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Ontological information system for the selection of technologies for the treatment and disposal of organic waste: engineering and educational aspects

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ABSTRACT

The article proves a problem of information processing in the field of the structuring of information and decision-making in environmental engineering, including education in this field. This article presents the ontology-information model that was used to systematize waste treatment equipment. The article presents the use of an ontological algorithm "Polyhedron" for engineers and teachers. The algorithm consists of integrating ontological solutions from abstract to specific. The proposed model consists of a general ontology of "waste treatment technologies selection", "waste treatment equipment selection" and "Ontology for the analysis of scientific publications". Users of the system can input the wastewater parameters that need to be disposed of, and after processing they can get approaches to achieve maximum treatment efficiency. The model, also, can provide decision-making in the field of environmental engineering solutions. For this, ontologies for the selection of specific waste treatment equipment have been created that allow you to choose specific solutions for a particular problem. System for processing information on scientific results, to analyze innovative decisions was also created. The proposed solutions allow you to quickly and efficiently process large amounts of information. Also, was describes ways of using this system in educational and engineering purposes.

Keywords: Waste; Ontology; Ontology-based approach; Cognitive IT platform polyhedron; Waste treatment equipment; Environmental management; Systematization

1. Introduction

As the extension of using information technology in different fields of human activity operations has extended, the capability of software to classification and systematization of information has become increasingly important. That is why in recent years, much progress has been made in developing ideas and tools to provide knowledge systematization such as ontologies [1].

In this article, an "ontology" is a term that means some software or web system that consists of nodes with certain data to provide a decision-making system. All nodes are arranged in a certain hierarchical order, often referred to as an ontological tree or ontological graph. The node from which all branches go is called the parent. The other nodes are called subsidiaries. If there are no additional branches in the graph from the child nodes, then this ontology is called simple. An ontology necessarily entails or embodies some sort of worldview concerning some domain. The world view is often conceived as a set of concepts entities, attributes, or processes their definitions, and their interrelationships; this is referred to as conceptualization. Also,

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all ontologies consist of vocabulary with some specification of the meaning or semantics of the terminology within the vocabulary. The various ontologies are also distinguished by their degree of formality in the specification of meaning [1].

1.1. Systems of ontology generation

Previously, there has been a rich amount of approaches in ontology-making systems, but there are still gaps to be filled in the actual deployment of the technology/concept in a real-life commercial environment. Ontology is widely used to support various types of information management including information retrieval, storage, and sharing on the web. Ontologies aim to capture the domain knowledge in a general way and ensure a common understanding of the domain. They share common domain conceptualizations, and they may include representations of these conceptualizations. They were used to facilitate the effective exchange of information between people, but now they are used for communication between program agents. To simplify the construction of ontologies, special software is used, which allows users to build hierarchies and create semantic links. A range of open-source and commercial tools are available. They assist in the development of various ontologies called Ontology Editors. Today a variety of developing environments are used to create ontologies like Protégé 3.5, Apollo, SWOOP, OilEd, IsaViz, Polyhedron.

IsaViz [2] is a visual environment for viewing and creating RDF models as graphs. This tool is offered by the W3C consortium. IsaViz imports RDF/XML and N-Triples, and exports RDF/XML, N-Triples, Portable Network Graphics (PNG), and Scalable Vector Graphics (SVG). That's why, it is possible to import ontologies to other editors, such as Protégé or OilEd.

SWOOP [3] is based on the model-view-controller (MVC [4]) pattern. SWOOP contains OWL (web ontology language) validation and offers various OWL presentation syntax views. It provides an environment with multiple ontologies. Ontologies can be compared, edited, and combined. OWL has been built with an open, extensible architecture. The programming environment is based on the Lua programming language and uses the library jQuery for data model querying and transformation. Control is handled through a plug-in-based system, which loads new Renderers and Reasoners dynamically. SWOOP has been using his ontology construction methodology.

Protégé 3.5 [5] is a knowledge-based ontology editor providing a graphical user interface. It provides better flexibility for meta-modeling, enables the construction of domain ontologies; customizes data entry forms to enter data. Protégé's plug-in architecture can be adapted to build both simple and complex ontology-based applications. Developers can integrate the output of Protégé with rule systems or other problem solvers to construct a wide range of intelligent systems.

