Reference Laboratory, in one of their station in Rabka-Zdrój from 15.02.2017 to 15.06.2017. Air cleaner used in experiment was AeraMax Pro AMIII from the company Fellowes Polska SA, equipped with three replaceable filters: prefilter, HEPA filter and activated carbon filter. The efficiency of air cleaner, according to the official manufacturer data, is 99.97% (Fellowes, 2018).

Measurements were repeated three times:

1. The first stage was carried out a week before the basic measurement, to assess the indoor air quality with no active fireplace;
2. The next steps were the measurements carried out while using the fireplace but with no simultaneous air cleaning;
3. The last one was completed with the usage of fireplace and air cleaner in the fireplace room.

The results of first stage and the measurement data from next stages has been compared and presented on the line graphs. Initial measurements has been carried out from 18.03.2019 to 24.03.2019. First use of a fireplace without air cleaning was carried out on 25.03.2019 and second use of a fireplace with simultaneous usage of air cleaner was on 23.05.2019. During the measurements there were also measured parameters such as: indoor and outdoor air temperature, atmospheric pressure and air humidity. The measurements has been carried out in a continuous mode, however temporal resolution of the presented measurements results was 1 hour. The result presented below are derived from measurements carried out in the room with fireplace.

3. RESULTS

Table 1 presents the atmospheric conditions in research day. Atmospheric conditions has an impact on the strength of chimney draught, which in turn determines concentration of particulate matter in the fireplace and emission trail. It is therefore important to properly choose days for experiment characterized with similar atmospheric conditions.

Table 1. Atmospheric condition in the research day

	First day of research (25.03.2019)	Next day of research (23.05.2019)
Measurement time	16:31	15:25
Indoor temperature	19°C	19.8°C
Humidity	54%	71%
Atmospheric pressure	1000hPa	1000hPa
Outdoor temperature	9°C	21°C

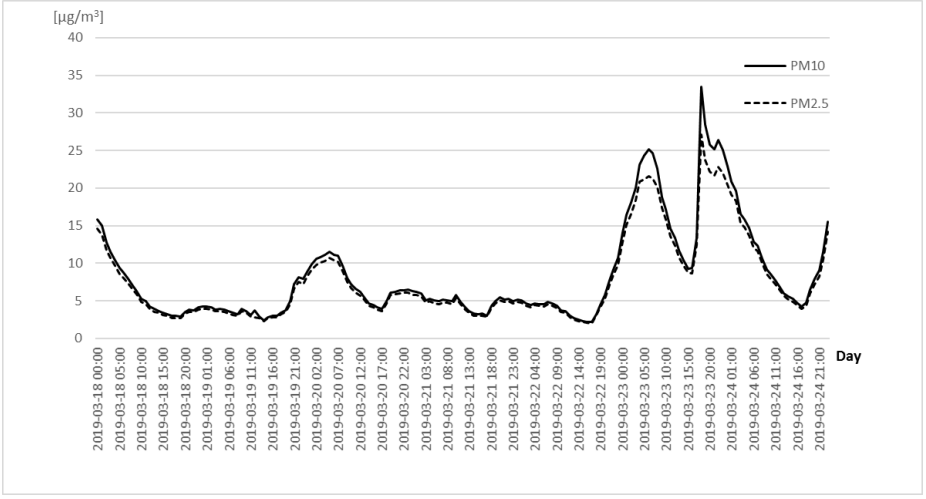

Fig. 1. Concentration of particulate matter in initial measurements (18-03-2019-24-03-2019).

Figure 1 shows concentration changes of PM_{10} and $PM_{2.5}$ in initial measurements from 18.03.2019 to 24.03.2019. Concentration of particulate matter was lower from Monday to Friday than in the weekends what is typical in the single-family housing areas due to the need of more intensive combustion of solid fuels on days off in order

to maintain adequate thermal conditions in the building throughout the day. The highest concentration of PM_{10} was 33 μg/m^3 and of $PM_{2.5}$ 28 μg/m^3.

Figure 2 shows comparison of PM_{10} concentration during the usage of the fireplace without simultaneous air cleaning and with the usage of fireplace and air cleaner in the fireplace room.

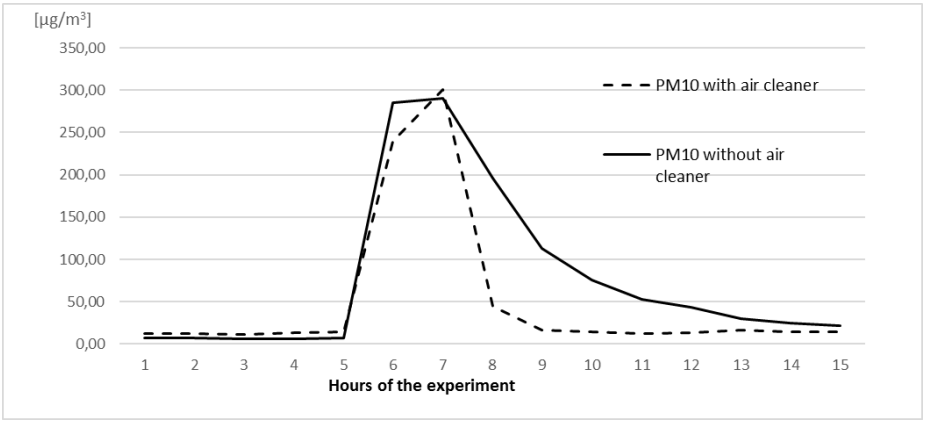

Fig. 2. Concentration of particulate matter comparison.

