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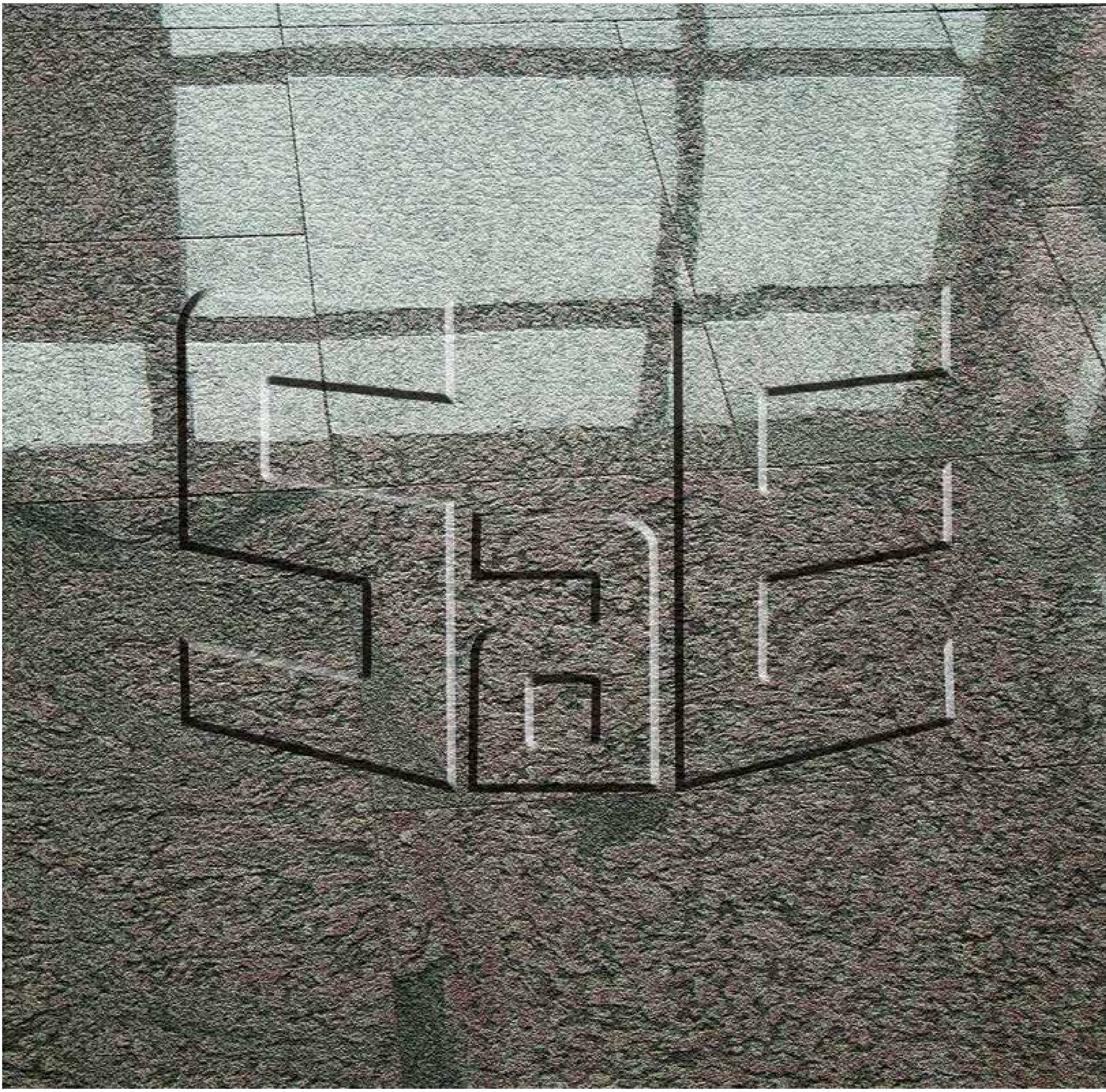

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SOME METHODOLOGICAL PRINCIPLES OF THE ARCHITECTURAL ENVIRONMENT'S OBJECTS DESIGN

NIEKTÓRE ZASADY METODOLOGICZNE PROJEKTOWANIA OBIEKTÓW ŚRODOWISKA ARCHITEKTONICZNEGO

DOI: 10.30540/sae-2020-011

Abstract

The article discusses the methodological principles of typology and design of architectural environment's objects with the analysis of its system-structural foundations. According to them, hierarchical levels of formation and stages of environmental systems and objects' design are revealed with some examples of author's designs. The research is based on systemic and environmental approaches that make it possible to view the architectural environment's objects as hierarchically subordinate.

Keywords: architectural environment's objects, typology, design, systemic-structural principles, hierarchical levels

Streszczenie

W artykule omówiono metodyczne zasady typologii i projektowania obiektów środowiska architektonicznego z analizą jego systemowo-strukturalnych podstaw. Zgodnie z nimi hierarchiczne poziomy formowania i etapy projektowania systemów i obiektów środowiskowych ujawniają się z niektórymi przykładami projektów autora. Badania opierają się na podejściach systemowych i środowiskowych, które umożliwiają oglądanie obiektów środowiska architektonicznego jako hierarchicznie podporządkowanych.

Słowa kluczowe: obiekty środowiska architektonicznego, typologia, projektowanie, zasady systemowo-strukturalne, poziomy hierarchiczne

1. INTRODUCTION

The various urban development objects and the existing method of their design are determined by the typology of the architectural environment, which consists of spatial and subject features of the environment state and, in fact, most of this state itself (atmosphere of environment), that exist in the conceptual unity and integrity. Into the basis of the study of characteristics and parameters of certain typological order the main criterion must be assigned – the leading dominant feature. The concepts of environment like residential, industrial, recreational, urban environment, etc., determine its functional features and purpose, determined by the types of human activity.

A variety of research studies have been dedicated to the issues of typology of environment [1-9]. These and other authors, relying on the concept of a systematic approach considering environment as an architectural integrity of conditions of the material world of human, that changes in transition from one system level to another.

In a system approach, the core of which is to implement the requirements of general theory of systems, the object of research is a set of interrelated elements and components that make up a system, linking the components of the overall objective.

2. THE MAIN PART

Modern dynamic changes of various factors and conditions of formation of architectural environment, diversity and versatility of environmental systems and objects and approaches to their typology and design cause the need to clarify the understanding of the quality of the environment and the methodological foundations of its creation in design activities.

It is noted that, depending on the problems that the architect-designer are facing, there are four levels of environmental design: micro level (object-spatial), mezo level (spatial), macro level (architectural planning), mega level (planning). At each level of environmental design, we can distinguish the types of architectural environment that will vary by properties of the material components; by lifestyles and situations of residents′ life; by features of environmental philosophy and concepts of the people who created it; by the principles and mechanisms of development [4].

Along with the fact that most authors believe the functional and spatial parameters or architectural environment are primary while creating typological classifications, it is also classified by figured characteristics, morphological characteristics, socio-cultural values, etc.

Among the recent researches doctoral dissertation, in which the principles of multilevelness, socio-orientation, awareness and integration are proposed, is based on the construction of a typology of architectural environment [5].

Despite the relevance of certain classifications of understanding the qualities of architectural environment and its compositional and spatial organization for the architectural design lies in the plane of open (exterior) space with no cover or roof and indoor – the interior space. These forms of environment differ by the degree of openness to the natural environment, but the same function to be resolved with quite different artistic and compositional means. Hereinafter this typological distribution should be differentiated into the open and closed subsystems respective, also to be divided into smaller-scale elements. Moreover, each element of the system or subsystem should be considered as a complete system a certain level.

The main statements of the theory of architectural environment systems organization are:

– the system of architectural environment is not the simple sum of the individual elements of building development and landscape fragments, but the single holistic unit;
– as a holistic unit, architecture system has certain boundaries that separate its territory from the external environment;
– every architecture system (the interior, the building, the area, the city, etc.) consists of a number of subsystems, which are also divided into smaller-scale items;
– the stability of system (immutability of its components in its vital activity) is determined by internal regulation, which is implemented through forward and backward linkages;
– every element of the system can be considered as a complete system of the second level of organization of matter;
– systems are distributed into the open systems, if they exchange information and energy with the external environment, selectively open systems and closed (locked) systems when this exchange and interaction does not occur; architectural systems belong to the selectively open for exchange with the environment, due to the human factor [7].

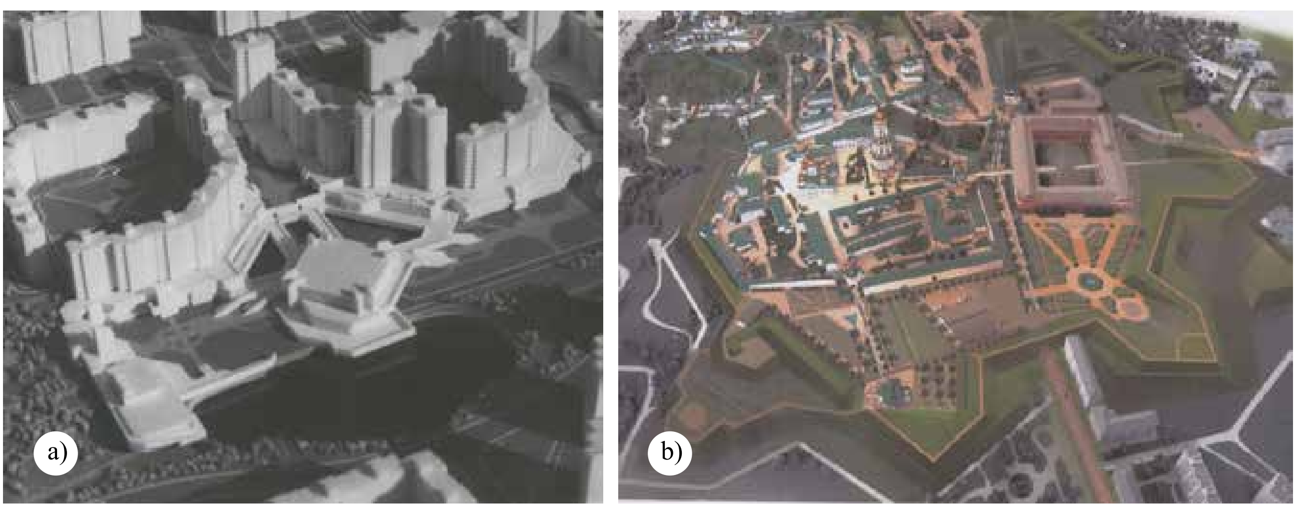

Fig. 1. Open spaces of architectural environment on the level of the projects of development of districts, neighborhoods, urban housing and public entities and ensembles: a) residential and public area in the city of Kyiv – architect Vadym Abyzov (in the group of authors); b) the historic area with recreation spaces adjacent to the National Historic and Cultural Preserve "Kyivo-Pecherska Lavra" – architect Vadym Abyzov (in the group of authors)

The first hierarchical level of open spaces of architectural systems is the urban development structural unit that defines the place and the role of environmental facility in the settlement area and its development under various natural and climatic conditions and urban location, characteristics of the surrounding natural and artificial environments.

Urban development conditions of design units′ location, together with the natural and geographical factors play a crucial initial role in the formation of both open and closed (interior) spaces of environment. And this hierarchical level has several structural sub levels or subsystems: the first level – general scheme (conception) of settlement of the country and planning of its territory (the concept of territorial development) considering placing the country in the European urban space; the second level – regional planning (planning regional territories); the third level – city master plan; the fourth level – projects of development of districts, neighbourhoods, urban housing and public entities and ensembles with relevant improvement of streets and squares (Fig. 1).

Regarding the formation of streets and squares, it is worth to pay attention that especially important this problem becomes in the historic cities of Europe that have a significant historical and cultural heritage and at the same time are the centres of countries, regions and districts with their business and commercial activity. In this case it is important to create a full urban environment by creating pedestrian and recreational zones, taking into account the socio-economic, urban, environmental, engineering, aesthetic and other factors and requirements. Renovation, regeneration, reconstruction and development of the historic part of the city with the creation of aesthetically valuable environment depends on the overall creative idea and concept of development of the central city area, matching its spatial and compositional structure to the design of functional processes and environments and provide the special recreational environment with unique multifaceted sound (Fig. 1b).

Along with the functions of recreation and cultural and community service, pedestrian zone is a place of cultural events like meetings, town fairs, exhibitions, festivals, theatre and sporting performances, but also for daily meetings and communication between people in shopping malls, restaurants, cafes, etc. At the same time urban environment areas have complex zoning caused by the number of different functions that they formed by. Multi-colouring and polycentrism become an important feature of these objects, that combine transport arteries, various buildings, structures and systems, sometimes planted area, gardens and frequently, in terms of historical development, monuments of cultural heritage [1, 8, 9].

The next hierarchical level of open space design is the level of organization of the environment of individual buildings and structures, subordinated to the respective urban formation and environment in general (Fig. 2). At this level, the following organizational subsystems can also be distinguished: defining the basic functional structure of an urban development object in the context of the overall environmental concept; its compositional and spatial organization, colour and lighting solutions, including some functional components.

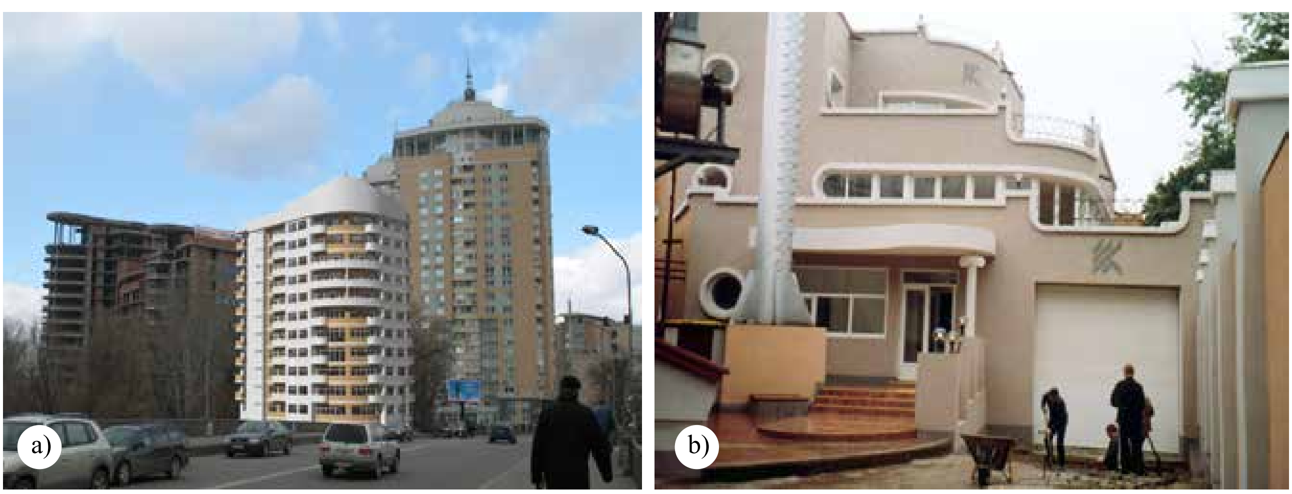

Fig. 2. Open spaces of architectural environment on the level of the individual buildings and structures: a) residential building – architect Vadym Abyzov; b) public building in Kyiv – architect Vadym Abyzov

Fig. 3. Open spaces of architectural environment on the level of the territorial and spatial fragments, surrounding the buildings: a) design of the recreation and entertainment complex in the town of Brovary, Kyiv region – architect Vadym Abyzov; b) design of the office building's entrance group in Kiev – architect Vadym Abyzov

The last structural block is the recreational environment of territorial and spatial fragments, surrounding the buildings, such as a variety of near-ground areas (e.g. relaxing and active recreation), entrance groups, outdoor terraces, exploited roofs, atriums, etc. (Fig. 3). In this case, this hierarchical level already has the subsystem of separate original structural elements such as specific elements of landscaping and improvement, small architectural forms, visual information facilities, various temporary and mobile devices, etc. For example, for an entrance group, it is envisaged a substantive filling of its environment and artistic and figurative solution of the main system-forming elements and fragments, synthesis of the design of the entrance group with decorative-applied, visual and landscape art; use of appropriate construction materials and products (Fig. 3a).