Apollo [6] is a convenient program for modeling knowledge systems. Apollo's knowledge system base consists of hierarchically organized ontologies, which can be inherited from other ontologies. The internal model is built as a frame system according to the internal model of the Open Knowledge Base Connectivity protocol. Apollo's class system is modeled according to The Open Knowledge Base Connectivity. Apollo's object model feature allows for robust typing, which enables a value check during editing. Apollo provides supporting metaclasses, multi-user, extensible plugins, ontology storage, and library.

1.2. Ontology-bases systems on environment management

The problems of waste management are very important and relevant nowadays. Nowadays, they're a lot of approaches related to solving problems in this field [7–10]. One of the methods that can be used to solve those problems is ontologies. For example, hierarchies with multi-criteria techniques can be used during the conceptual design of wastewater treatment plants to reduce the computational effort [11,12].

Ramasami et al. [13] had successfully solved various problems related to storage, retrieval, and visualization of waste management system data. The main purpose of the system is the classification of waste recycling methods. The classes and corresponding hierarchy were presented as a type of waste and recycling methods. Also, in their next version of the ontology, they will provide integration with GIS. The ontology was created by the Protégé tool + OWL.

Sinha and Couderc [14] had proposed a model waste classification based on the recyclable materials they are made up of. Their model utilizes the concept of N-ary relations with some modifications. The ontology-based model can be used to sort items in waste processing plants. The proposed system has to perform selective recycling and has sufficient knowledge for making decisions to accept or reject a waste item. To provide this, an RFID-based (Radio-frequency identification) intelligent bin was used. RFID uses electromagnetic fields to automatically identify and track tags attached to objects to detect the type of waste items. The application running on the bin uses ontology-based knowledge to infer the item's category. If it was suitable, the bin would accept the item. The ontology system was created by OWL and Protégé tools.

van Ittersum et al. [15] presented the ontology-based SEAMLESS (System for Environmental and Agricultural Modelling) and SEAMLESS-IF (non-ontology-based). The main component in the SEAMLESS software infrastructure is SeamFrame. It is used for predicting information at the SEAMLESS-IF system. SEAMLESS contains information about the land-bound agricultural activities (arable cropping, grasslands, livestock, perennials, including orchards, agroforestry, and vineyards) and their interactions with the environment, economy, and rural development. The results of the comparison of these works are also shown in Table 1.

Thus, previously, ontologies were applied in various fields of human activity. In environmental management, this usual approach has been used for specific industries and urban ecology [16,17]. None of the ontological systems previously proposed could offer a universal solution in the field of environmental protection [13,18]. This paper aims to propose a system that systematized the technologies for utilizing and recycling organic waste using the cognitive IT-platform Polyhedron to the implementation of the ontological system in environmental management. The core of the Polyhedron system contains advanced and improved functions of TODOS IT-platform which were previously used to provide semantic web, systematization, transdisciplinary support, GIS connectivity, and ecological management.

Cognitive IT-platform polyhedron can use the feature of ontological interface tools [19]. They have online information resources and interactive knowledge systems, which provide adaptability to the thematic profile of each user subject in the cognitive IT-platform polyhedron environment. The ontological interface is implemented by the procedure of activation of multiple binary taxonomy relationships. It is an intelligent means of user interaction with an ontology-based information system, which allows visualizing the results of integration and aggregation of distributed information resources in the process of organizing user communication in an easily accessible visual form [20].

This system is multi-agent. Usually, the resources on which the information is located are narrowly targeted. Combining such resources as multi-agents in the cognitive IT-platform polyhedron ontology-oriented system allows for transdisciplinary and interactive components in any educational and scientific research [21]. In the environment of the Polyhedron system, the construction of all chains of the process of transdisciplinary integrated interaction is ensured: a semantic content analysis of text documents; taxonomy; highlighting the properties of taxonomy concepts; formation of the ontology of the choice problem; transdisciplinary integration of contexts, based on properties-criteria concepts that determine the ontology of choice; the inclusion of documents found in the global environment through the recursive procedures of the system and the linguistic corpus [20].

