Technologies of environmental engineering protection in the context of sustainable architecture development: alternative approaches

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Abstract. The development of the concept of sustainable architecture requires in-depth research due to the exceptional complexity and relevance of this problem. In this regard, the purpose of this article is to consider the technologies of engineering environmental protection related to measures to preserve the environment, maintain ecological balance, and reduce the negative effects of human activity on the natural environment. A selection of project proposals of objects is given, where technological developments are presented, characterized by a new alternative approach to creating an eco-sustainable habitat by means of its engineering protection. The technologies that ensure sustainable waste disposal are revealed recycling of urban waste using a closed system for the production of energy and materials from garbage. A wide range of engineering proposals for seawater purification and processing of floating debris accumulation has identified: technologies for the disposal of such waste and their conversion into energy, the elimination of islands from oceanic debris from the water surface. Alternative technologies of engineering environmental protection and climate adjustment for managing its changes, as well as habitat restoration in the sinking coastal areas of the city are presented. Attention is drawn to the problem of eliminating the consequences of negative impacts on ecosystems and restoring the natural environment: the transformation and recreation of forests and areas with drained swamps, as well as the formation of agricultural biodiversity in the context of food security. The results of the study can be useful for the theory and practice of sustainable architecture formation, as they open up completely new opportunities for creative search.

1 Introduction

The sustainability of society’s development implies the possibility of solving environmental problems and simultaneously increasing the efficiency of natural resource consumption by improving technologies and engineering environmental protection. Rational use of space,
time and materials for the entire life of the facility in the conditions of changes occurring in society and the economy is the basic principle of sustainable development of architecture [1]. In order to maintain a balance between human needs and natural processes in nature, it is necessary to apply an approach to lean production in the environmentally oriented technological development of society. This opens up the prospect of researchers using tools not previously used in architectural theory [2].

This formulation of the problem attracts many specialists involved in the formation of habitat in the context of environmental engineering protection. These developments are of interest due to the fact that the social and cultural changes that have taken place in society have led to the need to rethink many familiar ideas. The development of the concept of sustainable architecture and urban planning requires in-depth research due to the exceptional complexity and relevance of this problem. In this regard, many technological developments have appeared in the world architectural theory and practice in recent years, which can be considered as the formation of a new approach to creating an eco-sustainable habitat by means of its engineering protection [3].

The purpose of this article is to consider the technologies of environmental engineering protection related to measures to preserve the environment, maintain ecological balance, and reduce the negative impacts of human activity on the natural environment. This concept determines the experience of considering new approaches to solving this important environmental problem in the following below considered directions in the study.

2 Materials and Methods

2.1 Technologies that ensure sustainable waste disposal

2.1.1 Recycling and recycling of urban garbage in a closed system

The process of urbanization and the increase in global population growth has had a great impact on the urban environment, the natural environment, technological development and industrial growth. As the city's population grows, there is a growing need for additional resources for the disposal of urban garbage, which is usually taken to the nearest landfill and buried there. At the same time, not only the earth, air and groundwater are polluted, but also a huge amount of useful substances is potentially lost. In addition to the recyclable material, methane gas, which can be collected during the decomposition of organic waste, can also be an extremely valuable product, since it can be converted into electrical energy [4].

In the expected context of overpopulation and mass urbanization, the new vertical urban infrastructure in Belgrade "Methanescraper" (author Marko Dragicevic) 2019 (Serbia), as a complex of waste disposal systems, serves as a response to the ever-growing shortage of natural resources and useful space for their processing. The towers are built on a modular principle, consisting of capsules with organic waste attached to the concrete core with cranes. Each capsule is equipped with an inhaler and a pipeline that connects to a reservoir for collecting methane formed during the reaction, which is later converted into energy. When the substance in the capsule is completely decomposed, the capsule can be removed, cleaned and refilled. This type of landfill not only significantly reduces the negative impact on air and land, but also significantly reduces the amount of space needed for waste storage [5].