As for the indoor (interior) spaces, they should also be divided into the corresponding hierarchical levels of architectural environment.

The first hierarchical level of indoor recreation spaces is to organize the internal environment of a building or ensemble of buildings, aggregating the complex with a single interior space. At this level, the overall design and spatial composition concept and ideology of the architectural environment of the entire interior space, the conditions of its relationship and interaction with the open space of the environment are solved.

The second hierarchical level of indoor spaces will be the organization of the internal environment of specific functional facilities inside the different types of buildings or complexes, taking into account the connection with other open and closed elements

Fig. 4. Inner spaces of the specific architectural environment inside the different types of buildings or complexes: a), b) interior of public buildings in Kyiv – architect Vadym Abyzov

of the environment. At this level, as well as at previous, functional zoning, architectural and spatial composition, overall colour solution is determined, not the total inner space of the building or complex, but a separate facility or rooms (Fig. 4).

The third structural unit is the subject content of the environment and the compositional and artistic-imaginative solution of the main system-forming elements and fragments of the interior of a particular room in the context of its general environmental design.

The elements of the subject content of the architectural environment primarily include its equipment, which has a functional purpose, such as furniture, visual advertising, equipment, small architectural forms, elements of engineering infrastructure. Artistic design of equipment, along with the need for a comprehensive solution of specific functional, structural, ergonomic, economic conditions of the environment must meet the aesthetic requirements that will reflect a certain style of environment. So the design of furniture, flower beds, fountains, sculptural installations, lamps, etc. should be designed according to the general conceptual design. The saturation of the composition and the creation of the stylistic expressiveness of objects is also due to the expressive details of decor and the synthesis of arts. Therefore, the fourth hierarchical level will be an aesthetic solution of the details of decor and synthesis of arts. Harmonious synthesis of design objects with fine and applied arts (artistic ceramics, monumental and decorative painting, artistic textiles, sculptural compositions, consumer goods made of wood, metal, glass, etc.) is a powerful means of their organic interaction and connection with the architectural environment. Here one should also remember about the skilful use of the means of landscape art and phyto design. After all, plants, herbs and flowers and their meaningful and aesthetic combinations are of great importance in the arrangement of the entertainment environment.

Finally, the use of appropriate building materials and products is a separate level for both indoor and outdoor spaces. Skilful use of traditional building materials (stone, ceramic, wood) and their texture provides special natural artistic-figurative characteristics of the environment. The high development of scientific and technological progress and the introduction of nanotechnologies reveals broad aesthetic and artistic features, along with traditional, innovative products and materials (concrete and reinforced concrete, anodized metal, glass and other materials and products from mineral melts, polymer and recycled materials) for the creation of extraordinary environmental compositions and implementation daring creative design ideas. At the same time, it is important to ensure the stylistic integrity of the spatial and artistic-figurative solutions of the complex.

3. CONCLUSION

The system-structural principles of typology and design of environmental objects provided in this article are important for proper understanding of the phenomenon of architectural environment as a system and can be used more effectively for further research and creation of various concepts and models. The proposed systematic and environmental approach will help to improve the architectural environment's objects organization, accurately determine the requirements and conditions of their formation and implementation at different hierarchical levels, and can be useful for both theory and practice of design.

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RECONSTRUCTING AIRPORT PAVEMENTS USING THE TECHNOLOGY OF PREFABRICATED CONCRETE SLAB

NAPRAWA NAWIERZCHNI LOTNISKOWYCH Z WYKORZYSTANIEM TECHNOLOGII BETONOWEJ PŁYTY PREFABRYKOWANEJ

DOI: 10.30540/sae-2020-012

Abstract

This article presents the construction and technical concept for the use of an innovative repair of the airport pavement. It consists in embedding a prefabricated concrete slab in place of the excessively degraded surface of the existing slabs. In addition, the introduced technology of connecting adjacent panels together increases the spatial stiffness of the entire functional element and significantly increases the load-bearing capacity of the pavement. The results of laboratory and field tests presented in the article confirm the effectiveness of the technology used. As a result, the application of the reconstructing technology ensures the safety performance of aircraft operations at airports facilities.

Keywords: prefabricated slab, airport, load capacity, airport pavements, cement concrete

Streszczenie

W niniejszym artykule przedstawiona została konstrukcyjno-techniczna koncepcja dotycząca zastosowania nowatorskiej naprawy nawierzchni lotniskowej. Polega ona na wbudowaniu prefabrykowanej płyty betonowej w miejscu nadmiernie zdegradowanej nawierzchni płyt istniejących. Ponadto wprowadzona technologia połączenia ze sobą płyt sąsiednich zwiększa przestrzenną sztywność całego elementu funkcjonalnego oraz znacząco wpływa na wzrost parametru nośności nawierzchni. Przedstawione w artykule wyniki przeprowadzonych badań laboratoryjnych i poligonowych potwierdzają skuteczność zastosowanej technologii. W rezultacie stosowanie przedmiotowej technologii napraw zapewnia bezpieczne wykonywanie operacji statków powietrznych na obiektach lotniskowych.

Słowa kluczowe: płyta prefabrykowana, lotnisko, nośność, nawierzchnie lotniskowe, beton cementowy

1. INTRODUCTION

The safety of air operations depends largely on the technical condition of the airport pavements used. Most of the airport pavements in Poland were made in the cement concrete technology, which should meet a number of requirements specified in the relevant normative documents. First of all, cement concrete intended for the driving layer of the pavement should ensure safe transfer of loads generated by aircraft and thermal loads to the ground [1].

Airfield pavements made in cement concrete technology can be divided into three basic groups, according to their current operating status. These groups include: newly built surfaces that are under construction, used surfaces that meet all standard requirements and surfaces that require remedial actions. In the case of the last group, we are talking about objects that require special attention, as a significant number of damage may directly affect the safety of air operations.

The construction and technical concept described in this article, related to the use of an innovative repair of the airport pavement, consisting in the incorporation of a prefabricated concrete slab, is intended to recreate the structural arrangement of the pavement with the assumed physical and mechanical properties. In addition, the technology used to connect the existing adjacent slabs with each other creates a new construction quality and provides load capacity at least comparable to that of adjacent airport slabs. The results of tests and studies presented in the article clearly confirm the legitimacy of using the above-mentioned technology.

2. ANALYSIS AND REVIEW OF THE TECHNOLOGY OF PREFABRICATED CONCRETE SLABS USED AT AIRPORTS IN POLAND AND AROUND THE WORLD

2.1. United States of America (USA)

The use of precast concrete slabs in the US, both in road and airport infrastructure, has been broadly covered in the Strategic Highway Research Program 2 (SHRP2). The main goal of the project was to create methods and technologies for the renovation of road surfaces, while maintaining the least inconvenience for users in a clearly defined time regime. The basic technology on which the team of experts worked was the PCP (Precast Concrete Pavement) technology [2] based on the use of prefabricated concrete slabs for quick renovation of the surface. The analyses and experiments carried out by SHRP2 were based on the creation and application of a technology that would be able to effectively meet the following conditions:

- production of precast concrete elements will ensure adequate strength and durability of concrete;
- the production techniques and equipment used will ensure the efficiency of PCP systems;
- connections of prefabricated slabs will ensure effective load transfer;
- the slabs used will be thinner than concrete built in place by using prestressing elements.

Over the years of using PCP technology, the system has been divided into two basic categories:

I. Intermittent repairs of concrete pavements consisting in carrying out local, single repairs of the surface with the use of prefabricated concrete slabs. Repairs were carried out both in the case of whole degraded and cracked boards as well as damage to board joints or corners.

II. Continuous application consisting in carrying out repairs of the entire section of the pavement by installing prefabricated panels on its successive parts.

An example of the use of the PCP precast concrete slab technology at the airport was the incorporation of prefabricated elements on the taxiway at La Guardia International, New York in 2000 (Fig. 1). The task was to perform two test sections with a total length of 61 m. Reinforced concrete slabs with dimensions of 3.8 × 7.6 m were used in both sections, 400 mm thick prefabricates were used on the first section, and

Fig. 1. Prefabricated PCP concrete slab used at La Guardia International airport in New York [2]

structure

Fig. 2. Prefabricated slabs used in the USSR (on the left airport slabs, on the right – the technique of connecting staples) [1]

300 mm thick on the second section. A characteristic feature of the technology used was the use of special screws, which were responsible for the correct height adjustment of the plates. Moreover, there was a gap under the boards (from 13 mm to 25 mm), which was filled with a prepared cement mortar. In addition, the plates were equipped with specially designed pockets for the use of dowels.

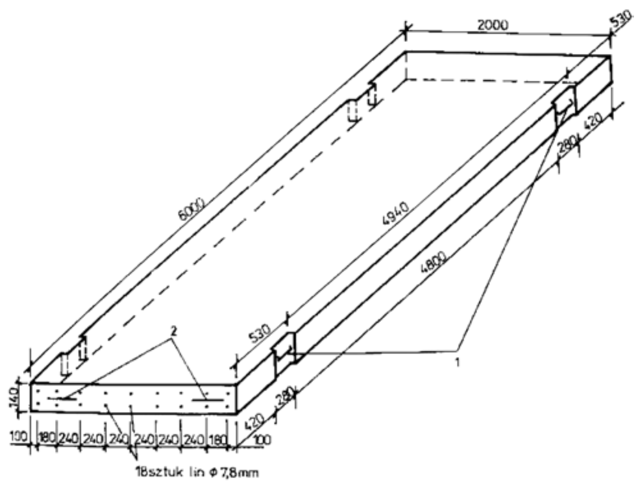
It is worth noting that numerous experiments with the use of prefabricated concrete slabs in the USA have led to the development of several innovative pavement repair systems based on the PCP technology. This group includes Fort Miller Super-Slab System, Kwik Slab System, Michigan System or the aforementioned La Guardia International Airport System, which have become rational methods of quick and effective surface repair.

2.2. Union of Soviet Socialist Republics (USSR)

Since the 1960s, the Union of Soviet Socialist Republics has pioneered the use of the technology of prefabricated concrete panels [1]. The technology was applied based on reinforced slabs, predominantly on the roads in the north of the country due to the economically attractive area (Fig. 2). The essence and innovation of the prefabrication technology used in the USSR was electrothermal compression by stretching longitudinal bars, the use of thinner plates and a unique method of joining plates. Slabs as standard, it had dimensions of 2 × 6 m or 2 × 4 m. The slabs were 160, 180, 200 or 220 mm thick. A characteristic feature of the method was the use of welded clamps installed along the longer edge of the plate. If the staples were more than 4 mm apart, a special rod was used, the diameter of which was three to four times larger than the gap between the staples.

2.3. Poland

The seventies of the twentieth century can be described – as the beginning of the use of prefabricated slabs in the form of pre-stressed slabs (LWS) in Poland (Fig. 3). Pre-stressed slabs were used primarily at military airfields. The standard dimensions of the board are: length 6.0 m, width 2.0 m and thickness 140 mm. A characteristic feature of the LWS panels were their connecting elements, namely the steel clamps that were placed in properly formed slab sockets before concreting. The clamps were placed in pairs on the front and side surfaces of the panel, creating characteristic linear joints that ensured sufficient cooperation between the plates [1, 3]. The clamps were welded together and the quality of this weld largely determined the effectiveness of the connections between the individual boards.



1 – side transport and connection clamps
2 – front connecting clamps

Fig. 3. Airfield pre-stressed slab (LWS) [1]

The concrete used at that time for the production of LWS slabs was B-40 class concrete. Concrete of this class guaranteed the transfer of high prestressing loads and direct benefits in the form of the reduction of the concrete cross-section in the pavement and thus the weight of the entire structure [1]. In addition, concrete had such properties as:

- transferring significant compressive loads across the entire section of the slab;
- high resistance to delamination in the tendon anchoring zone;
- transferring significant tensile stresses generated by aircraft.

For prestressing reinforcement, non-prestressing reinforcement and auxiliary reinforcement, steel of different properties and purpose was used. LWS boards could be used regardless of the season and weather conditions. The slabs constituting the airport pavement were laid on a properly prepared substrate, maintaining the condition of full adhesion of the slabs to the substrate.

3. ANALYSIS AND ASSESSMENT OF THE TECHNICAL CONDITION OF AIRPORT PAVEMENTS AND ITS IMPACT ON SAFETY

Airports where air operations are performed by aircraft used by both civil and military aviation, especially those with jet propulsion, require design and then construction of pavements meeting the highest quality standards [4]. In domestic conditions, the most common type of pavement are pavements made in the cement concrete technology.

Meeting the quality standards means first of all ensuring good adhesion of aircraft wheels to the surface, properly designed and made longitudinal and transverse slopes for effective water drainage, frost resistance and resistance to de-icing agents, as well as high compressive and bending strength. The airport pavement should also provide adequate load-bearing capacity, evenness, roughness and durability, especially for the subsurface layer.

In order to meet all of the above characteristics, it is necessary to constantly monitor and assess the condition of airport pavements, and in the event of damage – to take immediate action. One of the main conditions for maintaining the airport pavement in a condition that does not endanger the aircraft is the knowledge of the current technical condition of the pavement used [5].

Due to fatigue and destructive processes occurring as a result of the impact of traffic and the environment, the cement concrete causes damage that poses a real threat to aircraft. Such damage should be subject to a detailed inventory for each functional element at the airport, and then take immediate corrective action. The most common method of inventorying damage is the visual method consisting in direct inspection on the site, during which damage data is recorded on previously prepared sleepers. The inventory includes both newly created damage and those that have already been repaired. Thanks to this approach, it is possible to determine the overall rate of degradation of the facility, ongoing monitoring of repairs and assessment of their effectiveness [4]. In practice, concrete slabs with dimensions of 5 × 5 m are most often subject to inventory. An additional element facilitating the inventory of damage is their division into surface damage (e.g. flaking, hairline cracks), point damage (e.g. chipping, cracks in the corners) and line damage (e.g. cracks, losses of sealing compound in expansion joints) [1].

Technical diagnostics performed as part of the airport pavement condition assessment should include methods and procedures that will consist of [1]:

- a list of tests and measurements having a direct and indirect impact on the technical condition of the pavement;
- characteristics of research methodology and tools for their analysis;
- a list of tools and measuring devices;
- description and characteristics of the traffic taking place on a given surface;
- all repairs that have been carried out so far.