Due to active states are hyper-ratio plural partial ordering [22,23], cognitive IT-platform polyhedron is an innovative IT technology of ontological management of knowledge and information resources, regardless of the standards of their creation. The proposed ontology system functionality is based on information processing methods – Big Data, Data Mining, Semantic Web [24]. We propose to use this system for quick and accurate environmental management decisions such as the selection of waste treatment equipment.

Cognitive IT-platform polyhedron previously was used and integrated with GIS. The potential and example of such applications were also demonstrated [25]. The practical implementation of the proposed theoretical approach is a model of ontological GIS-application that is an interactive document. Such a document is characterized by a natural system of coordinates defined over affine space and due to this, the geospatial information is most suitable for displaying naturally. The models of the interactive document and ontological GIS-application provide a high level of representativeness of information available in text documents (in particular, geospatial) for using structured text representation. Realization of the model of transdisciplinary representation of information as an interactive feature of the document provides the possibility of obtaining operative access to large arrays of thematic information, and in combination with the capabilities of ontological GIS-applications – solves the problem of transdisciplinary representation of geospatial information [19,26].

The innovative component of IT-platform Polyhedron is the availability of special features. For example, there is a function comparison with some standards called auditing. One of the applications in the field of ecology is the use of environmental standards to compare and determine the status of specific objects. For example, previously it has been scientifically justified to apply this methodology use of this method to estimate water quality in reservoirs [27].

2. Materials and methods

Ontologies were created using tools of IT-platform polyhedron using ontology editor. Two types of sheets, xls to create structure (hierarchy of nodes; in further – structure file) and csv to add internal information for both, numeric and semantic data (in further – data file) was uploaded to ontology editor to generate hierarchy. After generation, ontologies were uploaded to the store (if it was necessary to use ranging, it was chosen). To store information and provide its sharing, google sheets were used, with their further conversion into the.xls and.csv Excel sheets.

Semantic characteristics for the ontology of the selection of wastewater treatment technologies were taken from the educational manuals and books on environmental engineering. For the ontology for the selection of anaerobic digesters, information has been taken review paper on anaerobic digestion [28] that contains data in scientific studies on anaerobic digestion [29–37]. For creating ranking ontologies were used module “Alternative”.

2.1. Creation ontologies with choosing using module ″Alternative″

Module Alternative can be used to provide filtering of information [38]. To achieve this, it was necessary to create nodes of graphs filled with semantic data grouped in semantic classes. This function was used to create a general ontology of the wastewater treatment system and specific ontologies of technologies devoted to finding specific parameters of technologies.

To create both ontologies were created 3 sheets. As was noted before, they were the structure in datasheets and they were provided an additional sheet with pictures links

Table 1
Comparison of existing ontologies for environment management

Propose	Ontology dots	Software	GIS connectivity	Author
Waste Management System	Waste	Protégé + OWL	no	Van Ittersum et al. [15]
Waste Sorting System	Technology	Protégé + OWL	no	Sinha and Couderc [14]
Environmental Management System	Technology	SeamFrame	yes	Van Ittersum et al. [15]

for each node. Inputted information in the node was structured by semantic classes which were located in table rows. Describing node of ontology was determinate by cells located in a column. At their intersection was located semantic data related to specific semantic classes and specific nodes of the ontology. One node can contain one or more pictures, for example, real-life installation, principles of working, and technological scheme. For building ranking systems were used only numerical values and ranking were selected during saving graphs in the database.

3. Results

3.1. General concept of ontological-based model based on Polyhedron

The proposed ontological-based model consists of "waste treatment technologies selection", "waste treatment equipment selection" for each technology, "ontology for the analysis of scientific publications" and general ontology-classification which contains nodes with links on them (Fig. 1). The ontology-classification consists of a simple ontology without branching.

The ontology of "waste treatment technologies selection" proposes an approach when the user can firstly choose a general type of technology. Then after the user-chosen specific parameters of this technology by using an ontology of "waste treatment equipment selection" he chose equipment that he needs and it gives the possibility to implement innovations by using "ontology for the analysis of scientific publications" on specific technology.