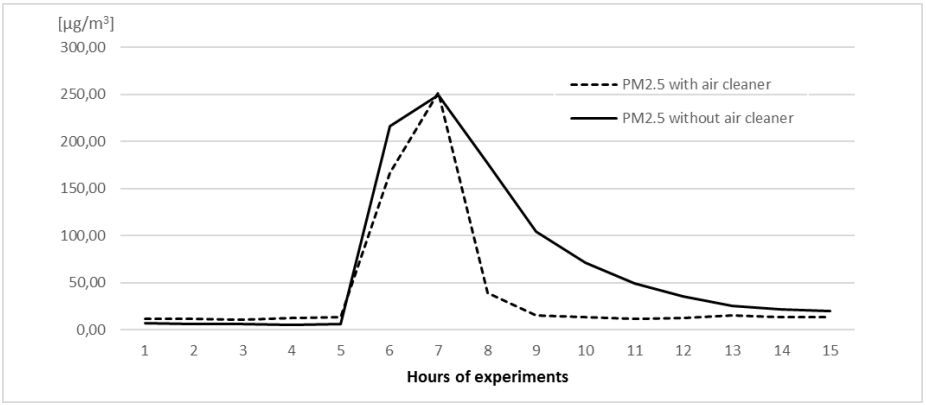

Fig. 3. Concentration of particulate matter comparison.

Figure 3 shows similar comparison for $PM_{2.5}$. On the horizontal axes subsequent hours of the experiment are presented. 5 hours after the experiment started, concentration of PM_{10} and $PM_{2.5}$ increased to 290 μg/m^3 249 μg/m^3 respectively while using a fireplace with no simultaneous air cleaning and to 300 μg/m^3 and 250 μg/m^3 while using a fireplace and air cleaner in the fireplace room. It demonstrates that the presence of the air purifier has no influence on the initial concentration of PM in the

room with the source of emission. It has however the influence on the air quality after the certain amount of time of air cleaner usage. Concentration of particulate matter decreased significantly, almost returning to the previous state after 8 hours from lightning the fireplace without using the air cleaner (from 6 μg/m^3 at the beginning, to 20 μg/m^3 after 8 hours). For using a fireplace with a simultaneous usage of air cleaner it took 2 hours.

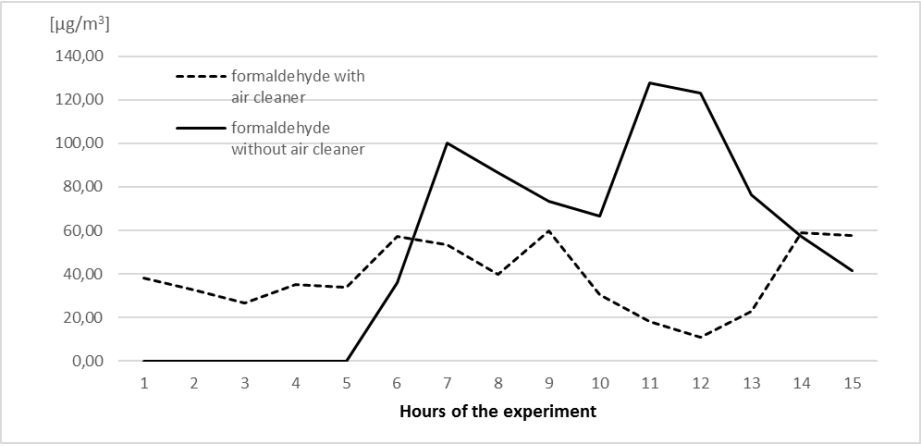

Fig. 4. Concentration of formaldehyde comparison.

Figure 4 shows comparison of formaldehyde concentration during the usage of a fireplace with no simultaneous air cleaning and with the usage of fireplace and air cleaner in the fireplace room. On the horizontal axis subsequent hours of the experiment are presented. 5 hours after the experiment started, concentration of formaldehyde increased to 100 μg/m^3 while using a fireplace with no simultaneous air cleaning and did not increased in case of using a fireplace and air cleaner in the fireplace room. In case of lightning up the fireplace while using air cleaner, concentration of formaldehyde wasn't zero. It could be caused of different atmospheric conditions or influence of roommates. Concentration of formaldehyde almost returned to the previous state (from 33 μg/m^3 at the beginning, to 57 μg/m^3 after 8 hours). after more than 8 hours from lightning the fireplace without using a fireplace without using the air cleaner.

3. CONCLUSION

Basing on the results the following conclusion was made: air purifier does have minimum influence of the PM concentration during lightning the fireplace, air purifier reduced the time needed to clean air polluted by the combustion products from fireplace,

reducing also the possibility of their migration to other rooms. It also allowed to clean efficiently the air from formaldehyde not allowing them to be spread over the house. Thus, the air purifier allows to maintain proper air quality in the presence of an internal emission source, such as fireplace, limiting the exposure of household residents to high concentrations of air pollutants characterized by the negative influence on health.