The final assessment of the pavement condition should clearly indicate whether a given infrastructure object meets the requirements and can be operated, or whether it is necessary to take measures to introduce restrictions or close it [22]. For this purpose, a three-level scale for assessing the degree of pavement damage is used (Fig. 4):

- level I – applies to new, renovated surfaces and those that will not require renovation works in the next 5 years (no actions are taken);
- level II – also known as a warning level, where it is necessary to perform additional detailed studies to determine what corrective actions are required;
- level III – defined as critical, where it is necessary to take immediate actions to improve the condition of the pavement, and in some cases to exclude a given object from use.

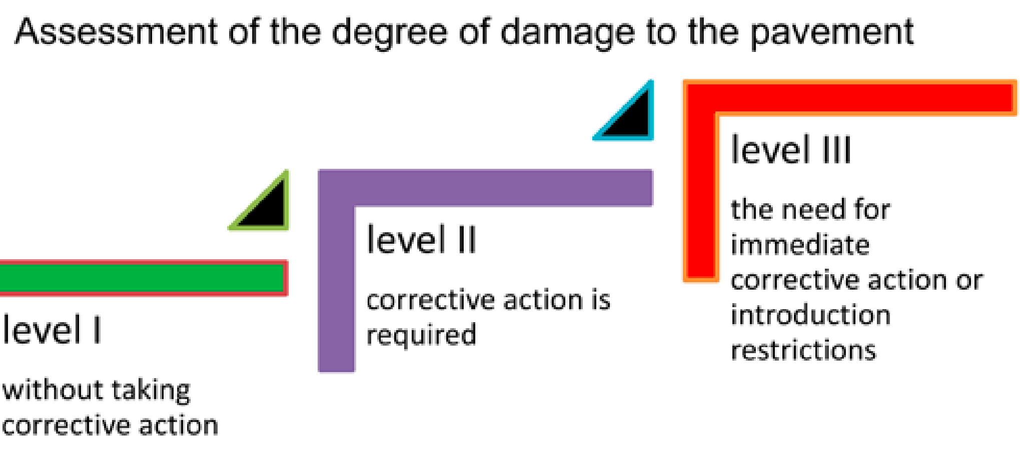


Fig. 4. Assessment of the degree of damage to the pavement

Airport pavements are a probabilistic system in which certain behaviours and changes in the technical condition cannot be clearly predicted and determined [6]. In this case, we can only test the appropriate level of confidence in the events that occur in the pavement structure.

In the process of diagnostics of airport pavements, first of all, attention should be paid to the continuity of its operation, which is a necessary condition for the functioning of the airport. Any renovation works should be understood as local repair works or replacement of the entire element, which in both cases will lead to the recovery of the operational properties of the pavement. In some cases, when the airport pavement is subject to several dozen years of use, and the scale of damage is so large that single, local repairs turn out to be ineffective, then it is necessary to carry out a major renovation of the pavement. The appropriate selection of diagnostics of the airport pavement is a key element, the detailed analysis of which leads to the determination of the predicted condition of the pavement, which in turn makes it possible to safely perform air operations [17].

4. TECHNOLOGY OF REPAIRING THE AIRPORT PAVEMENT USING A PREFABRICATED CONCRETE SLAB

The long-term exploitation period of concrete airfield pavements leads to numerous damages, which may constitute a very real threat to air operations [7]. In the event that the damage is related to the destruction of entire fragments of concrete slabs, and the repairs carried out so far turn out to be ineffective, it has become necessary to introduce a repair technology consisting in replacing the entire slab or its part. It should be added that the time of decommissioning a given object should be as short as possible due to the very large financial losses incurred by the airport in the event of disabling certain parts of the infrastructure, especially the runway, which is a key element of air operations. The introduced technology of prefabricated airport slabs assumes the reconstruction of damaged airport pavements and the reconstruction of operational parameters at least as present on the adjacent slabs. At the same time, the duration of the entire repair task does not exceed 5 hours [8].

4.1. Characteristics of the prefabricated airport slab

The prefabricated concrete slab, which is prepared in advance in the prefabrication plant, has dimensions: 2.50 × 5.00 m and a thickness of 0.24 m (Fig. 5). The slab is made of concrete class C35/45 and in its cross-section it has the following main reinforcement made of steel class AIII:

- top reinforcement in the form of ribbed bars ø 14 mm with a spacing of 30 × 30 cm;
- bottom reinforcement in the form of ribbed bars ø 14 mm or 16 mm, spaced 15 × 15 cm.

A characteristic feature of the slab is the use of dowelled joints, which, based on the analysis and calculations performed, are as follows:

- dowels with a diameter of 25 mm and a length of 60 cm were used;
- the dowel spacing on the long board edge (5.0 m) is 62.5 cm, while the dowel spacing on the shorter board edge (2.5 m) is 55.0 cm.

It should also be added that the design of the dowel joint was developed for the loading of the main shin of the Boeing 737-800, as the design aircraft most frequently used by Polish civil airports.

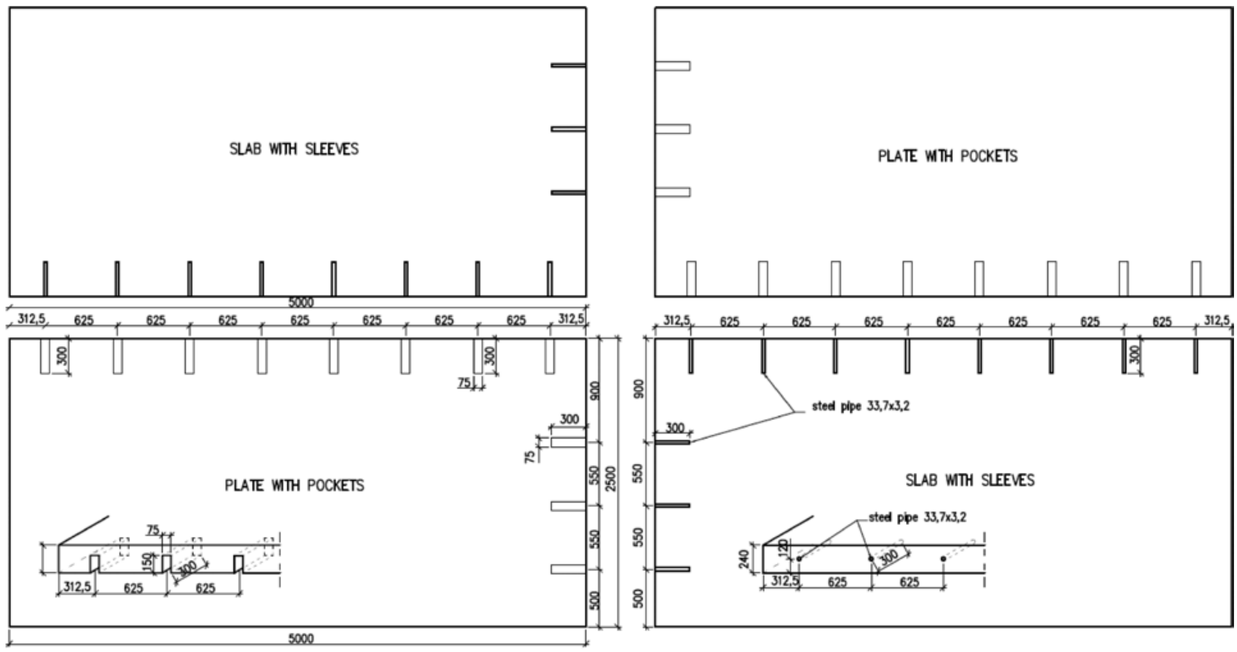


Fig. 5. Prefabricated slabs with dowel joint

4.2. Description of the hob embedding technology

The first stage of the airfield pavement repair process with the use of prefabricated slabs is to demolish damaged, old slabs. Each damaged monolithic slab is mechanically dismantled with the use of demolition hammers. The necessary condition for the research experiment is to check whether the foundation, preserved after the demolition of the damaged slab, has an appropriate load capacity, which should correspond to a 20 cm layer of lean concrete of C8/10 class (Fig. 6). Then the foundation is filled with concrete of C16/20 class and compacted with a heavy vibrating plate. On the substrate prepared in this way, in four or six support points of the prefabricated element, steel sheet washers (pads) are applied to such a height that the prefabricated slab is placed at the same ordinate as the adjacent slabs. Additionally, the washers act as a temporary support for the

Fig. 6. Installation of a prefabricated concrete slab

structure

prefabricated element until the mortar achieves the required strength. The next stage of works consists in filling the space between the washers with a non-shrink mortar, which is intended for the repair of concrete and reinforced concrete structures.

Then, using a crane and appropriate slings, the prefabricated slab is installed on previously prepared steel pads. The slab is finally lowered after it is horizontally stabilized and the width of the gaps is maintained. The last stage of assembly works involves injection of a sealing substance under the slab, which is forced under the appropriate pressure through previously prepared holes. Then, after a few days, an expansion cord is installed in the gap between the built-in board and the neighbouring boards and the gap is filled with a sealing compound.

4.3. Precast concrete slab testing

4.3.1. Laboratory tests

Laboratory tests of the precast concrete slab included the analysis of both the mechanical and physical properties of the concrete. The mechanical properties were determined in the concrete compressive strength and tensile strength test. The physical properties were checked during tests of concrete weight absorption and frost resistance.

Compressive strength

The compressive strength of concrete was tested in accordance with the PN-EN 12390-3:2019-07 Standard. Concrete tests – Part 3: Compressive strength of test samples [9]. The calculation of the course of concrete strength during the hardening period was made according to the Skramtajew formula [10]:

$$B_{wn} = B_{w28} \frac{\lg n}{\lg 28} \tag{1}$$

where:
B_{wn} – concrete strength after n days from concreting ($3 \leq n \leq 28$ days);
B_{w28} – compressive strength of concrete after 28 days;
$\lg n$ – the decimal logarithm of the number of days of concrete hardening.

The above formula is appropriate for the concrete hardening temperature at +15°C.

Concrete testing for the prefabricated slab was carried out on 12 test samples (cubes) with dimensions of 15 × 15 × 15 cm. The test results are presented in Table 1. On the basis of the obtained results, it should be concluded that the cement concrete used for the production of the slab met the requirements for class C35/45 concrete, in accordance with the Defense Standard NO-17-A204: 2015 Airfield pavements – cement concrete pavements – Requirements and test methods [11], because the average value of the compressive strength was 50.2 MPa.

Table 1. Results of concrete compressive strength

Sample number	Volume density [kg/m³]	Force [kN]	Compressive strength [MPa]
1	2407	1078	47.9
2	2319	1143	50.8
3	2365	1173	52.1
4	2313	1145	50.9
5	2405	1190	52.9
6	2320	1116	49.6
7	2331	1016	45.2
8	2321	1184	52.6
9	2389	1045	46.4
10	2318	1101	48.9
11	2347	1150	51.1
12	2323	1222	54.3
Average value:	2347	1130	**50.2**

Bending tensile strength

The bending tensile properties of concrete were tested in accordance with the PN-EN 12390-5: 2019-08 Standard. Concrete tests – Part 5: Bending strength of test specimens [12]. The calculations were made according to the following formula:

$$f_{cf} = \frac{P \times l}{d_1 \times d_2^2} \tag{2}$$

where:
f_{cf} – concrete tensile strength marked according to standards [MPa];
P – maximum loading force [kN];
l – spacing of supports (supporting rollers) [mm];
d_1, d_2 – transverse dimensions of the tested beam [mm].

The test was carried out on 8 beams with dimensions of 70 × 15 × 15 cm, applying the load with one concentrated force (centrically). The average value of the strength obtained on the basis of the tests was 5.79 MPa (standard deviation 0.24 MPa). Based on the tests performed, it should be confirmed that the prefabricated slab is made of cement concrete that meets the requirements for class C35/45, according to the Defense Standard [11].

Concrete water absorption test

The water absorbability of concrete is a physical feature that determines the ratio of the mass of water that the concrete is able to absorb to its dry mass. The test was performed in accordance with the PN-88/B-06250 Standard Concrete [13].

In the experiment, the water absorption test was carried out on six cubic samples, each of which had dimensions of 15 × 15 × 15 cm. Table 2 presents the results of the obtained measurements. The average value of concrete water absorption was 3.9%. On the basis of this test, it can be confirmed that the cement concrete met the standard requirements because its water absorption did not exceed 5% of the limit value, according to the Defense Standard [11].

Table 2. Concrete water absorption test results

Sample number	Sample weight [g]		Absorption [%]
	saturated	dry	
1	7828	7536	3.9
2	7983	7693	3.8
3	7831	7531	4.0
4	7834	7540	3.9
5	7824	7539	3.8
6	7920	7615	4.0
Average value	7870	7576	**3.9**

Concrete frost resistance test

On the basis of the PN-B-06265 Standard, which is the national supplement to the PN-EN 206-1 Concrete [14]. Standard, a concrete frost resistance test was performed. The test method consists in verifying the designed degree of frost resistance (F) of concrete, which corresponds to the index (N), which determines the number of expected years of use of the structure.

The test was performed on 12 cubic samples, each measuring 15 × 15 × 15 cm. The number of freeze-thaw cycles was 200.

The test results are presented in Table 3 indicate that the cement concrete subjected to the assessment met the requirements for the frost resistance degree F200. In accordance with the applicable standard, the weight loss of samples after the test was less than 5%, and the average decrease in compressive strength did not exceed 20%.

Table 3. The results of concrete frost resistance tests

<table>
<tr><th rowspan="2">Sample number</th><th colspan="2">Sample weight [g]</th><th rowspan="2">Loss of weight ΔG [%]</th><th rowspan="2">Strength R_i [MPa]</th><th rowspan="2">Decrease Endurance ΔRi [%]</th></tr>
<tr><th>before research</th><th>after study</th></tr>
<tr><td>1</td><td>7940</td><td>7925</td><td rowspan="6">0.22</td><td>51.9</td><td rowspan="12">15.3</td></tr>
<tr><td>2</td><td>7815</td><td>7795</td><td>46.4</td></tr>
<tr><td>3</td><td>7860</td><td>7840</td><td>49.2</td></tr>
<tr><td>4</td><td>7800</td><td>7775</td><td>45.8</td></tr>
<tr><td>5</td><td>7930</td><td>7915</td><td>52.1</td></tr>
<tr><td>6</td><td>7925</td><td>7915</td><td>52.0</td></tr>
<tr><td>7</td><td colspan="3" rowspan="6">samples-witnesses
60.1
56.2
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58.1
59.7</td><td>55.7</td></tr>
<tr><td>8</td><td></td></tr>
<tr><td>9</td><td></td></tr>
<tr><td>10</td><td></td></tr>
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</table>

4.3.2. Field tests for the assessment of pavement load capacity

The research experience consisting in the incorporation of a prefabricated concrete slab was carried out on the DK-Z4 taxiway at one of the airports in Poland. The taxiway had plates with numerous damage, which, according to the diagnostics specified in Chapter 3, required immediate corrective action. The place of installation prefabricated slab is shown in Figure 7.

Tests of the load-bearing capacity of precast concrete slabs were carried out using the HWD (Heavy Weight Deflectometer), in accordance with the Defense Standard NO-17-A500: 2016 Airfield and road pavements. Load capacity tests [15]. The tests were carried out both on the existing slabs (before replacement) and on new, embedded precast concrete slabs.