The program, thanks to which methane collected from garbage is processed into electricity, not only contributes to the secondary production of garbage and provides a
source of inexpensive energy, but also collects a significant amount of methane, which otherwise would simply evaporate into the air. According to this concept, cities and regions will move from a linear to a circular or closed system that allows producing a significant amount of energy and materials from garbage.

2.1.2 Technologies for the disposal of hazardous waste by recycling them

The safe and proper use of waste containing hazardous components is a challenge for many industrialized countries that are producing more and more garbage. Instead of coping with the proper disposal of waste, they export it to third world countries, where the transfer of waste is prohibited by international law. As a result of improper disposal, toxic pollution and heavy metals enter the environment. Waste left in fields and near water tanks is eaten by terrestrial and aquatic animals, which affects environmental degradation[6].

In this regard, the project of the “Revival Tower” (authors Tomasz Wagner, Marta Yagoda, Agnieszka Dominik) 2018 is proposed. (Poland), the concept of which is the problem of storage and recycling of landfills is solved in such a way as to use waste for the construction of a building. After recycling and compaction of waste, compressed bricks are obtained from the main building material, which is garbage. The bricks used are introduced into the frame structure, which strengthens the entire building. The volume of the building includes constructions of cubes with a certain functional purpose[7].

The space of the facility is divided into seven levels, in which there are living and working areas, as well as areas for tourists. On the levels intended for employees, there are additionally small residential complexes for two, three and four people. On the levels intended for tourists, there are libraries of educational institutions, auditoriums and gastronomic points.

The purpose of the facility is to preserve species and landscapes. Toxic pollutants entering the environment increase the impact on the destruction of fauna and flora. In fact, this leads to the mass extinction of many endangered species of plants and animals. According to the authors, the proposed complex is a nature reserve with a scientific center and a place where nature will be born again, as it solves the important problem of stopping environmental degradation.

2.1.3 Closed system of energy and materials production from garbage

Eco-efficient cities will have less impact on the environment, as they can significantly reduce the deposits of garbage, as well as reduce the need for natural resources. The integration of water and energy in the city turn sites into a complex metabolic system. Just like in the human body, cycles and flows are observed in cities, which has always been viewed in a negative way (for example, solid and water waste), now acquires a productive orientation and meets the needs of the city, including energy[8].

An example is the skyscraper project "Skyscraper Uses Garbage as Building Material" (authors Carlos Morales Hendry, Julian Restrepo, Pablo Forero, Andrea Montes, Luis Hernan Saenz) 2010 (Colombia), which uses garbage and industrial waste as a building material in the context of the paradigm of combating irresponsible consumption. It is located near a large city park in a densely populated area with good transport services. Its space includes sports facilities, a hotel, offices, a museum and restaurants. The Urban Sustainability movement has long promoted such an approach to the city in order to get away from the city—a mechanism that destroys natural resources forever. The movement for urban Sustainability, according to the authors, has long been promoting such an approach in order to get away from the city-mechanism that destroys natural resources forever[9].
2.2 Engineering proposals for seawater purification and processing of floating debris accumulation

2.2.1 Technologies for recycling floating waste and its conversion into energy

The problem associated with the safe and proper use of waste containing hazardous components is a challenge for many industrialized countries. As a result of improper disposal, toxic pollution and heavy metals enter the environment. One of the most serious problems in the world is the purification of oceans from waste. The project proposal "Filtration Skyscraper" (author Honglin Li) 2019 (USA) is a high-modular collapsible mega structure of a power plant operating on waste collection and their processing into energy. The complex contains several facilities for the disposal of materials and water treatment plants for processing the accumulation of floating debris and seawater purification.

Unlike conventional equipment for the disposal of materials, gravity is mainly used, where several containers lift the main stream of garbage several times to sort it into various items. The facility uses seawater to pump garbage along with contaminated water to the highest point of the building, filter the water and recycle the material from top to bottom of the building, where the recycled material is then taken out.