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Key words:
particulate matter concentration, PM_{10}, $PM_{2.5}$, air pollution, bronchial asthma, chronic obstructive pulmonary disease

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AN ATTEMPT TO ASSESS THE RELATIONSHIP BETWEEN PM_{10} AND $PM_{2.5}$ CONCENTRATION AND DEVELOPMENT OF RESPIRATORY DISEASES

The topic of the article was an influence of air pollution with particulate matter PM_{10} and $PM_{2.5}$ on human's health. Analysis of the data about number of patients with respiratory diseases and data from the National Environmental Monitoring allowed to find dependence between changes in PM concentration and number of patients with respiratory diseases. Analysis of the impact of particular matter on the number of patients with respiratory diseases were made for PM_{10} and $PM_{2.5}$ separately. To prove a negative impact of air pollution to human's health the analysis for two cities was made. The cities were chosen basing on particulate matter concentration. Olsztyn was chosen as a city with lower PM concentration, and Zabrze as a city in industrial area with higher PM concentration. The analysis demonstrated that increasing PM_{10} and $PM_{2.5}$ concentration caused the rise of the number of patients with bronchial asthma and chronic obstructive pulmonary disease (COPD) symptoms and that inhabitants of the city with higher PM concentration more often have to visit medical facilities due to respiratory diseases symptoms.

1. INTRODUCTION

Particulate matter (PM) is the term which clearly defines the fraction of the aerosol understood as an air pollutant, having its amount in air standarised by proper regulations on the global [6], European [7,8] and national level [9]. Due to the fact that PM can be emitted from various sources, it has also an influence on the chemical composition of particulates.

There are lots of anthropogenic sources of air pollution, including also natural sources. Municipal sector, including households and buildings heating using old

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furnaces or boilers which often operate on solid fuels, energy use in industry and transportation (road transport in particular) are the biggest anthropogenic sources of particulate matter, however natural sources like volcanic eruption or forest fire can also produce considerable amount of particulate matter. The impact of PM on human health should be considered while taking into account its physical properties (particle sizes and thus the possibilities of transferring them to various parts of the organism, particularly migration through the airways to the circulatory system) and chemical composition (e.g. polycyclic aromatic hydrocarbons or heavy metals) [10,11]. Besides the components of particulate matter and the size of particles also concentration, duration of exposure and exposure frequency are factors that affect human's health. The article describes an impact of particulate matter on respiratory system and is focused on respiratory diseases such as bronchial asthma and chronic obstructive pulmonary disease. It presents the exposure on PM_{10} (particles with an aerodynamic diameter not greater than 10 μm) and $PM_{2.5}$ (particles with an aerodynamic diameter not greater than 2.5 μm) demonstrating that $PM_{2.5}$ cause more serious diseases than bigger particles. It is caused by a size of particles little enough to reach deeper parts of respiratory system but also the cardiovascular system. Respiratory system is very vulnerable to particulate matter, because little particles can easily get to deep parts of the respiratory system e.g. larynx, lungs and even alveoli with breathing air [4]. Fine particles, penetrating deep parts of the respiratory system, can initiate the inflammation and after long enough exposure also damage it, making respiratory system more vulnerable to such diseases like bronchial asthma or chronic obstructive pulmonary disease (COPD). Small particulates are also able to make people suffering from asthma or COPD feel intensification of symptoms [5]. There is a comparison of a data of number of patients from two cities in Poland to find relationship between respiratory diseases and concentration of particulate matter. Chosen cities have similar number of inhabitants, but different PM concentration. Location and meteorological conditions of cities have also been taken into consideration.

2. METHODOLOGY AND DATA ANALYSIS

The analysis consist of the health data from The National Health Fund and the PM concentration from the General Inspectorate for Environmental Protection. The data about concentration of PM_{10} and $PM_{2.5}$ were taken from air quality monitoring stations in both analyzed cities. Monitoring stations operated as a part of State Environmental Monitoring use reference method (gravimetric) to measure PM concentration or other methods for which compliance with the reference method has been demonstrated (calibrated by gravimetric method), Specified in the proper regulation of the Minister of Environment [12]. The locations and thus the representativeness of the air quality

monitoring stations in both cities should also be in line with the requirements of the same regulation.

To demonstrate the relationship between high particulate matter concentration and respiratory diseases, the data about the number of patients visiting in 2017 medical facilities in both cities has been considered.

To make them clear charts shows sums of number of patients and PM_{10} or $PM_{2.5}$ concentration for every month for both cities. However statistical parameters were calculated from daily data about number of patients or PM concentration to make them more reliable. Statistical parameters show how fast number of patients and PM concentration was changing . The analysis was supposed to show, whether growing particulate matter concentration is related with increasing number of patients with respiratory diseases.

3. RESULTS OF THE ANALYSIS

3.1. DEPENDENCE BETWEEN NUMBER OF PATIENTS AND AVERAGE MONTHLY $PM_{2.5}$ CONCENTRATION

Average monthly $PM_{2.5}$ concentration in Olsztyn in 2017 was the highest at the begging of the year and the lowest in summer months. The highest value (37 $\mu g/m^3$) was noticed in January and the lowest average monthly $PM_{2.5}$ concentration (8 $\mu g/m^3$) on August.