The assessed airport pavement of the taxiway had the following structural system:

- cement concrete pavement, class B-40, thickness 25.0 cm;
- bituminized aggregate sliding layer, thickness 3.0 cm;
- upper layer of asphalt concrete foundation, thickness 10.0 cm;
- ARMAPAL GL 100 × 100 anti-crack reinforcing mesh;

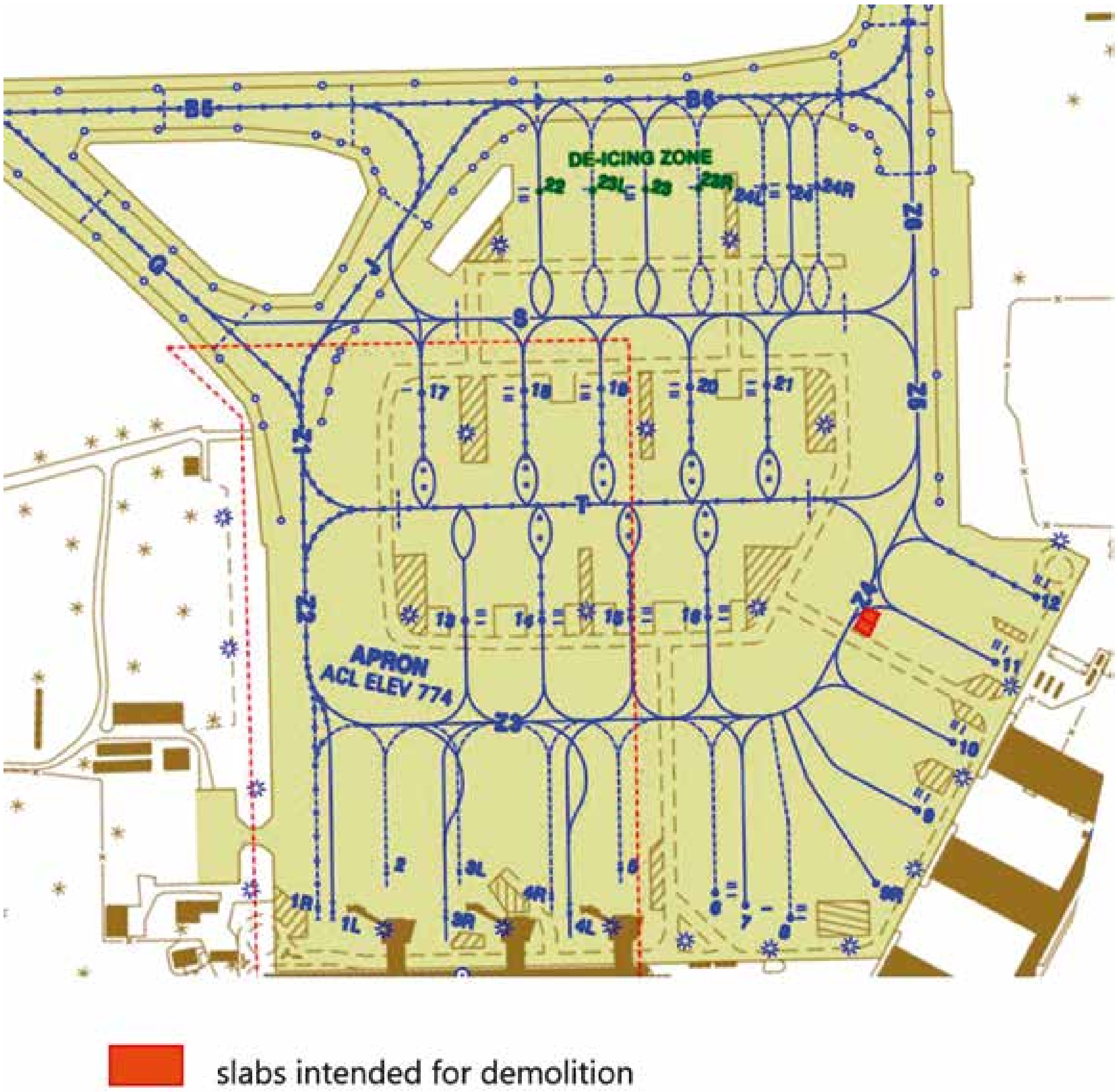


Fig. 7. The airport apron with the locations of damaged plates marked

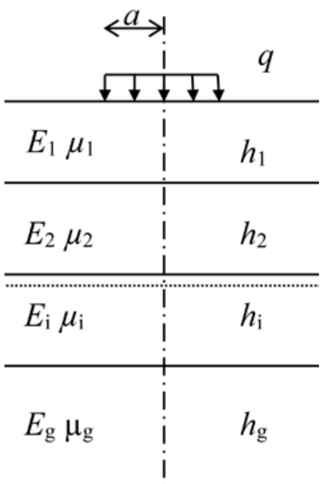
– lower layer class B-25 cement concrete foundation, thickness 24.0 cm;
– drainage layer of medium gravel, thickness 15.0-30.0 cm;
– REHAU-FILTRAM 1B1 drainage mat with double-sided geotextile;
– mineral soil embankment – permeable, with good compactability, thickness 75.0 cm including the bedding;
– the existing subsoil (according to geological research).

The Boeing 737-800 computing aircraft was adopted for research purposes. It is an aircraft most often used at civil airports in Poland. The basic parameters of the load capacity state of the aircraft, including the ACN indexes corresponding to the ground load category (A, B, C, D – see Table 7), are presented in Table 4.

Table 4. Basic parameters of the adopted aircraft type

Aircraft type	Mass [kg]	Substrate load capacity category							
		Rigid pavement				Flexible pavement			
		A	B	C	D	A	B	C	D
B 737-800 ACN (aircraft classification number)	79 242	49	52	54	56	43	45	50	55
	41 413	23	24	25	27	20	21	22	26

Based on the results of the field tests, the calculation model for the assessed structure of the airport pavement was determined, as shown in Figure 8.



where:
E – layer modulus;
μ – layer Poisson's ratio;
h – layer thickness;
q – load on the pavement;
a – radius of the load on the pavement

Fig. 8. Calculation model of the assessed pavement structure

Measurements of elastic deflections of the plates were measured in the places indicated in Figure 9.

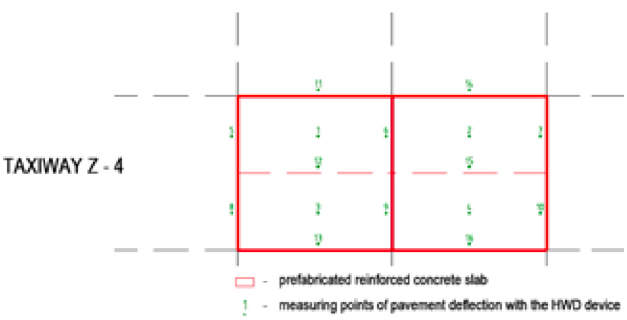


Fig. 9. Plan of deflection measurements on the assessed prefabricated slab

The results of the elastic deflection tests, both on the existing slabs and on the newly built-in prefabricated slabs, are presented in Tables 5 and 6. The replacement modules were calculated according to the following formula:

$$E_z = \frac{2qr}{d} \quad (3)$$

where:
E_z – construction replacement module [MPa],
q – stress under the pressure plate [MPa],
r – pressure plate radius [mm],
d – elastic deflection in the axis of the pressure plate [mm].

Table 5. The results of the plate elastic deflection test (before replacement)

Measurement point	Stress under the slab [kPa]	Drop force [kN]	Deflection [μm]	Replacement module [MPa]
1	1247.00	198.33	370.60	1514.17
2	1249.00	198.64	285.40	1969.34
3	1245.00	197.98	424.00	1321.34
4	1247.00	198.33	304.90	1840.44
Average	1247.00	198.32	**346.23**	**1661.32**
Standard deviation [μm]	1.63	0.27	63.38	296.76
Coefficient of variation [%]	0.13	0.14	18.31	17.86

Table 6. The results of the plate elastic deflection tests (after replacement)

Measurement point	Stress under the slab [kPa]	Drop force [kN]	Deflection [μm]	Replacement module [MPa]
1	1250.00	198.72	139.50	4032.26
2	1243.00	197.61	141.40	3955.80
3	1242.00	197.45	145.70	3835.96
4	1246.00	198.22	148.40	3778.30
Average	1245.25	198.00	**143.75**	**3900.58**
Standard deviation [μm]	3.59	0.58	4.04	114.77
Coefficient of variation [%]	0.29	0.29	2.81	2.94

As shown the comparative studies, the average deflection value measured on new prefabricated slabs (**143.75 μm**) is 59% lower than the average deflection value measured on the existing slabs. The average value of the calculated equivalent module of the pavement structure with prefabricated slabs (**3900.58 MPa**) is 135% higher than the replacement module determined for the reference structure.

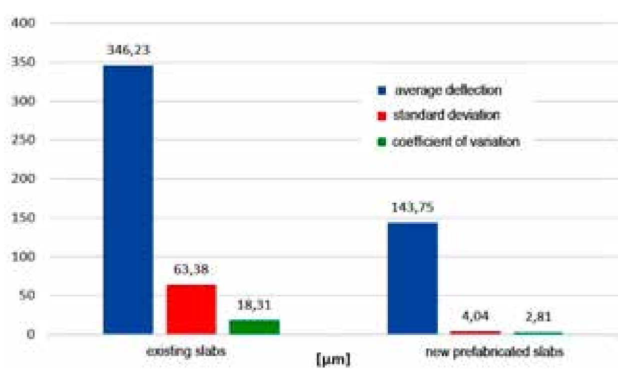


Fig. 10. Comparison of deflection values for the existing slabs and the new prefabricated elements

Table 7. Interpretation of ACN-PCN method indications [16]

1	Dimensionless PCN number				
2	Type of surface	R	rigid		
		F	flexible		
3	Soil category (for rigid pavements – k, for flexible pavements – CBR)	A	high strength	k > 120 MN/m^3	CBR > 13
		B	medium strength	60-120 MN/m^3	8-13
		C	low strength	25-60 MN/m^3	4-8
		D	ultra low strength	k < 25 MN/m^3	CBR < 4
4	Aircraft tire pressure allowed	W	unlimited		
		X	high to 1.5 MPa		
		Y	medium to 1.0 MPa		
		Z	low to 0.5 MPa		
5	Assessment method	T	indicates technical evaluation		
		U	indicates usage – a physical testing regime		

Taking into account the results of the elastic deflections measured on the existing prefabricated slabs, the deflection bowl was determined, followed by the stresses in the airport pavement. As a result of further analysis, the current load capacity index of the PCN was determined and the allowable total number of flight operations for the adopted calculation aircraft, determined for the existing plates.

In accordance with the assumptions of the International Civil Aviation Organization ICAO, the classification number of PCN expresses the load capacity of the airport pavement. It is equivalent to 1/500 of the allowable load (expressed in kg of mass) applied to the pavement via a single wheel with the standard pressure of 1.25 MPa [8, 16]. In the ACN-PCN (Table 7) method, the pavement load capacity is described by a group of symbols characterizing individual parameters of the structure and informing about the method of determining the PCN number [18-20].

In order to calculate the allowable number of loads, the stresses in the pavement for the adopted calculation model should be compared with the allowable stresses, which are determined using the stress criterion taking into account the repeatability of loads [16, 17]. Then compare the PCN of the pavement under test with the ACN number of the design aircraft. The analysis carried out in this way will allow to determine whether an aircraft can safely operate on a test surface and what will be the forecast, allowable number of air operations.

The designated total number of air operations is specified in Tables 8 and 9.

Table 8. The load capacity results for the Boeing 737-800 design airplane for the existing plates

Functional element of the airport	Indicator load capacity PCN	Total number air operations
Taxiway Z4 (before change)	52/R/B/W/T	145 000

According to the same operation algorithm, taking into account the determined PCN load index equal to 52, the allowable total number of flight operations for the structural system with new prefabricated slabs was determined, as shown in Table 9.

Table 9. The results of the load capacity for the Boeing 737-800 design airplane for prefabricated slabs

Functional element of the airport	Indicator load capacity PCN	Total number air operations
Taxiway Z4 (prefabricated slabs)	52/R/B/W/T	255 000

The carried out load capacity analysis proves that the newly applied technology of the precast concrete slab significantly increases the pavement load capacity parameter.

As a consequence, the number of permissible air operations on existing plates in relation to the number of operations on newly built prefabricated slabs increased by 76%.

Additionally, during the field tests, the cooperation of adjacent plates was analyzed. The aim of the study was to determine the level of plate cooperation after the use of dowelling technology.

For this purpose, the load transfer coefficient was determined, which is the main factor determining the cooperation of the plates. We calculate this indicator according to the formula:

$$J = \frac{U_n}{U_o} \times 100 \quad (4)$$

where:
J – load transfer factor [%];
U_n – deflection on an unloaded plate;
U_o – deflection on the loaded plate.

During the measurements with the HWD device, three load drops were made at each designated measurement point. The sensors in the HWD device were arranged as shown in Figure 11, however, only sensors 2 and 3 were taken into account for testing the cooperation of adjacent plates.

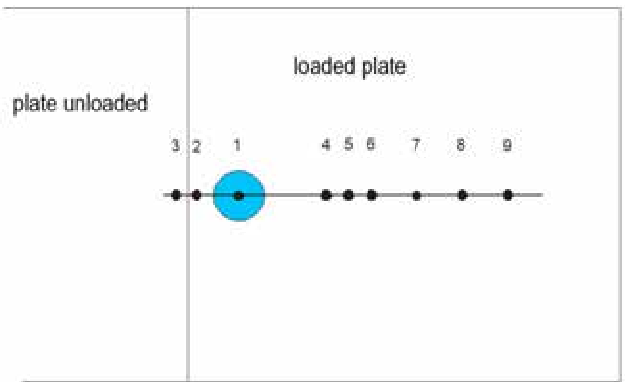


Fig. 11. Arrangement of the HWD sensors

Based on the obtained results presented in Table 10, it was found that the cooperation of the plates is ensured at a very high level, as the determined average value of the load transfer coefficient was over 90%.

5. CONCLUSIONS

The data published by agencies related to air traffic research, including the Civil Aviation Authority responsible for statistics on Poland, prove that air traffic is currently one of the most developing modes of transport. The growing air transport also means the increased impact of aircraft on airport surfaces.

Airport pavements in Poland are very often made of cement concrete, due to its features such as resistance to de-icing agents, frost resistance or high mechanical and operational parameters. Despite so many indisputable advantages of concrete pavements, they are also subject to gradual damage and, consequently, degradation, which can cause a threat to the safety of air operations by aircraft.

Considering the above, it has become necessary to search for new repair technologies that will allow the reconstruction of damaged pavements, but within a strictly defined time regime.

Such a technology is the proposed prefabricated concrete slab with the dowelling option. As the research presented in the article showed, the method used allows not only to quickly and effectively restore the load-bearing capacity of degraded slabs, but even to significantly increase the load-bearing capacity of the pavement. In addition, the use of connecting adjacent panels with dowels creates a new design quality that increases the spatial stiffness of the entire functional element. As a consequence, the loads generated by aircraft on concrete slabs are evenly distributed, thus preventing premature damage to the slab in use.