The core of the main structure can provide a flexible and comprehensive set of objects and plants attached to it on four sides in the form of a vertical cluster of energy-efficient residential buildings at the base of the tower. Most of the facility consists of modular parts that can be replaced as needed. This proposal, according to the author of the project, not only gives a revival to floating waste, but also gives a second chance to restore relations between nature and people [10].

2.2.2 Cleaning and elimination of floating islands from ocean debris from the water surface

Humanity is facing the challenge of countering one of the most serious problems in the world - cleaning the oceans of waste. In the project of the skyscraper for cleaning oceans from waste "The Clean Up" (authors Karol Łącki, Dominik Pierzchlewicz, Szymon Ciupiński) 2019 (Poland) a model of a skyscraper is presented, which will be placed in the largest garbage spots in the oceans. Its main task will be to start the process of cleaning up the oceans and completely eliminate floating garbage islands. The shape of a skyscraper is determined by its main function - the pressing of oceanic debris.

The designer object is a huge floating piston that compact waste directly on site without the use of pumps. The only force that allows waste to penetrate into the pressing chamber is gravity. When the garbage is inside the piston, the press device grinds it into a horizontal disc, the height of which depends on the density and type of garbage. After this process, the waste is pushed beyond the length of the piston and passed into a specially designed reusable chamber so that the waste can no longer spread across the ocean. A network filled with disks is assembled by a specially designed vessel, and then disposed of or recycled. On the two lower floors there is a warehouse and two medical facilities that serve people working in the building, as well as veterinary support for animals that have suffered living in the polluted ocean. The last floor serves as a helipad on the roof and equipment for the lighthouse [11].


2.3 Alternative technologies for engineering environmental protection and climate correction

2.3.1 Technological advances for managing the planet's climate change

Using some of the latest innovative technological advances from around the world is not only to counter current environmental problems such as air and water pollution or rising temperatures, but also to provide a living environment for people affected by climate change. [12]. Global cooperation and unity of nations aimed at these global circumstances through the exchange of technologies and knowledge led to the creation of the project “Heal-Berg” (authors Luca Beltrame, Saba Nabavi Tafreshi) 2017 (Italy, Iran). The concept of the proposal consists in the formation of independent complexes (from the point of view of energy supply and mobility) designed for the process of restoring the climate and stopping the process of its impact on the environment.

The technologies used in the project function mainly according to four procedural purposes proven in practice: purification (conversion of carbon dioxide into oxygen by laser treatment and ocean water cooling); energy generation (disbandment of electricity from wind energy by two streams of water with a difference in salinity - a specific aerodynamic design is proposed to direct the wind route through turbines); quality of building material (three-dimensional formula of the strongest and lightest material - graphene); transportation (quick access and connection via drones, as well as mobility of residential units between different complexes). According to the authors, this confirms the fact that the complex is a source of clean energy, sustainability and completely frees the environment from pollution [13].

2.3.2 Habitat restoration in the sinking coastal areas of the city

In many parts of the world, the sinking of the earth has become inevitable, caused mainly by an increase in the sea water level, which is aggravated by the simultaneous decrease in the groundwater level. The sinking of the land causes a shortage of land, which causes residents of coastal areas around the world to lose their homes. The rapid rate of lowering of the earth below sea level is often associated with excessive intake of groundwater for drinking and everyday hygiene purposes by citizens. Thus, the main problem is to provide drinking water to the remaining residents on land.

The project "FUN(S)I: The Vanguard of Habitat Restoration" (authors Lesyuk A., Kogut M., Shkolyar S., Ivashchuk E., Duda N., Shkolnik M., Kitsyuk O., Goncharenko A.) 2022 (Indonesia) allows solving this problem using two approaches. Firstly, the flooded zone provides water supply to the residents of the city by filtering seawater through a system using coal, freeing it from almost all dissolved salts in the waste stream. Clean water is distributed to the residential buildings, and some is pumped back to the city to supply the remaining residents, so that there is no need to extract groundwater for everyday needs. Secondly, the floating zone provides housing for citizens who have lost their homes by creating a new habitable platform to support the population in a restored habitat in the future [14].