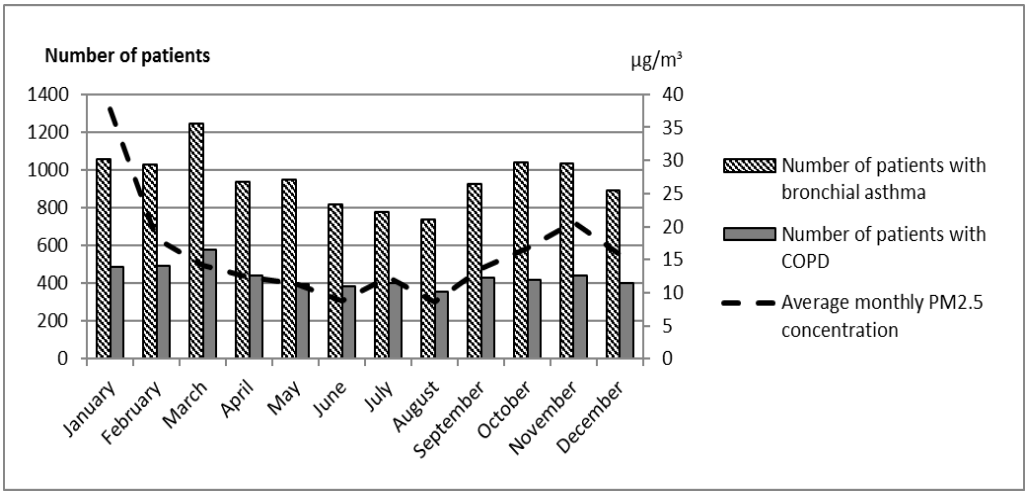

Fig. 1. Number of patients with respiratory diseases and average monthly $PM_{2.5}$ concentration in Olsztyn in 2017

From August to November average monthly $PM_{2.5}$ concentration increased by about 140%. At the same time the number of patients with bronchial asthma also increased by about 40%. At the end of the year $PM_{2.5}$ concentration decreased about at 24% and the number of patients decreased at about 14%. Although from January to March the $PM_{2.5}$ concentration decreased, number of patients in March increased, what may be due to the fact that symptoms of bronchial asthma do not manifestate themselves immediately after exposure.

Number of patients with COPD decreased from March to June by about 33%, at the same time that average monthly $PM_{2.5}$ concentration decreased at about 37.6%. Then $PM_{2.5}$ concentration increased at about 40% and number of patients increased at about 4.15%. From August to November concentration increased at about 140%, but growth of number of patients was about 23.7%. In case of both asthma and COPD the relationship between changing mean $PM_{2.5}$ concentration and number of patients has been demonstrated.

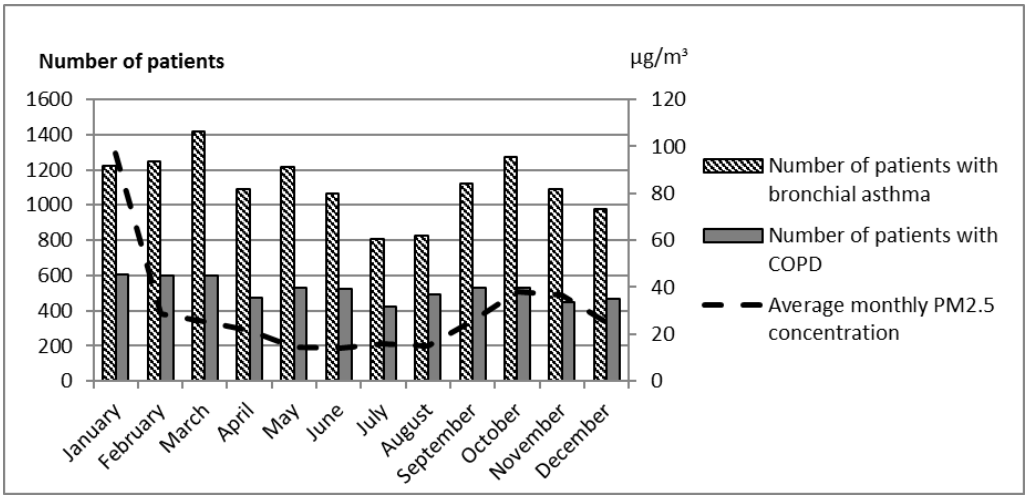

Fig. 2. Number of patients with respiratory diseases and average monthly $PM_{2.5}$ concentration in Zabrze in 2017

In Zabrze average monthly $PM_{2.5}$ concentration was the highest at the begging of the year, exactly like in Olsztyn. It is due to the heating period, and mostly caused by heating of houses and buildings with old furnaces or boilers using solid fuels. The highest average monthly concentration in Zabrze was 97 $\mu g/m^3$ and was more than twice higher than the highest value in Olsztyn. The lowest concentration in Zabrze was at the level of 14 $\mu g/m^3$ and was measured in summer.

Growth of average monthly $PM_{2.5}$ concentration at about 157% was observed from August to October. At the same time growing number of patients with bronchial asthma

by 54% was noticed. From October to December $PM_{2.5}$ concentration decreased by 35% and the number of patients with asthma decreased by 23%.

Number of patients with COPD increased from August to October by 7%, while $PM_{2.5}$ concentration decreased by 157%. When the concentration decreased by 78%, number of patients with COPD decreased by 22%.

In some cases the change of $PM_{2.5}$ concentration was not related with changes in the number of patients what could be caused by weather changes or pollen period in April or May. These factors have also influence on intensification of respiratory diseases, however they have not been considered in the presented analyses. Symptoms of analyzed diseases do not have to appear immediately, but may be observed within few days after exposure, however in general the relationship between PM concentration and patient's number changes has been noticed.

3.2. DEPENDENCE BETWEEN NUMBER OF PATIENTS AND AVERAGE MONTHLY PM_{10} CONCENTRATION

The highest average monthly PM_{10} concentration has been observed at the beginning of the year, in January. The highest monthly PM_{10} concentration in Olsztyn was 48 $\mu g/m^3$. The lowest average monthly PM_{10} concentration (14 $\mu g/m^3$) was noticed in June.