Table 10. The results of the cooperation of prefabricated panels

Measurement point	Stress under the slab [kPa]	Drop force [kN]	Deflection of sensor 2 [µm]	Deflection of sensor 3 [µm]	J [%]
6 (only prefabricated slab)	1241.00	197.34	159.60	145.20	**91.0**
9 (only prefabricated slab)	1240.00	197.21	155.30	136.30	**87.8**
12 (only prefabricated slab)	1243.00	197.69	122.50	112.80	**92.1**
15 (only prefabricated slab)	1243.00	197.61	118.60	107.40	**90.6**
Average	1241.75	197.46	139.00	125.43	**90.3**

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A STUDY OF THERMAL COMFORT AT KIELCE UNIVERSITY OF TECHNOLOGY

BADANIE KOMFORTU CIEPLNEGO NA POLITECHNICE ŚWIĘTOKRZYSKIEJ

DOI: 10.30540/sae-2020-013

Abstract
The article presents the research of thermal comfort based on the Fanger model. The research was conducted in three educational rooms. The study involved 98 people whose age is between 19 and 23 years old. The study consisted in measuring the parameters of the thermal environment. During the research, students completed surveys regarding the thermal sensation. On the basis of the research, the predicted mean vote PMV score and the predicted percentage of dissatisfied PPDs were determined. This made it possible to compare the assessment of respondents with those indicated according to the standard, which showed that the Fanger model does not reflect the results of the respondents. The best solution will be to modify the Fanger model.

Keywords: thermal comfort, thermal sensation, room air quality

Streszczenie
W artykule przedstawiono badania komfortu cieplnego na podstawie modelu Fangera. Badania prowadzono w trzech pomieszczeniach edukacyjnych. Wzięło w nich udział 98 osób, których wiek zawiera się w przedziale od 19 do 23 lat. Badanie polegało na zmierzeniu parametrów środowiska termicznego. Podczas wykonywanych badań studenci wypełniali ankiety dotyczące odczucia cieplnego. Na podstawie przeprowadzonych badań określono przewidywaną średnią ocenę PMV oraz przewidywany odsetek osób niezadowolonych PPD. Pozwoliło to na porównanie oceny ankietowanych ze wskazanymi według normy, co pokazało, że model Fangera nie odzwierciedla wyników ankietowanych. Najlepszym rozwiązaniem będzie modyfikacja wzoru Fangera.

Słowa kluczowe: komfort cieplny, odczucia termiczne, jakość powietrza w pomieszczeniu

1. INTRODUCTION

Ensuring adequate thermal comfort is one of the main reasons why we spend most of our time inside buildings. Adequate thermal conditions are key elements for our well-being, health and productivity. Not providing the right conditions can adversely affect our immune system and we start to feel tired. Our efficiency of performed activities will also decrease, which will make us less efficient regardless of whether the work is mental or physical. That is why it is so important to ensure adequate parameters of the air in the room and try to keep them at an appropriate, as far as possible unchanging level.

Thermal comfort is important when designing heating and air conditioning systems. The main purpose of air-conditioning devices is to maintain air parameters within set limits. These include air temperature, air speed, humidity, pressure. Modern available technologies make it possible to construct buildings that ensure precise compliance with these parameters. Well-designed air conditioning improves the comfort of living and also provides friendly working conditions for people staying in a given room.

The key element of feeling thermal comfort is the air temperature. The human body adapts itself at a given moment to the prevailing climatic conditions. It has a wide range of functionality under given conditions, but only in a small climatic range it feels thermal comfort [1]. The adaptation of the air temperature in the room is calculated on the basis of the model developed by Fanger [2]. There is a model in which the thermal comfort is expressed using the Predicted Mean Vote (*PMV*). *PMV* determines the average voting rating in the category on a seven-grade rating scale [3]. The *PMV* index is a function of environmental conditions, which include air temperature, air velocity, humidity, average radiation temperature, metabolic rate and clothing insulation. The Fanger's comfort equation is also associated with the PPD index – the predicted percentage of people dissatisfied with the existing conditions [3]. International standards concerning thermal comfort have also been developed, e.g. ASHRAE 55 [4] and PN EN 16798 [5].

Farraj [6] conducted research on thermal comfort in air-conditioned residential buildings. He compared the Actual Mean Vote – *AMV* with the Predicted Mean Vote – *PMV*. He stated that the ISO 7730 standard for calculating *PMV* does not assess the actual thermal sensation of the person tested in a desert climate. According to Siewa et al. [7], the thermal comfort model should be improved to provide reliable guidance for designers. A similar study was conducted by Ricardo et al. [8], who examined the relationship between *PMV* and Mean Thermal Sensation (MTS) and operating temperature, and found a significant relationship. Arslanoglu and Yigit [9] conducted research in the climate chamber and studied the effect of radiation heat flux on human thermal comfort. They concluded that the respondents felt thermal discomfort because the heat stream caused differences in skin temperatures. They proved that the head is most affected by radiation. Similar conclusions were reached by Atmaca [10], who examined the differences between body segments caused by high radiation temperature and the temperature for the construction of walls and ceiling structures with an impact on thermal comfort. The issues of thermal comfort are inextricably linked to the issue of heat exchange, which was discussed inter alia in [11, 12].

Based on the presented literature review, it can be concluded that Fanger's model does not reflect the actual thermal sensations, because the *PMV* index determined by him is a function of human physical activity, thermal insulation of clothing, temperature, humidity and speed of air movement, and average temperature of ambient radiation. According to Fanger, the *PMV* model does not take into account, for example *BMI* mass index. Therefore, the article verifies this thesis for educational rooms in Kielce, and then a modification of the model will be developed in order to reproduce as accurately as possible the optimal conditions of thermal comfort obtained from the surveys.

2. MATERIAL AND METHOD

The research was conducted at the Kielce University of Technology for three groups. In February, two measurements were made in the Energis building at the Faculty of Environmental, Geomatic and Energy Engineering, and the outside temperature was 1°C. And at the beginning of March one measurement was made in building C at the Faculty of Management and Computer Modeling and the outside temperature was equal to 3°C. The test consisted of measuring parameters such as air temperature, air velocity, average

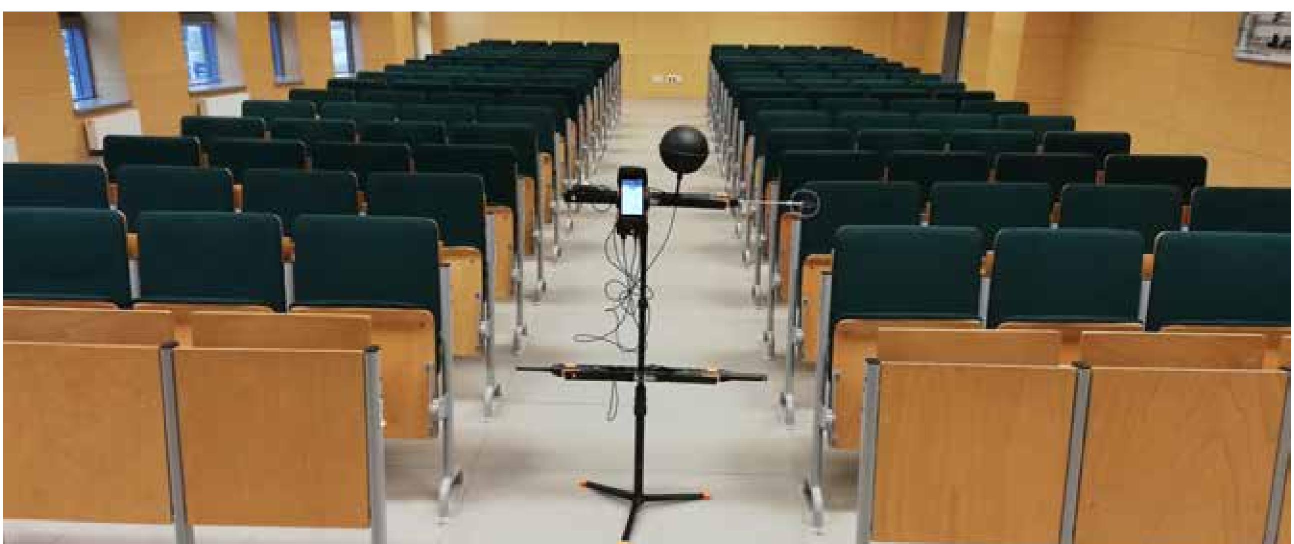

Fig. 1. Data acquisition device on the tripod

radiation temperature, black sphere temperature, relative humidity of air and air velocity, and light intensity. The microclimate meter was used to measure these parameters, which is shown in Figure 1.

During the measurements, people in the room completed a survey on the characteristics of the thermal sensations of the microclimate and what outfit they are currently wearing. On this basis, the type of clothing was averaged and the clothing insulation level was determined by adding the thermal resistance of the office chair (0.1 clo). Respondents marked the type of physical activity during 30 minutes before coming to the room where the measurement was taken. If you answered: intensive effort, such a survey was rejected due to the likelihood of disturbed thermal sensations due to increased metabolism. The rest of the answers related to this question were taken into account. When asked about the current state of health, when the respondent marked the answer "yes", such a survey was canceled because the thermal sensations of the sick are not meaningful. Each survey had a record at the end, which provided information on the sex, age and weight of the person surveyed.

Based on the program on the website [13], the *PMV* and *PPD* index were determined. This made it possible to compare the assessment of respondents with those indicated according to the standard. An important element was the question about current thermal sensations on a seven-point scale (from –3 "too cold" to +3 "too hot").

3. RESULTS

98 people took part in the study, of which 39 questionnaires were rejected, 13 because of marking the "yes" answer to the question of whether they are ill, and 26 because of averaging the isolation of clothing, so 59 questionnaires were considered for further analysis, including 33 women and 26 men. The study involved young people, whose age is between 19 and 23 years old. After the analysis of the studies, the results from the questionnaires were compared with the results from the website [13].

3.1. Comparison of the Fanger model for PMV and PPD

Based on the research, graphically presented the opinions of the respondents with the Predicted Mean Vote (*PMV*), based on the standard. The results of tests for three rooms are presented below, comparing the Fanger model with the results based on surveys in Figure 2.

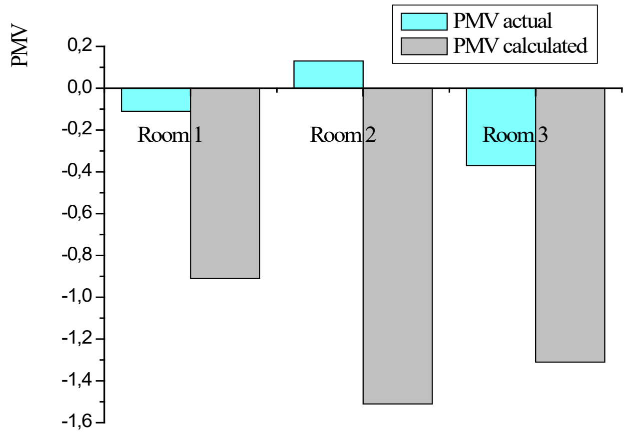

Fig. 2. Comparison of actual test results and calculations according to the Fanger model for PMV

The graph shows that there is a significant discrepancy between the calculation results according to the Fanger model and the results developed on the basis of surveys. Analyzing the figure above, it can be seen that the Fanger model does not correctly map the actual thermal sensations of the subjects. This means that when assessing the microclimate in these rooms, standard guidelines would not be meaningful. By the shape of the bars, it can be seen that on average these values differ by 1. Then the percentage of dissatisfied PPD was compared according to the opinions of the respondents and based on the Fanger model. Figure 3 presents this relationship.

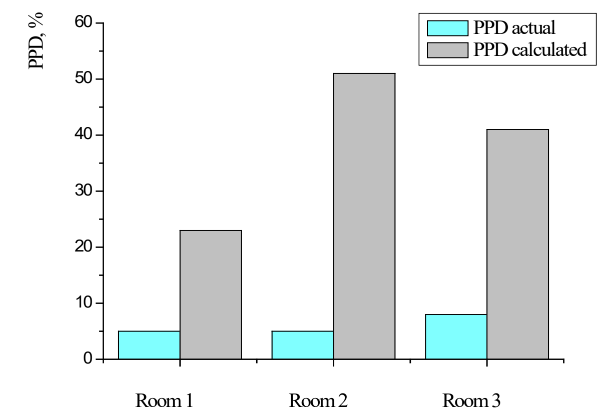

Fig. 3. Comparison of actual test results and calculations according to the Fanger model for PPD

The above figure illustrates how PPD [%] calculated on the basis of the standard [13] and determined from surveys is presented. According to this figure, it can be seen that the values of the predicted percentage of dissatisfied people do not coincide with the Fanger model.

3.2. The effect of BMI on the PMV formula

The *BMI* mass index was calculated on the basis of formula (1), which is the quotient of weight and height, which respondents entered in the metric. Figure 4 illustrates its impact on the feeling of thermal comfort in a given facility.

$$BMI = \frac{weight[kg]}{height^2[m^2]} \tag{1}$$

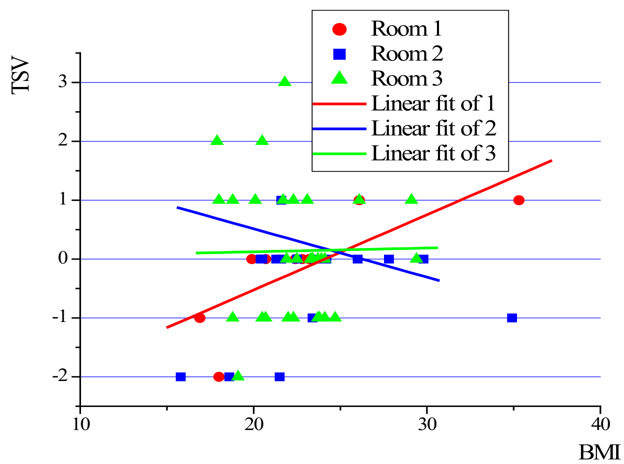

Fig. 4. Influence of BMI factor on TSV (Thermal Sensation Vote)

From Figure 4 there is no special relationship that the subjects in these conditions with a lower *BMI* prefer a higher temperature. It can be seen that the respondents did not give a clear picture of the dependence of TSV on the *BMI* mass index. To observe if *BMI* affects TSV, more tests should be performed.

3.3. Voting on the thermal impression

Figure 5 shows the thermal impression, which is expressed as TSV, with TSV values based on the seven-point ASHRAE scale [4].

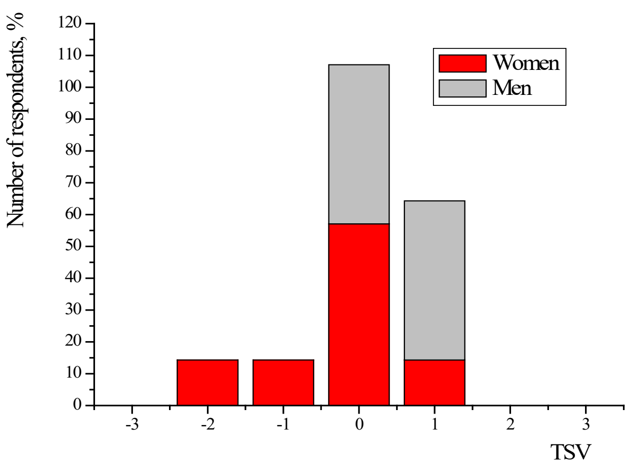

Fig. 5. Frequency distribution of Thermal Sensation Vote (TSV)

Analyzing the responses of the respondents, it can be seen that the largest percentage of people voted for a comfortable thermal sensation (0), 50% men and 57% women. Women dissatisfied with the room conditions are 15%. No man on the set scale is dissatisfied with the conditions. The room is pleasantly warm (+1) for 15% of women and 50% of men, and 15% of women think that the room is pleasantly cool. The next figure shows the dependence of thermal voting on preferences.