The flooded and floating zones connect to each other, creating a mushroom-like platform for the inhabitants. This project uses a modular configuration that allows you to build an object in any part of the world. It uses a construction that combines structural objects found in nature. This structure organically divides the space into smaller spaces and creates a natural pattern on the facade of the building. In addition, it saves more space in the
building itself, and also contributes to energy conservation, as it lets natural light into the building [15].

2.4 Elimination of the consequences of negative impacts on ecosystems and restoration of the natural environment

2.4.1 Conversion of a "lifeless" ecosystem and re-creation of forests

Due to the increasing intensity of fires caused by human activity (arson and climate change), a big environmental problem arises. In the case of large and severe forest fires, the complete destruction of the ecosystem and, in some cases, the impossibility of its restoration is characteristic. The project of the skyscraper "Regenera Skyscraper" (author Alberto Roncelli) 2020 (Italy) is designed to implement the process of restoring ecosystems and recreating forests. The complex is located in the center of the burned ecosystem and aims to distribute nutrients and seeds to the wind, and also accommodates a temporary shelter for birds and small animals. The skyscraper will accompany the surrounding ecosystem at all stages - from the burned forest to the complete restoration. It is through the destruction of its own structure and, consequently, due to its decay, the complex can transform and develop, spreading in the ecosystem.

At the initial stages, the skyscraper laboratory on the lower level is engaged in experimentation, monitoring and research of the current process and development of the ecosystem. At the next stages, scientists leave the skyscraper, which allows it to be repopulated with small and medium-sized animals and plants. In the process of regrowth of the forest, the skyscraper self-destructs.

The new concept proposed in this project makes it possible to carefully program and diversify each part of the structure, defining its life cycle in order to realize the needs of each "lifeless" ecosystem. In the end, according to the author, the constantly transforming complex is trying to become a manifesto for a new possible way to connect architecture and nature, structure and ecosystem, time and erosion, skyscrapers and forests [16].

2.4.2 Solving the problem of restoring the natural environment in areas with drained swamps

Swamps are the "lungs of the planet" - they absorb carbon dioxide and constantly release oxygen. The massive development of swamps, which began in the middle of the last century by draining them, led to irreversible consequences, such as fires, drought, soil degradation and the complete destruction of some species of animals and plants. In this regard, the purpose of the proposal "The Floating Tower" (authors Piotr Yurchanka, Alexey Kunko, Vladislav Sidorenko, Dmitry Tkachuk) 2019 (Belarus) is the restoration of drained swamps by abundant irrigation of these lands.

The resuscitation object in the form of a spherical structure floating in the air can develop and form depending on the specific task. The structure consists of two spheres connected by a system of cables. The upper sphere, which provides movement through the air of the entire structure, is a high-tech ball, covered from the outside with a membrane fabric in which condensate accumulates. This allows you to collect thousands of liters of water per day. The lower sphere is a reservoir for the accumulation of this water and irrigation of future swamps, which is moved from the upper sphere to the lower part using a special system of pumps and cables. In addition, inside in the upper and lower parts of the structure there are research center, laboratory rooms and wards for short-term stay of people [17].
2.4.3 Formation of agricultural biodiversity in the context of food security

The limited resources consumed forces the architect to change his view of traditional resources or use their new untapped potentials, as well as to look for promising forms of organization of habitable space in the context of energy conservation. All this suggests the need to revise the existing consumption paradigm and introduce a new methodology for the formation of the habitat as an integral ecological system. [18].

The world's food production is largely dependent on an extremely small number of types of crops and livestock. Along with changes in the use of land and water resources, population growth, urbanization and changing food culture, the lack of agricultural diversity poses a threat to global food security in the context of a new paradigm of nutrition. The proposed project of the agroecological skyscraper "New Spring: Agroecological Skyscraper" (authors Michał Spólnik, Marcin Kitala) 2022 (Austria, Poland) is a large-scale structure consisting of proto-garden modules. Each module belongs to a specific biome containing a special flora, soil, microorganisms, small animals and microclimate [19].