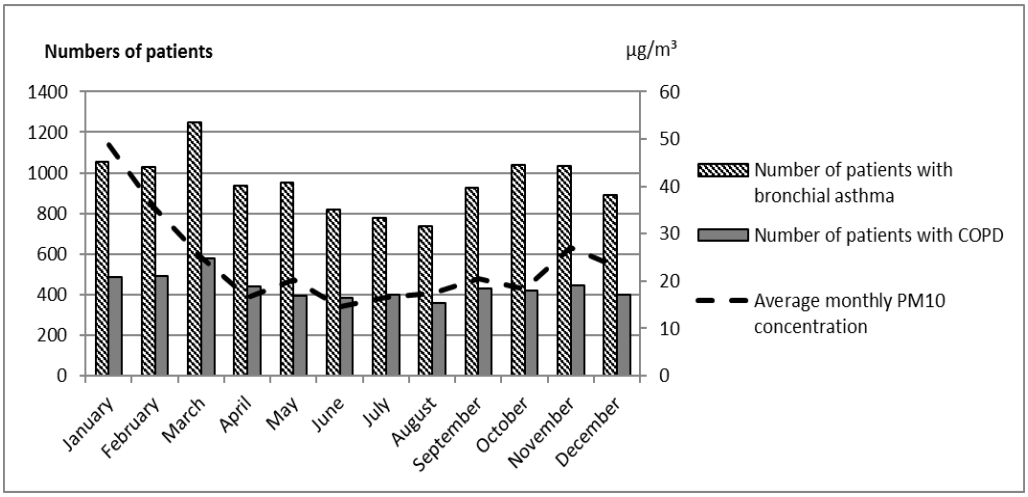

Fig. 3. Number of patients with respiratory diseases and average monthly PM_{10} concentration in Olsztyn in 2017

Number of patients with bronchial asthma increased from April to May by 1.2%, while average monthly PM_{10} concentration has grown by 21%. From May to June PM_{10} concentration decreased by 39% and the number of patients with asthma decreased by

16%. While concentration of PM_{10} increased about 17%, the number of patients increased by 25%.

The increase of PM_{10} concentration in Olsztyn was observed from April to May, and from August to September. From June to July there was a 17% increase of concentration of particulate matter. At the same time the 4% increase of number of patients with COPD was noticed. From August to September the 17% increase of PM_{10} concentration was observed. At the same time the number of patients with COPD increased by 19%. The growth of PM_{10} concentration from October to November was at the level of 49%, while increasing number of patients with COPD at 6%. These observations also demonstrates the relationship between changing PM_{10} concentrations and similar trends in case of the number of asthmatic and COPD patients.

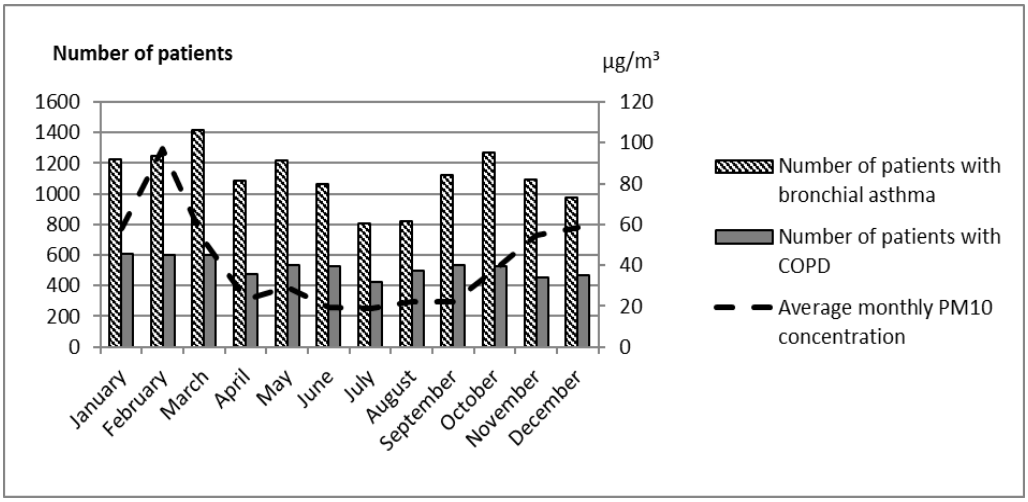

Fig. 4. Number of patients with respiratory diseases and average monthly PM_{10} concentration in Zabrze in 2017

Average monthly PM_{10} concentration in Zabrze was increasing from January to February, from April to May, from July to August and from September to the end of the year. In the rest of the periods the concentration was decreasing. The highest average monthly PM_{10} concentration was 97 $\mu g/m^3$ and was two times higher than in Olsztyn. The lowest concentration was 19 $\mu g/m^3$.

The number of patients with asthma from April to May increased by 14% with growing average monthly PM_{10} concentration by 27%. While the PM_{10} concentration increased by 18% from July to August, the number of patients increased by 2%. From September to October the PM_{10} concentration also increased by 69% and so the number of patients did (the number increased by 13%). Also when the concentration decreased, the number of patients decreased. From February to April the PM_{10} concentration decreased by 76,1%, while number of patients with asthma decreased by 12,9%. When

the PM_{10} concentration decreased by 34% from May to June, so the number of patients did (the number of patients decreased by 1,7%).