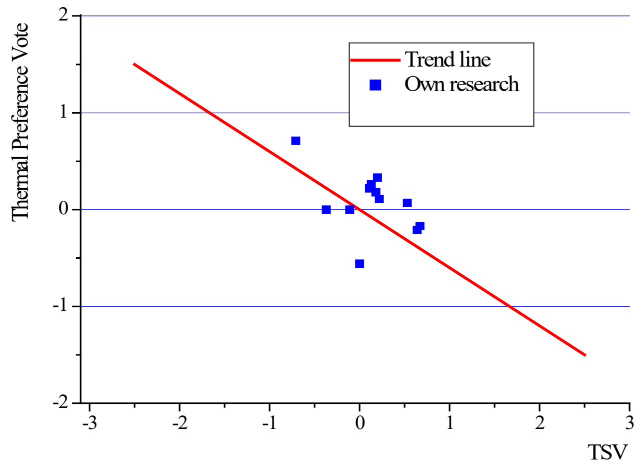

Fig. 6. TSV dependence on thermal preference vote

From the above points marked on the graph, it appears that the respondents are satisfied with the room temperature. Only individuals would like the room to be warmer.

3.4. New model

The Fanger model is expressed using the predicted mean vote (*PMV*). The *PMV* index was calculated according to the formula [3]:

$$\begin{aligned} PMV = {} & [0.303 \cdot exp \cdot (-0.036 \cdot M) + 0.028] \cdot \\ & \{(M - W) - 3.05 \cdot 10^{(-3)} \cdot [5733 - 6.99 \cdot (M - W) - \\ & p_a] - 0.42 \cdot [(M - W) - 58.15] - 1.7 \cdot 10^{(-5)} \cdot \\ & M \cdot (5867 - p_a) - 0.0014 \cdot M \cdot (34 - t_a) - \\ & 3.96 \cdot f_{cl} \cdot [(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] - \\ & f_{cl} \cdot h_c \cdot (t_{cl} - t_a)\} \end{aligned} \tag{2}$$

where:
M – metabolic rate [W/m²];
W – effective mechanical power [W/m²];
I_{cl} – thermal insulation of clothing [m²K/W];
t_a – air temperature [°C];
$\bar{t}_r$ – average radiation temperature [°C];
p_a – partial pressure of water vapour [Pa];
t_{cl} – surface temperature of clothing [°C].
1 unit of metabolism = 1 met = 58.2 W/m²,

1 clothing thermal insulation unit = 1 clo = 0.155 m^2°C/W.

Referring to Figure 2, it can be seen that formula (2) based on the Fanger's model does not correctly reproduce real test results. It is necessary to modify formula (2). The new formula after modification is presented below:

$$\begin{aligned}PMV = {} & [0.303 \cdot exp \cdot (-0.036 \cdot M) + \\ & 0.028] \cdot \{(M - W) - 3.05 \cdot 10^{(-3)} \cdot \\ & [5733 - 6.99 \cdot (M - W) - p_a] - \\ & 0.42 \cdot [(M - W) - 58.15] - 1.7 \cdot 10^{(-5)} \cdot \\ & M \cdot (5867 - p_a) - 0.0014 \cdot M \cdot (34 - t_a) - \\ & 3.96 \cdot f_{cl} \cdot [(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] - \\ & f_{cl} \cdot h_c \cdot (t_{cl} - t_a)\} \cdot (-0.0098) \cdot BMI\end{aligned} \tag{3}$$

Equation (2) has been extended by the product (– 0.0098) · *BMI*, which influenced the approximation of test results to the trend line. Below is Figure 7, which shows the modification of the Fanger formula taking into account the *BMI*. The green points are the test results (from surveys and calculations according to the Fanger's formula), while the black points are the results after modification of the formula (3). The red trend line means 100% compliance with the model.

From the above chart, you can see a significant improvement in pattern modification. However, you should look for another parameter, e.g. CO_2, which will improve the model, or the addition of CO_2 + *BMI* together.

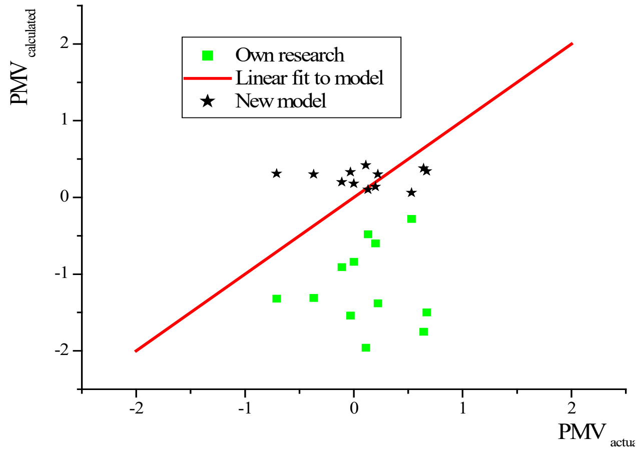

Fig. 7. Modification of the Fanger model

4. SUMMARY AND CONCLUSIONS

Based on the research, it can be concluded that the standard guidelines for the calculation of thermal comfort in terms of the predicted mean vote *PMV* and the predicted percentage of dissatisfied PPD are not reflected in the assessment of the respondents. There was also no clear correlation between the impact of *BMI* on *PMV*. The best solution is to modify the Fanger formula by finding another parameter, e.g. CO_2, or adding CO_2 + *BMI* together. It is important that in school buildings, the rooms have adequate thermal conditions, because failure to provide such conditions is tiring on the body, and thus on thought functions. Detailed analysis of thermal comfort including statistical analysis will be carried out in a separate article, after expanding the experimental base.

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ESTROGEN REMOVAL FROM WASTEWATER

USUWANIE ESTROGENU ZE ŚCIEKÓW

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Abstract

Currently, a significant problem of water and sewage management is the presence of human hormones, especially estrogens and progestagens, consumed by women in contraceptives and then excreted from the body. While other drugs are used by a small part of the population and rather sporadically, hormonal contraception is used by a large number of women, which contributes to their high concentration in sewage. Even relatively low estrogen concentrations (compared to other drugs) can have harmful effects on the body, disturbing the hormonal balance and leading to various endocrine disorders. In this paper the types of individual estrogen groups were characterized. Next, different methods of their removal from wastewater were presented. The parameters of estrogen removal efficiency depend on which parameters. Next, the effectiveness of each method was compared, also taking into account economic aspects. The work was summarized with appropriate conclusions.

Keywords: estrogens, hormones in sewage, methods of estrogen removal from sewage, sewage treatment

Streszczenie

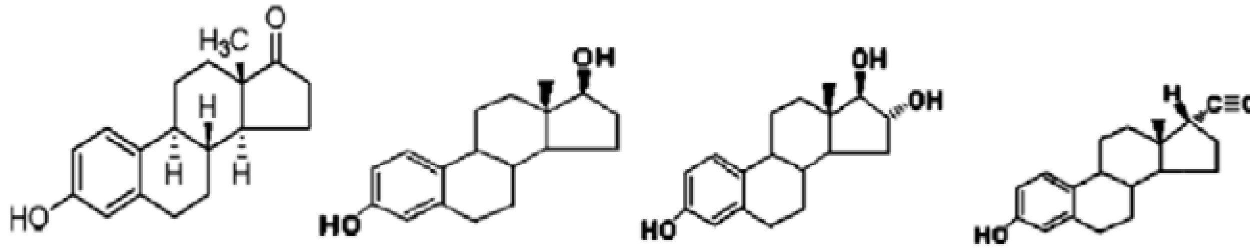
Obecnie istotnym problemem gospodarki wodno-ściekowej jest obecność w ściekach ludzkich hormonów, a zwłaszcza estrogenów i progestagenów, spożywanych przez kobiety w preparatach antykoncepcyjnych i wydalanych następnie z organizmu. O ile po inne leki sięga niewielka część populacji i to raczej sporadycznie, o tyle z antykoncepcji hormonalnej korzysta olbrzymia liczba kobiet, co przyczynia się do wysokiego ich stężenia w ściekach. Nawet stosunkowo małe stężenie estrogenów (w porównaniu z innymi lekami) może mieć szkodliwe skutki dla organizmu, zaburzając w nim równowagę hormonalną i prowadząc do różnych schorzeń endokrynologicznych. W pracy scharakteryzowano rodzaje poszczególnych grup estrogenów. Następnie przedstawiono różne metody ich usuwania ze ścieków. Przedstawiono, od jakich parametrów zależy efektywność usuwania estrogenów. Następnie porównano skuteczność każdej z metod, biorąc również pod uwagę aspekty ekonomiczne. Pracę podsumowano odpowiednimi wnioskami.

Słowa kluczowe: estrogeny, hormony w ściekach, metody usuwania estrogenów ze ścieków, oczyszczanie ścieków

1. INTRODUCTION

Natural and synthetic oestrogen groups E1 (ester), E2 (oestradiol), E3 (oestriol) and EE2 (oestradiol) have a very high impact on water and wastewater management, their chemical structure is shown in Figure 1. A large proportion of hormones pass through wastewater treatment systems and are discharged continuously to the environment, mainly to surface water. These compounds are subjected to biotransformation, bioconcrete and potentially bioaccumulate. As a consequence of this behaviour, problems arise for organisms living in water. Due to the fact that surface water is used for the production of drinking water, the problem of estrogen content seems to be important, especially in terms of possible endocrine disruption to humans and animals.

The article presents methods of estrogen removal from sewage. There are two ways to effectively remove estrogens from wastewater. The first is the optimization of existing treatment technology, while the second is the modernization of existing wastewater treatment plants using the new “end of pipe” technology.



Estrone (E_1) 17β-Estradiol (E_2) Estriol (E_3) Ethinyl Estradiol (EE_2)

Fig. 1. Molecular formula of estrogens: estrone (E1), 17β-estradiol (E2), estriol (E3) and ethinyl estradiol (EE2) [1]

2. CONVENTIONAL WASTEWATER TREATMENT

Conventional Wastewater Treatment (STW) is usually a three-stage process comprising an initial stage, i.e. treatment, primary sedimentation and secondary treatment. However, it has already been found that biodegradation and biotransformation of steroids took place in the sewage network, before the inflow to the treatment plant [2]. This is due to the presence of bacterial sludge, which accumulates on the pipe walls, often leading to anaerobic biodegradation. In large catchments, the retention time of the sewage system may be significant, allowing for a high degree of degradation and processing into other compounds [3]. Conventional sewage treatment is the best model to study the mechanisms thanks to which natural estrogens are suppressed in nature and technical systems. It is commonly believed that processing and biodegradation are the two main processes of estrogen removal from wastewater; however, some question that adsorption may play a significant role in estrogen removal. The content of individual estrogen groups in the wastewater flowing into wastewater treatment plants worldwide is shown in Figure 2.

The Figure 2 above shows that most countries are dominated by higher levels of E1 or E3, with the exception of Spain which showed the highest levels of synthetic EE2, which may be due to the high rate of contraceptive use by Spanish women. The high

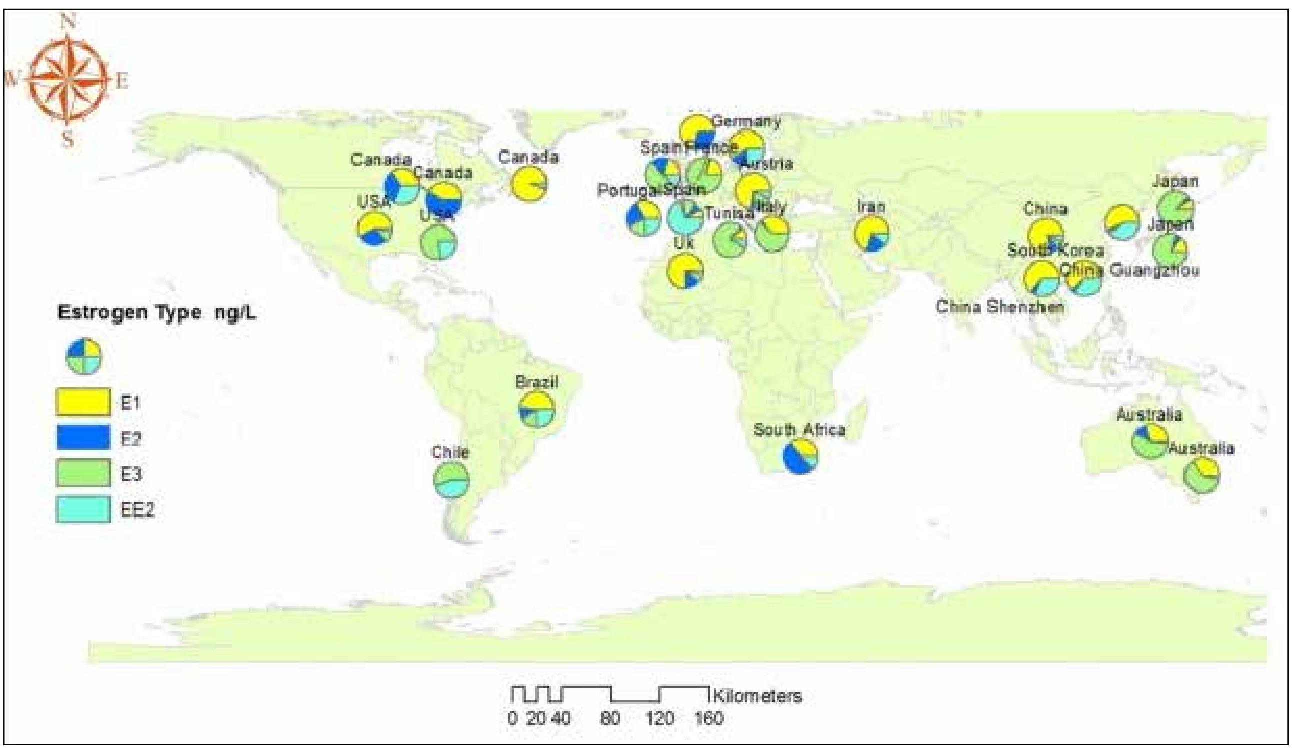


Fig. 2. Worldwide distribution of steroidal estrogens through WWTPs. Each pie chart comprises the natural estrogens: E1, E2, E3 and the synthetic EE2 as percentages [4]