When forming a complex, modules can be freely added, removed or replaced. Behind the shell of the modules and their wooden supporting structure is hidden a core filled with hardware functions: seed and plant tissue banks, laboratories, lecture halls, data processing centers, warehouses and high-tech compost. Капсулы изготавливаются из поперечно-клееной древесины, что обеспечивает гибкость изготовления и относительно легкий повторяющийся процесс сборки и разборки. Capsules are made of cross-glued wood, which provides manufacturing flexibility and a relatively easy repetitive assembly and disassembly process. Following the principles of agroecology, each proto-garden is experimental from the very beginning, combining plants that do not occur in the natural environment. This is especially important in the fight against climate change, when some losses cannot be eliminated, and new solutions and adaptation techniques are needed. This project, according to the authors, will stimulate biodiversity through cross-pollination of ecosystems and agricultural crops [20].

3 Results and Discussion

As a result of the research, the presidents of the use of environmental engineering technologies in the context of sustainable architecture development that have appeared in scientific and design developments are considered. This made it possible to identify alternative approaches to its formation in the followings considered and the results obtained, discussed in this review:

1. The technologies providing sustainable waste disposal are revealed:
   • Recycling and recycling of urban garbage in a closed system is based on a program through which methane collected from garbage is processed into electricity.
   • Technologies for the disposal of hazardous waste by recycling them make it possible to solve the problem of storage and recycling of landfills in such a way as to use the waste for the construction of a building.
   • A closed system for the production of energy and materials from garbage uses hers and industrial waste as a building material in the context of the paradigm of combating irresponsible consumption.

2. A wide range of engineering proposals for seawater purification and processing of floating debris accumulation has been identified:
   • Technologies for the disposal of floating waste and its conversion into energy are associated with the safe and proper use of waste containing hazardous components by recycling the accumulation of floating debris and purification of seawater.
• Cloning and elimination of floating islands from ocean debris from the water surface, associated with one of the most serious problems in the world - cleaning the oceans from waste, is carried out through the use of innovative technologies.

3. Alternative technologies for engineering environmental protection and climate correction are presented:
• Technological advances for managing climate change on the planet are due to an engineering proposal consisting in the formation of independent complexes (from the point of view of energy supply and mobility) designed for the process of restoring the climate and stopping the process of its impact on the environment.
• Restoration of habitat in the sinking coastal areas of the city is associated with solving the problem of land shortage and the loss of housing in its flooded part. The proposed technologies provide water supply to city residents and housing for citizens who have lost their homes.

4. The problem of eliminating the consequences of negative impacts on ecosystems and restoring the natural environment are considered:
• Solving of a "lifeless" ecosystem and the recreation of forests are associated with a major environmental problem caused by the increasing intensity of fires caused by human activity. The proposed regenerating complex allows, through the programmed destruction of its own structure, to transform and develop, spreading in the ecosystem.
• Solution to the problem of restoring the natural environment in areas with drained swamps is carried out by abundant irrigation of these lands. A resuscitation facility is proposed in the form of a spherical structure floating in the air, which can be developed and formed depending on the specific task.
• The formation of crop biodiversity in the context of food security is associated with changes in the use of land and water resources, population growth, urbanization and changes in food culture. To solve the problem, proposed an agro-ecological structure consisting of proto-garden modules with a certain special flora, soil, microorganisms, small animals and microclimate.

4 Conclusions

The open key research questions and their corresponding solutions in this article are considered as future research directions when considering technologies of environmental engineering protection related to measures to preserve the environment, maintain ecological balance, and reduce the negative impacts of human activity on the natural environment. Design proposals of facilities equipped with special technological devices open up one of the possible promising directions in architecture for solving important tasks of sustainable development of the living environment.

In the future, it is possible to identify new trends in the development of a sustainable architecture strategy by in-depth evaluation of the latest innovative research developments and their comparative studies in the field under consideration. New ideas in the reviewed projects, where technological developments are presented, characterized by a new alternative approach to creating an eco-sustainable habitat by means of its engineering protection, reveal limitless spaces for creative search.

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References