Increasing (by 27%%) PM_{10} concentration from April to May was also related with increasing (by 13%) number of patients with COPD. Number of patients with COPD increased also from July to August by 17%, while the PM_{10} concentration increased by 18%. Also increasing (by 7%) PM_{10} concentration from November to December was related with increasing (by 4,2%) number of patients. From March to April the 55% decrease of the concentration of PM_{10} was noticed, while the number of patients decreased by only 26%.

Basing on analyses results it have to be highlighted that the relationship between the increase of PM_{10} concentration and the number of patients was not a rule, however it was observed that generally trends in number of patients and PM_{10} concentrations variability were similar. Some deviations from the general rule result mainly from the fact that health consequences in the form of exacerbations of existing respiratory diseases may appear with some delay in relation to the peak PM concentration, as well as due to the existence of other factors that may condition the exacerbation of diseases such as bronchial asthma or COPD.

Table 1. Statistical parameters for analyzed data for Olsztyn

	Olsztyn			
	COPD	Bronchial asthma	PM_{10} [μg/m^3]	$PM_{2.5}$ [μg/m^3]
Quartile 1	12	23	12.9	8.1
Median	17	31	18.5	12.8
Quartile 3	22	37	29.6	20.4
Standard deviation	8.1	13.4	16.3	14.2
Mean value	16.1	28.1	23.4	16.9
Coefficient of variation	50.3 %	47.6%	69.9%	83.8%

The rapidity, which is speed of changing, of concentration of particulate matter changes was much bigger than the rapidity changes of number of patients. Coefficient of variation of both diseases was very similar, and was nearly 50%. Coefficient of variation for PM_{10} was at the level of 69.9% and for $PM_{2.5}$ at 83.8%.

The rapidity of PM_{10} concentration changes was more than twice bigger than rapidity of number of patients changes. The value of PM_{10} variation coefficient was 109.4%. Rapidity of $PM_{2.5}$ concentration was also high with a value of coefficient of variation at the level of 94.6%.

Table 2. Statistical parameters for analyzed data for Zabrze

	Zabrze			
	COPD	Bronchial asthma	PM_{10} [$\mu g/m^3$]	$PM_{2.5}$ [$\mu g/m^3$]
Quartile 1	16	28.3	17.4	13.2
Median	21	42	26.1	19.8
Quartile 3	26	52	45.3	34.9
Standard deviation	8.5	20.3	42.9	29.0
Mean value	20.1	37.6	39.2	30.7
Coefficient of variation	42.4%	53.9%	109.4%	94.6%

It should be emphasized that Zabrze as a city with higher PM concentration than Olsztyn is also characterized by bigger number of patients with bronchial asthma and COPD. The presented analyses proved that with increasing concentration of particulate matter, the number of patients also increase. Rapidity of changes was however not the same. Concentration of PM was changing much faster and some of the changes in PM concentration may not immediately manifest in changing number of patients with respiratory diseases exacerbations. The dependence between number of patients and $PM_{2.5}$ concentration was seen both in case of bronchial asthma and COPD. The number of patients was changing with the changes in $PM_{2.5}$ concentration. In some months number of patients increased although the concentration decreased, but it was presumably caused by other factors that could have an impact on respiratory diseases, like pollen period on April and May or some meteorological conditions. On March there are rapid weather changes what also have an impact on respiratory system. Number of patients in some months increased with increasing PM_{10} concentration, but it was not a rule. In Zabrze the dependence could be seen and in most examples the number of patients increased with growing PM_{10} concentration. However in Olsztyn tendency of changes of number of patients was different than tendency of changes of PM_{10} concentration. It could be caused by meteorological and climatic condition which in Olsztyn are very conductive to respiratory diseases, due to strong winds and lower temperature, because of a location in lake district. While in Olsztyn the PM_{10} and $PM_{2.5}$ changes patterns seems to be very similar, in Zabrze some differences has been observed. These differences were mainly observed in winter months. It is quite difficult to clearly conclude about the reasons of such phenomenon, however slightly higher PM_{10} concentration in late autumn and early spring may appear due to increased use of wood or other biomass (being the source of a bit more coarse particles emission) for households heating (especially in the mornings and evenings) as opposed to typical winter months, when mostly coal is used, within the whole day.

4. CONCLUSION

The analysis showed that increasing $PM_{2.5}$ concentration may have an impact on increasing number of patients with bronchial asthma and COPD symptoms, while in case of increasing PM_{10} concentration, the impact was not unequivocal. Climatic conditions had presumably also visible impact on increasing number of patients besides growing PM_{10} concentration. Stronger relationship in case of $PM_{2.5}$ may arise from the fact that fine particulates migrate to the deepest parts of the respiratory system, thus they can influence the exacerbation of asthma or COPD. Further investigation, including also daily changes in the $PM_{2.5}$ concentrations and daily number of visits due to respiratory problem, is needed and is planned to be completed by the authors.

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communication, green strategy,
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THE GREEN STRATEGIES INTERNAL COMMUNICATION*

Clear articulation of the strategic plan or organisation strategy is equally important as creating it in the first place. This need is based on the assumption that if organisations internal and external stakeholders do not understand the strategy, there is no point to have one. The answer to a question and reason for the action is significant in the organisations which gain no profit or seem to aim in the realisation of the ideas like a sustainable development idea. The organisations which produce goods and provide services can reduce the negative impact of human economic activity becoming a green or even sustainable organisations driven by the green strategy. The green strategies are based on the knowledge and technology transfer, which evolved together with the pro-ecological approach.