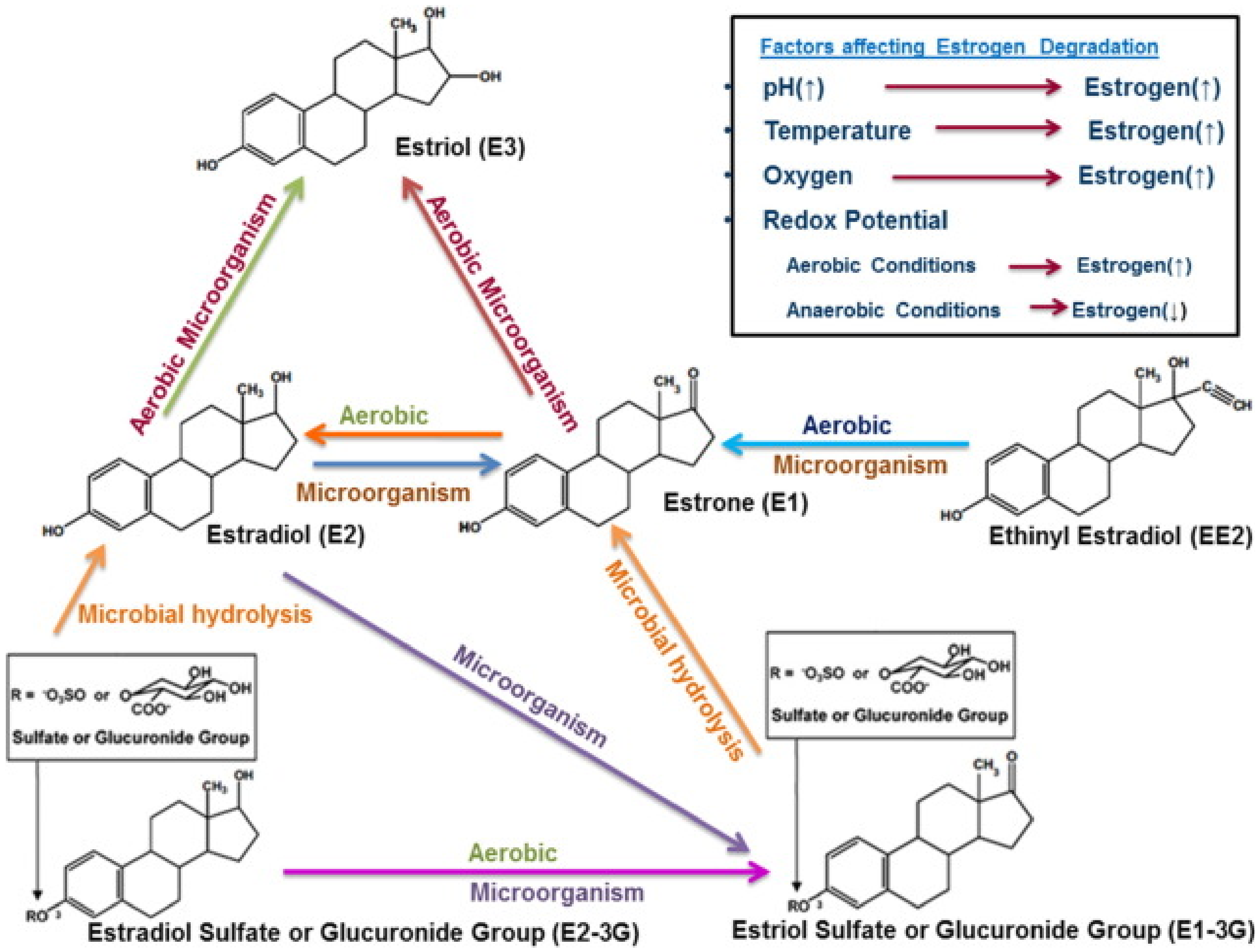


Fig. 3. Interconversion pathways of natural and synthetic estrogens [10]

content of E3 may correlate with high fertility, since it is the hormone mainly produced by pregnant women.

A pregnant woman's organism produces even 120 times more estriol (E3) hormone than a woman's organism during the menopause [5].

As mentioned earlier, estrone (E1), oestradiol (E2) and estriol (E3) lie on interrelated metabolic pathways [6]. Aerobic microorganisms can convert one estrogen into another as shown in Figure 3. For example, some microorganisms (e.g. nitrifying bacteria) can convert E1 to E3 and others decompose E1, E2 and EE2 (e.g. Novosphingobium sp. in the active sediment) [7]. Moreover, synthetic EE2 can be converted to E1 by Sphingobacterium sp. [8]. There is also a diverse range of anaerobic bacteria, which can convert one estrogen into another. For example, in lake water and sediments under anaerobic conditions, E2 was chemically converted to E1 under methanogenic, sulphate, iron and nitrate reducing conditions, but in contrast, no degradation of synthetic EE2 was observed [5, 9].

2.1. Pre-treatment

During mechanical cleaning, larger solids, easily dropping suspensions, oils and fats and granular particles from 0.1mm are removed. During mechanical wastewater treatment processes such as straining, flotation and sedimentation take place. A small amount of organic material is removed from the screens. At this stage the presence of micro pollutants and steroid hormones is observed [11].

2.2. Sedimentation

The sedimentation process consists in the free fall of particles to the bottom under the influence of gravity. The basic criterion required for this process is the difference in density between the fluid and the particles that are suspended in it. In the sedimentation tanks, the mechanism of estrogen removal takes place through adsorption. The degree of micro-pollution removal depends primarily on the hydrophobicity of hormones, content of suspended solids and their subsequent deposition, retention time and surface loads [12].

Lipophilic compounds, such as fats, oils and greases, may be adsorbed by a significant amount of hydrophobic compounds, including many endocrine disrupters, which are removed. Estrogens are hydrophilic, which is indicated by low adsorption [13].

2.3. Secondary treatment process

Secondary biological purification has been shown to be a key process behind the ability of some STWs to remove most or all estrogenic activities. Transformation and biodegradation play a significant role in the removal of hormones, as some microorganisms present in biological STWs have the potential to use steroid estrogen among other micro-pollutants as a source of carbon for metabolism [13]. The fastest and fullest degradation of contaminants present in STW occurs under aerobic conditions through catabolic routes [14].

3. REMOVAL OF STEROID HORMONES BY MEANS OF ACTIVATED SLUDGE

During biological treatment with activated sludge, the impurities in the wastewater are broken down by microorganisms. Due to the life processes of the microorganisms, the pollutants (mostly organic) are broken down. Biological processes are mostly aerobic processes and therefore require a constant supply of oxygen. Microorganisms consume oxygen during their life processes and therefore require a constant supply of oxygen during biological purification; unfortunately, this process is highly expensive. Wastewater from microbial processes is less susceptible to crumpling. In active sludge technology, suspended biocoenosis can be observed, slowly floating in the treated liquid [15].

In a study with active sludge carried out by Bernardelli et al., the concentration of E2 and E1 decreased by about 81.5 and 76.7%, respectively, over 24 h, as shown in Figure 4 [16]. In order to verify the share of adsorption in estrogen removal, the test with inactive sediment was carried out in Figure 4. The concentration of EE2 decreased with time more than the concentration of E1 and E2 (94% in 1 h). This fact resulted potentially from higher hydrophobicity of EE2 (LogKow = 4.1) compared to natural estrogens E1 and E2 (LogKow = 3.1 and 3.4 for E1 and E2 respectively) [17].

The high capacity to remove E2 of activated sludge potentially resulted from various factors, including mechanisms of biodegradation and/or sorption. Thus, Li et al. considered that this estrogen is strongly adsorbed on active sludge particles [16], while other authors indicated that E2 is rapidly oxidized to E1 [18].

4. REMOVAL OF STEROID HORMONES BY MEMBRANE BIOREACTORS

In municipal wastewater treatment, bioreactors with UF/MF membranes are used. Separation of particles from the solution is a sieve mechanism, which means that particles with a diameter smaller than the membrane pores pass through the microporous membrane: in microfiltration (MF) it is 0.1-10 μm in diameter, in ultrafiltration (UF) it is 0.001-0.1 μm in diameter. The most commonly used membranes have pore sizes in the 0.01-0.3 μm diameter range. Membranes in MBR reactors are made of special hollow-fiber hollow fibers with pore diameter of 0.03-0.04 μm [19]. The individual fibres are fixed in packs forming modules immersed in the activated sludge. Filtration takes place from the outside of the tube to the inside using a light vacuum

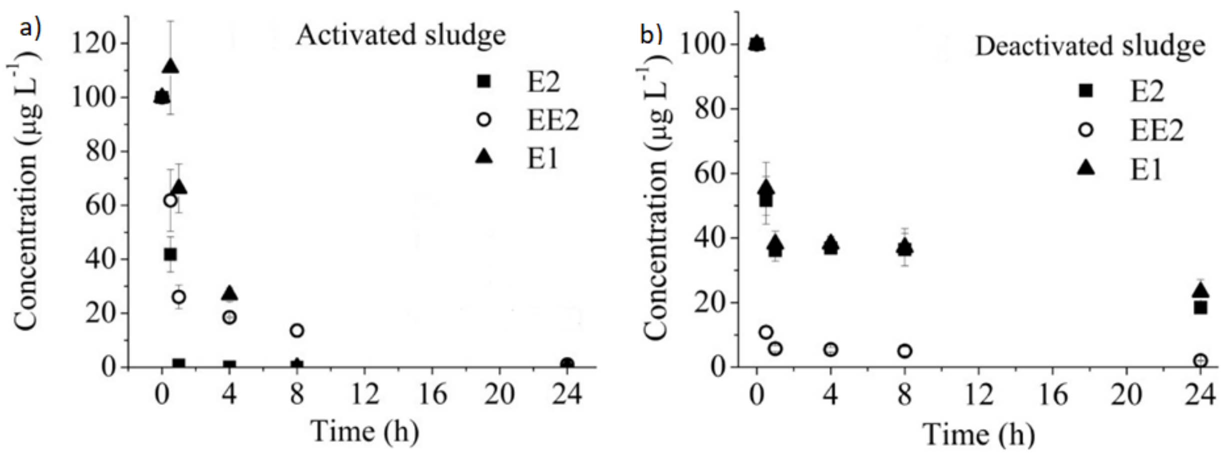


Fig. 4. The removal of estrogens with (a) activated sludge and (b) deactivated sludge (error bars give the standard deviation ± SD). Insert: estrogen concentrations over 24 h [16]

environment

produced by the filtrate pump. The membranes can be installed in the activated sludge chamber itself or in an additional reactor (cross-flow type). These systems effectively remove organic and inorganic compounds as well as biological contaminants from waste water. The efficiency of estrogen removal in membrane bioreactors with nitrification and denitrification is over 90% [20].

The authors did not find significant differences in the removal of EE2 between the two systems and concluded that estrogen removal was mainly caused by biodegradation; the removed estrogens were not absorbed into the sediment particles or retained in the membrane material or membrane biofilm. Weber et al. [21] found that the rotation coefficients E2 to E1 did not differ significantly between conventional and membrane activated sludge. Moreover, no degradation was observed for permanent EE2 in both sediments. While the microfiltration membranes themselves will not provide an increased degree of estrogen removal, it was suggested that the adsorption of estrogens to solid particles retained by the membrane would reduce the concentration of estrogens in sewage. Some researchers found that microfiltration membranes are able to demonstrate some retention of smaller solids or colloidal material on which estrogens can adsorb [22, 23]. Since the pore size of the membrane material is not uniform among manufacturers, it is possible that the difference in membrane material may explain some of the differences in colloidal retention. The differences in detection limits may also play a role.

5. REMOVAL OF STEROID HORMONES WITH BIOLOGICAL NUTRIENT REMOVAL (BNR)

In the biological treatment plants of the BNR, which use biological processes to remove nitrogen and phosphorus compounds, they exhibit significant values for the removal of estrogen. In BNR reactors, for biological removal of phosphorus, an anaerobic zone between the activated sludge and the sewage inflow is necessary, as shown in Figure 5 [24]. Biological removal of nitrogen includes nitrification and denitrification reactions. Nitrification causes the conversion of nitrogen from the reduced form (ammonia) to the oxidized form (nitrate). In BNR reactors the reduction of E1 to E2 takes place under anaerobic conditions, without nitrate. The removal of EE2 takes place largely only under aerobic conditions. According to the studies carried out on E2 and E1

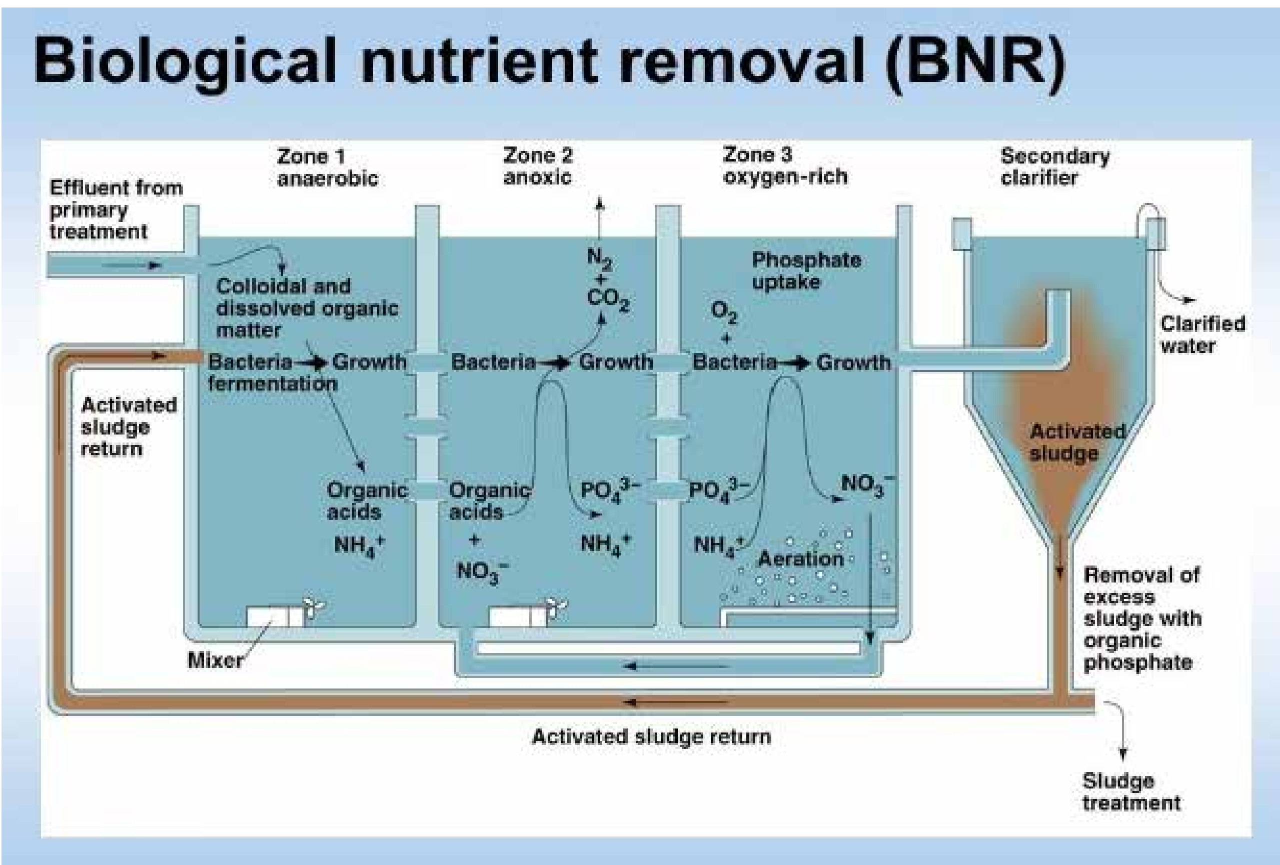


Fig. 5. Biological nutrient removal (BNR) process [24]

decomposition in 18 selected municipal wastewater treatment plants, no statistical correlation was found between HRT or SRT and estrogen removal. Moreover, Josse and others found that the nitrification process showed higher estrogen removal capacity from sewage [25]. Since autotrophic bacteria grow very slowly, a high sediment age is required to achieve nitrification.