1. INTRODUCTION

The communication process is most important in any form of organisation, and the most important seems to be an internal communication [1], because of its role and side effects, which the internal communication cause [2], it can influence the image of the company as employer, and through employees influence also the brand exclusivity perception [3].

However, there is a question about the reason for the difference between thousands of similar companies, organisations that only a few are successful and are famous? It is well known that there was a large number of computer engineers in early '80s and many groups worked together to create a Personal Computer (PC), to make a dream about possession own computer at home come true [4]. There were many teams, which were better equipped and qualified than groups of Bill Gates or Steve Jobs. Some companies

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already had the know-how, and all needed assets to thrive on future markets. What makes then a difference between the successful and unsuccessful organisations? According to this paper, the communication of strategy and how leaders inspire action are secrets of success.

This paper will focus on the newly emerging sector of the new, green economy, the green sector which aims to reduce negative effects of human activity (anthropopressure) reducing waste, emissions and creating a world the better place to live by protection, reverence of nature and natural assets [2]. Authors of this paper are convinced that there is no organisation without an internal communication because this spread information about goals, strategy, processes and instructions within the organisation and involves an infrastructure for this communication process [3]. Proper communication of the green strategy, and therefore a strategic approach, can be an essential determinant of success for green sector organisations, led by the great leaders who know how to inspire others.

This paper aims to discuss the internal communication of green strategies and provides a golden circle model of effective strategic communication.

2. COMMUNICATION

The future of any company strongly depends on how is it perceived by the key stakeholders: shareholders, investors, customers and consumers, employee and members of the communities in which the company operates [5]. The critical role of creating an image of any company is harboured in its actions and processes, and in a modern world where information plays a leading role [6], it is the communication that creates the company's perception and influence also customer choices.

The notion "communication" comes from the Latin word *communicato*, which means connectivity, exchange and conversation. The standard definition of communication determines it as a process of mutual contact or exchange of information between people or social groups, within which we can distinguish the sender of the message and the recipients.

Communication is present in every area of life, as well as in economic activity. The company communicates with its employees (internal stakeholders) customers, and the public (external stakeholders) [7]. The primary purpose of communication is to shape the desired and coordination behaviour of specific members. Through communication, the company is affecting its surroundings [8]. What is significant, if an enterprise communicates effectively, then communication "can be a valuable management tool that accomplishes the goal of creating a better future for the organisation" [9].

2.1. CORPORATE COMMUNICATION

In the '70s of the last century, in response to the growing importance of communication on the enterprise line, the term corporate communication was developed [10]. Initially, corporate communication played a tactical role. With the development of the discipline, both researchers and practitioners appreciated its importance and impact on business processes [11]. Scientists from around the world have proven over the time that communication is an indispensable business instrument to accelerate change [12], improve organisational performance and employee motivation [13].

The growth of the role of corporate communication has its source in several external factors. It include: acceleration of the product life cycle, deregulation, privatisation programs, increased competition in all sectors, globalisation and establishment of free zones, mergers and acquisitions, demand of highly specialised employees, breakdown of borders between internal and external aspects of the organisation, social expectations related to corporate social responsibility [14].

Nowadays, corporate communication is defined as any action taken by an organisation in order to inform, persuade or create relationships between individuals and groups in its environment [5]. Importantly, it applies to all business process that through communication activities [3], affect customer preferences, employee motivations or create a desirable image of the company from the other stakeholders' points of view [15].

2.2. THE GOLDEN CIRCLE OF COMMUNICATION

The communication process is based on the simple pattern of the spreading information presented in Figure 1. The vast majority of members of any organisation know *what* the organisation does, only really involved know *how* these processes or products are done. Only a few people know *why* the organisation exists and does. These only few can inspire others in organisation members to give them "motivation, safety and opportunities, education" [16]. The great leaders can show them also the way *how* and *what* to do to be successful and makes the organisation thrives.

On Fig. 1, there are two arrows which represent two types of communication: internal (1) and external (2). The lengths of the internal and external communication combined create the line of the modern corporate communication to not only the support of sale (*what* we sell) but also to present *how* and *why* we do so. Crucial then is the reason for the organisation actions, processes and organisation management style. Therefore, so important is to answer the question *of why* and share this answer in internal communication to make a strategy understandable for all organisation members.

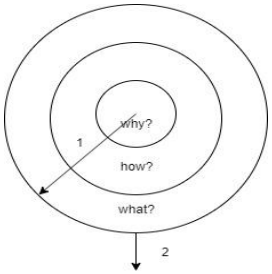

Fig. 1. The golden circle of communication.
Source: Authors' elaboration based on [16]

3. INTERNAL COMMUNICATION

Among different areas affected by corporate communications, internal communication with employees and leaders is considered to be the essential discipline [17]. Whereas, the most important goals of internal communication are to inform and motivate employees. Areas in which communication has been identified as key are also related to the impact on the interior of the organisation. They include, among others, facilitating the implementation of significant cultural changes, building a climate of mutual trust and understanding between managers and employees and facilitating the creation of capable internal and external architecture [18].

Internal communication, i.e. all communication activities directed towards the inside of the organisation, include official organisational and management communication, as well as informal chat and rumours among employees [19]. Internal communication can also take many different forms such as verbal and non-verbal communication, individual, group and mass communication, conscious and unconscious, intentional and spontaneous, centralised and decentralised [15]. The variety of forms of communication can be considered as an advantage, but in the case of internal communication, such diversity poses a challenge. Mainly through the difficulties in managing information transmitted through informal channels and the fact that communication takes place always at all levels of the organisation [20].

3.1. IMPORTANCE OF INTERNAL COMMUNICATION

Many reasons are explaining the growing role of internal communication. Bill Quirke points out that their sources come from several factors. First, the greater control, strict financial regulations, and the risk of leakage of sensitive information outside, force enterprises to carefully manage the information they share with employees. Second,

outsourcing and employing contract employees blurs the boundaries between what is outside and inside the organisation. Internal communication includes nowadays more people than the formal number of employees. Third, the reputation of companies often depends on the behaviour of their employees. At the same time, the development of new media and the spread of the Internet caused that employees can share information with an unlimited number of recipients [21]. Company's image is shaped by both formal and informal communications so all the messages published by the employees can have a decisive impact on the choices of potential future employees, customers and other vital stakeholders.

The role of internal communication has grown over the years, also due to the increasing importance attached to the function it fulfils in organisations. They are as follows:

1. Providing current information which is necessary for efficient and appropriate functioning in the company [22] including [21]: underlining the links between different elements of the message, shedding light on a network of interrelationships between various elements, providing employees with the information they need for work and helping in placing them in the broader context (big picture);
2. Educating employees on how to behave appropriately in dealing with the external environment [23];
3. Preparing for pending changes and providing employees with information on important decisions that affect them in order to make them more willing to accept these decisions [24];
4. Unification of around the company's mission, values and strategy [25].
5. Creating a pleasant working atmosphere [24];
6. Building a positive internal positive corporate identity [22];
7. Motivating the employees to work in a company [12];
8. Integrating by establishing strong relations between the company and employees, which result in a high level of loyalty and dedication to the workplace [24];

Internal communication helps to solve problems and introduce necessary changes in the organisation, which translates into a positive organisational climate and interpersonal relations [26]. Effective internal communication primarily creates the company culture and motivates its members to work [27]. Its positive impact is also reflected by improving the ability to respond to the needs of other employees. It also gives a greater sense of responsibility in achieving common goals in the company's strategy [24]. The efforts made by organisations to build a high-quality relationship with employees through communication can be perceived as a valuable investment. Actions were taken to communicate effectively result in employees' loyalty and commitment to solving the organisation's problems [28].

Companies that often and openly communicate with their employees have higher employees' involvement. Moreover, sharing the "big picture" of the company's directions increases employee a sense of safeness. Regular communication with employees contributes to reducing resistance, minimising uncertainty and personal anxiety, as well as ensuring clarity of goals [29].

Despite the fact that research has shown that communication is one of the crucial factors determining the success of top management, most organisations neglect communication, considering technical or financial problems as more important [30]. For this reason, the first step towards effective communication is to place it very high in the organisation hierarchy, and ensure that the director or vice president of communications has a crucial role in the management structure [15].

Placing communication high enough in the structure of an organisation has an impact on the harmonisation and consistency of communication processes, that stakeholders have the impression that they receive a clear message and the company would actually speak to them with one voice.

Exclusion from direct contact with the person managing the organisation lowers the range of communication processes that become a tactical rather than strategic support function.

In addition to placing communication processes high in the organisational hierarchy, a well-thought-out message is also essential. Effective communication occurs when the goals that have been planned as part of passing the message to the recipient are achieved [31]. The starting point from creating a message should be defining what change or attitude the sender wants to bring about to the recipient.

The second step is to target the specific audience and create the message which will be adjusted and understandable. Instead of the content, the significant impact on understanding the message also has the choice of the right communication channels. Effective employee communication uses all forms and tools (vehicles) to reach recipients like direct face-to-face communication, communication via indirect, printed or electronic media [16, 29]. Importantly, face-to-face communication is perceived as the most valuable and desirable by the recipients [32].

Last but not least effective communication is determined by the regularity [33]. The communication content should be provided to employees before, during and after change initiatives [29].

3.2. GREEN STRATEGIES

Green strategies developed from sustainable development theory and increasingly changed the approach of the production and services of the goods. Over the years, there was a shift from the dilution of the emissions on the end of the pipe towards the clean production, as presented in Figure 2.

Fig. 2. Technology change based on a different strategy
Source: Authors' elaboration

Early strategies were based on the satisfaction of the demanded specification of the emission described in regulations. Therefore “end of pipe” technologies were mostly used. Then philosophy of reduction of the waste material was a reason for the introduction the lean management. Finally, the green technology based on the approach that more important is a prevention of the negative impact of the product or service, so the whole product life cycle should be sustainable and green, had led to the green strategy concept.

Green strategies are based on scaling up small processes, accompanied by technology improvement. Then mega processes are created so that all company can achieve sustainability. For this kind of strategic communication and understanding of the goals which organisation wants to achieve is crucial, and also has a tremendous impact on its external image. The understanding of the goals is related to the relations [33] and the knowledge transfer process.

4. CONCLUSIONS

The green sector plays a crucial role in the modern world in the ongoing change towards the green, circular economy. Actions taken to minimise the negative impact on the environment are one of the priorities of the economies of many countries. Thus, companies that operate in the green economy should particularly emphasise the importance of their role. Effective communication in green enterprises can not only affect the involvement and awareness of employees but also change the attitudes of other members of the community. This increases the chances of successful implementation of these companies' strategies, and thus also of the overall climate improvement and environmental protection.

The green strategies are the right response for a modern turbulent challenge in a social dimension and are the part of the socially responsible strategies, based on the individualised relations and knowledge.

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