The nature of adapted microbiological populations is an important variable in estrogen removal. Servos and others found that the efficiency of E2 removal in municipal wastewater was 80% higher than in industrial wastewater [6]. The system of periodic biotransformation tests using activated sludge showed slight or no transformation of EE2 within 20 hours. However, another laboratory test with nitrifying activated sludge, in which ammonium and hydrazine were the energy sources, showed good results of EE2 removal. Using nitrifying activated sludge (NAS) in the presence of nitrosomonas europaea bacteria oxidizing ammonia, it was observed that NAS degraded 98% of E2 at a concentration of 1 mg/m^3 within 2 hours. The study group also discovered the E1 content when NAS completely removed E2, whereas when Nitrosomonas europaea decomposed E2 compounds, no E1 content was detected either [5]. This suggests that the degradation of E2 by nitrifying activated sludge is caused by other heterotrophic bacteria that exist in NAS and not by nitrifying bacteria such as Nitrodomonas europaea. Heterotrophic bacteria that have been identified in the environment to degrade estrogen include Rhodococcus erythropolis and Mycobacterium fortuitum. Using Rhodococcus strains isolated in activated sludge from a sewage treatment plant, rapid decomposition of highly concentrated ions (100 mg/m^3) of natural and synthetic steroid estrogens (E1, E2, E3 and EE2) was found [26].

6. STEROIDAL ESTROGEN REMOVAL – END OF PIPE MODIFICATIONS

Many of the technologies associated with the water treatment process have been successfully transferred to use in the removal of steroid oestrogen in waste water treatment.

Chemical coagulants such as iron and aluminium salts can be used to remove estrogen from waste water. Schafer and White in their studies presented a comparison of adsorbents used in the water and wastewater industry and found that $FeCl_3$ and MIEX do not show the ability to remove estrogens from wastewater [27]. However, a high removal rate (>90%) can be achieved with powdered activated carbon when added in a sufficiently high dose. Estrogen removal is minimal during coagulation. The researchers found low removal rates (about 18%) for steroid hormones in the sewage treatment plant with chemical precipitation using iron or aluminium salts without biological treatment [27]. Laboratory tests of various doses of ferric chloride and pH conditions showed that coagulation was ineffective in removing E1 from sewage and only a combination of powdered activated carbon (PAC) and microfiltration can be effective in removing estrogens from water and sewage. Moreover, the use of coagulants, such as aluminium and iron salts, is often considered impractical due to high costs and is often environmentally and economically unsustainable [28].

Chlorination has been widely used in the United States as a disinfectant and oxidant for reduced inorganic compounds such as Fe(II), Mn(II) and S(II) in water and wastewater treatment processes. However, disinfection by-products show mutagenic and carcinogenic properties. Studies carried out by Itoh et al. have shown that the chlorination performed in many treatment plants increases the level of estrogen, but also reduces individual strongly estrogenic compounds [29]. Therefore, the authors stressed that the overall effect should be assessed as a sum of increased and decreased chlorination activity. Recent studies have shown that estrogenic activity is usually reduced due to chlorination. Due to EU and river wildlife protection regulations, chlorination is only used to supply drinking water as a disinfectant and not to discharge wastewater.

Membranes can remove most trace micro-pollutants depending on the size of the compound, the chemical conditions of the feed solution and the membrane material. Several studies on oestrogen removal with membranes have concluded that determining the mesh size is very important. Tight and small pore membranes (reverse osmosis (RO) and nanofiltration (NF)) can achieve up to 90% removal, while large pore membranes (microfiltration and ultrafiltration) show less removal [30]. The results of the study to investigate the removal of 52 steroidal estrogens with NF and ultrafiltration (UF) membranes showed that many steroidal estrogens are retained on NF membranes due to both hydrophobic adsorption and size exclusion, whereas the UF membrane usually retains only hydrophobic steroid hormones due to hydrophobic adsorption [30]. Several researchers have pointed out the important role of adsorption in the removal of estrogen by membranes. They found significant concentrations of accumulated estrogen on hydrophobic microfiltration membranes with empty fibers. A reduced retention was observed as the amount of ester accumulated on the membrane surface which leads to potential puncture. Since most organic micro-pollutants or steroidal estrogens have a small molecular size, usually in the range of 150 to 500 Daltons, only those compounds that bind to particles or colloidal organic matter will be physically removed during MF and UF. Although the use of membranes seems promising, several factors need to be considered. The RO and NF systems are very expensive and produce a concentrated discard stream that requires further treatment. Moreover, the membranes are susceptible to soiling, which makes the process less efficient and requires regular cleaning [30].

Granular Activated Carbon (GAC), widely used for water and wastewater treatment, has the ability to remove estrogen at different levels. Adsorption depends on the properties of both sorbent and impurity. The dominant mechanism of removing organic micro-pollutants by means of an adsorption system on active carbon is a hydrophobic effect. However, ion exchange interactions can also take place when removing polar dissolved substances. The researchers found that the amount of absorbed E2 was reduced to about one thousandth in river waters and municipal sewage [31].

Ozone (O_3) is effectively used as a disinfectant and oxidant. Ozone can lead to the transformation of steroid hormones through two strong oxidants: molecular O_3 and free hydroxyl radicals (HO^-) [32]. The hydroxyl radical reacts less selectively with organic micro pollutants whereas the more selective ozone reacts with amines, phenols and double bonds in aliphatic compounds. The removal of estrogens depends on their initial concentrations, the coexisting compounds and their reactivity to ozone and OH radicals. OH radicals are more susceptible to absorption by co-existing compounds, which are relatively high in environmental water. Ozone was not particularly effective in oxidation of iodine contrast agents, and combinations of AOP with ozone did not significantly increase the removal rate [32].

Using manganese oxide (MnO_2), 81.7% EE2 was removed. The initial concentration of 15 µg l-1 EE2 was introduced to tap water and filtered through bioreactors filled with MnO_2 granules [33]. The researchers concluded that large amounts of EE2 were removed due to the adsorption capacity of MnO_2 and its catalytic properties. As the MnO_2 reactor was not yet saturated after 40 days of treatment, they concluded that EE2 was also degraded to other compounds. This treatment gives promising results in the removal of similar estrogenic compounds thanks to the MnO_2 self-regeneration cycle [33].

Ironate (Fe (VI)) is often tested as an alternative oxidant in waste water treatment as it can be used as a dual oxidation and coagulation process. Under acidic conditions, the redox potential of ferrous (VI) ions is higher than that of ozone and is capable of oxidation of phenol, amines and alcohols [34]. The determination of a constant second order of oxidation of EE2 and E2 by Fe(VI) at pH close to neutral ranged from 400 to 900 M-1 s-1, which suggests that significant removal of EDC phenols can be achieved [34].

UV lamps are very often used for microbiological disinfection of water and sewage. It has been reported that several endocrine disrupters are susceptible to transformation during UV radiation as they have chromophores, which encourage the adsorption of UV wavelength light [35]. The direct photolysis of two estrogens E1 and E1 in aqueous solutions exposed to UV-disinfection lamp and high-pressure mercury lamp (UV-vis light) was studied. Photolysis of both estrogens causes cracking and oxidation (A) of the benzene ring with the formation of compounds containing carbonyl groups [35].

7. SUMMARY

Estrogens are excreted from the body in large quantities and can enter the aquatic environment in concentrations that are unacceptable and harmful to aquatic and human organisms, so great attention should be paid to their removal using appropriate processes. Biological processes in STW play a key role in the removal of most hormones, biotransformation, biodegradation and adsorption are used for this purpose. The efficiency of these processes depends to a large extent on such parameters as HRT, sediment age, organic charge and redox potential. Diaphragms are very effective in removing estrogen from wastewater, the efficiency is 90%, but it is quite expensive. It can also be seen that the biological methods of wastewater treatment, effectively dealing with estrogen, the activated sludge technology, as well as BNR reactors, have given very good results.

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VADYM ABYZOV

SOME METHODOLOGICAL PRINCIPLES OF THE ARCHITECTURAL ENVIRONMENT'S OBJECTS DESIGN

NIEKTÓRE ZASADY METODOLOGICZNE PROJEKTOWANIA OBIEKTÓW ŚRODOWISKA ARCHITEKTONICZNEGO

Structure and Environment vol. 12, No. 3/2020, p. 105 DOI: 10.30540/sae-2020-011

Abstract

The article discusses the methodological principles of typology and design of architectural environment's objects with the analysis of its system-structural foundations. According to them, hierarchical levels of formation and stages of environmental systems and objects' design are revealed with some examples of author's designs. The research is based on systemic and environmental approaches that make it possible to view the architectural environment's objects as hierarchically subordinate.

Streszczenie

W artykule omówiono metodyczne zasady typologii i projektowania obiektów środowiska architektonicznego z analizą jego systemowo-strukturalnych podstaw. Zgodnie z nimi hierarchiczne poziomy formowania i etapy projektowania systemów i obiektów środowiskowych ujawniają się z niektórymi przykładami projektów autora. Badania opierają się na podejściach systemowych i środowiskowych, które umożliwiają oglądanie obiektów środowiska architektonicznego jako hierarchicznie podporządkowanych.

BARTOSZ ŚWIERZEWSKI

RECONSTRUCTING AIRPORT PAVEMENTS USING THE TECHNOLOGY OF PREFABRICATED CONCRETE SLAB

NAPRAWA NAWIERZCHNI LOTNISKOWYCH Z WYKORZYSTANIEM TECHNOLOGII BETONOWEJ PŁYTY PREFABRYKOWANEJ

Structure and Environment vol. 12, No. 3/2020, p. 111 DOI: 10.30540/sae-2020-012

Abstract

This article presents the construction and technical concept for the use of an innovative repair of the airport pavement. It consists in embedding a prefabricated concrete slab in place of the excessively degraded surface of the existing slabs. In addition, the introduced technology of connecting adjacent panels together increases the spatial stiffness of the entire functional element and significantly increases the load-bearing capacity of the pavement. The results of laboratory and field tests presented in the article confirm the effectiveness of the technology used. As a result, the application of the reconstructing technology ensures the safety performance of aircraft operations at airports facilities.

Streszczenie

W niniejszym artykule przedstawiona została konstrukcyjno-techniczna koncepcja dotycząca zastosowania nowatorskiej naprawy nawierzchni lotniskowej. Polega ona na wbudowaniu prefabrykowanej płyty betonowej w miejscu nadmiernie zdegradowanej nawierzchni płyt istniejących. Ponadto wprowadzona technologia połączenia ze sobą płyt sąsiednich zwiększa przestrzenną sztywność całego elementu funkcjonalnego oraz znacząco wpływa na wzrost parametru nośności nawierzchni. Przedstawione w artykule wyniki przeprowadzonych badań laboratoryjnych i poligonowych potwierdzają skuteczność zastosowanej technologii. W rezultacie stosowanie przedmiotowej technologii napraw zapewnia bezpieczne wykonywanie operacji statków powietrznych na obiektach lotniskowych.

NATALIA KRAWCZYK
ANDREJ KAPJOR

A STUDY OF THERMAL COMFORT AT KIELCE UNIVERSITY OF TECHNOLOGY

BADANIE KOMFORTU CIEPLNEGO NA POLITECHNICE ŚWIĘTOKRZYSKIEJ

Structure and Environment vol. 12, No. 3/2020, p. 127 DOI: 10.30540/sae-2020-013

Abstract
The article presents the research of thermal comfort based on the Fanger model. The research was conducted in three educational rooms. The study involved 98 people whose age is between 19 and 23 years old. The study consisted in measuring the parameters of the thermal environment. During the research, students completed surveys regarding the thermal sensation. On the basis of the research, the predicted mean vote PMV score and the predicted percentage of dissatisfied PPDs were determined. This made it possible to compare the assessment of respondents with those indicated according to the standard, which showed that the Fanger model does not reflect the results of the respondents. The best solution will be to modify the Fanger model.

Streszczenie
W artykule przedstawiono badania komfortu cieplnego na podstawie modelu Fangera. Badania prowadzono w trzech pomieszczeniach edukacyjnych. W badaniu wzięło udział 98 osób, których wiek zawiera się w przedziale od 19 do 23 lat. Badanie polegało na zmierzeniu parametrów środowiska termicznego. Podczas wykonywanych badań, studenci wypełniali ankiety dotyczące odczucia cieplnego. Na podstawie przeprowadzonych badań określono przewidywaną średnią ocenę PMV oraz przewidywany odsetek osób niezadowolonych PPD. Pozwoliło to na porównanie oceny ankietowanych ze wskazanymi według normy, co pokazało, że model Fangera nie odzwierciedla wyników ankietowanych. Najlepszym rozwiązaniem będzie modyfikacja wzoru Fangera.

AGNIESZKA GRDULSKA
ROBERT KOWALIK

ESTROGEN REMOVAL FROM WASTEWATER

USUWANIE ESTROGENU ZE ŚCIEKÓW

Structure and Environment vol. 12, No. 3/2020, p. 133 DOI: 10.30540/sae-2020-014

Abstract

Currently, a significant problem of water and sewage management is the presence of human hormones, especially estrogens and progestagens, consumed by women in contraceptives and then excreted from the body. While other drugs are used by a small part of the population and rather sporadically, hormonal contraception is used by a large number of women, which contributes to their high concentration in sewage. Even relatively low estrogen concentrations (compared to other drugs) can have harmful effects on the body, disturbing the hormonal balance and leading to various endocrine disorders. In this paper the types of individual estrogen groups were characterized. Next, different methods of their removal from wastewater were presented. The parameters of estrogen removal efficiency depend on which parameters. Next, the effectiveness of each method was compared, also taking into account economic aspects. The work was summarized with appropriate conclusions.

Streszczenie

Obecnie istotnym problemem gospodarki wodno-ściekowej jest obecność w ściekach ludzkich hormonów, a zwłaszcza estrogenów i progestagenów, spożywanych przez kobiety w preparatach antykoncepcyjnych i wydalanych następnie z organizmu. O ile po inne leki sięga niewielka część populacji i to raczej sporadycznie, o tyle z antykoncepcji hormonalnej korzysta olbrzymia liczba kobiet, co przyczynia się do wysokiego ich stężenia w ściekach. Nawet stosunkowo małe stężenie estrogenów (w porównaniu z innymi lekami) może mieć szkodliwe skutki dla organizmu, zaburzając w nim równowagę hormonalną i prowadząc do różnych schorzeń endokrynologicznych. W pracy scharakteryzowano rodzaje poszczególnych grup estrogenów. Następnie przedstawiono różne metody ich usuwania, ze ścieków. Przedstawiono od jakich parametrów zależy efektywność usuwania estrogenów. Następnie porównano skuteczność każdej z metod, biorąc również pod uwagę aspekty ekonomiczne. Pracę podsumowano odpowiednimi wnioskami.

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