3.2. Systematization of waste treatment equipment in the form of an ontology

All existing wastewater treatment methods consist of six major groups: mechanical, physical, physico-mechanical, chemical, physico-chemical, biological. These groups were used as parent nodes of ontology. Using the features and tools of the "Polyhedron IT-platform", the system of waste treatment equipment selection was developed. Each child node of ontology presents one technology for purification and recycling of organic waste. The ontology provides a possibility for the user to provide a selection of wastewater treatment technology they need. The proposed ontology may be used in the form of taxonomy, objective ontology, and table. The function of selection is allowed during using the ontology in a table view (Fig. 2).

In the table view, all technologies are presented as a list of their characteristics. Users can provide filtering using nodes characteristics such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH values of the suspended particles including colloid coarse dispersed and emulsified wastewater, they could choose equipment that is needed. For example, if wastewater is characterized by BOD/COD ≥ 0.75, COD more 2,000 g O_2/L, the system will propose anaerobic/aerobic digestion. The list of some examples of cases filtering usage as shown in Table 2.

For each technology, it is proposed to create its ontology for "waste treatment equipment selection" which will be able for both, filtering and ranking. Both of them are a simple ontology without branching. For example, let's describe the ontology "waste treatment equipment selection" for anaerobic digestion. The child node in the ontology will represent the most common anaerobic digesters. Nodes will include data specific for each technological equipment, for example, in this case, it will be: minimum and maximum operating temperature (°C), minimum and maximum possible COD (g O_2/L) of the loaded substrate, values of COD (g O_2/L) after treatment, minimum and maximum possible loading (kg VS/L) on the reactor, maximum and minimum humidity of the loaded substrate (%). The general view of this input system in ranking ontology is shown in Fig. 3.

This system allows users to choose the priorities in their selections. Users can choose the importance of the parameters (from 1 to 10 or chose don't use this parameter) and input

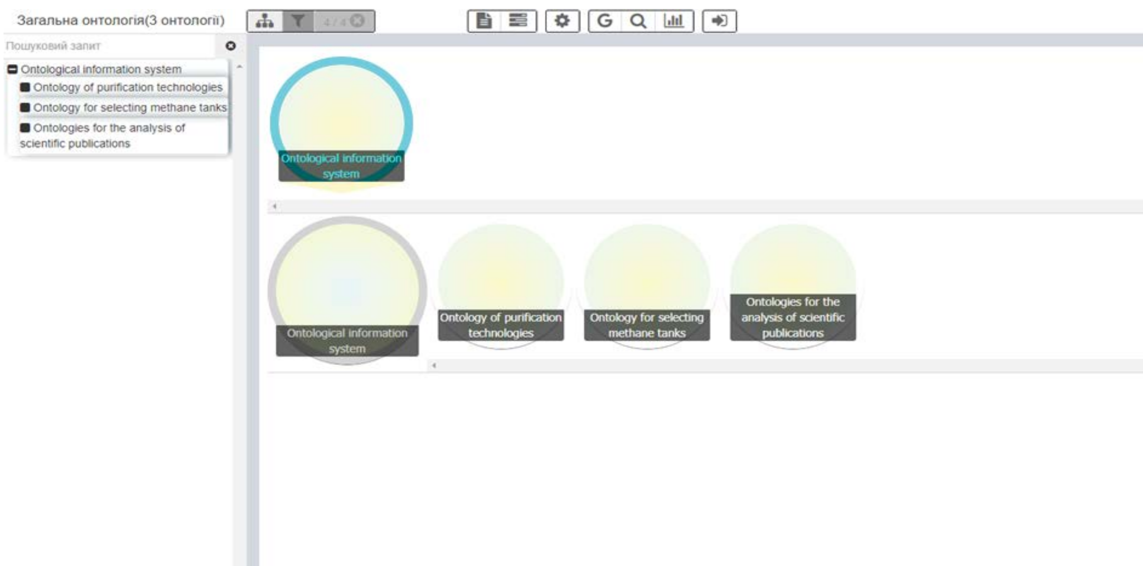


Fig. 1. The general view of the ontology-based model.

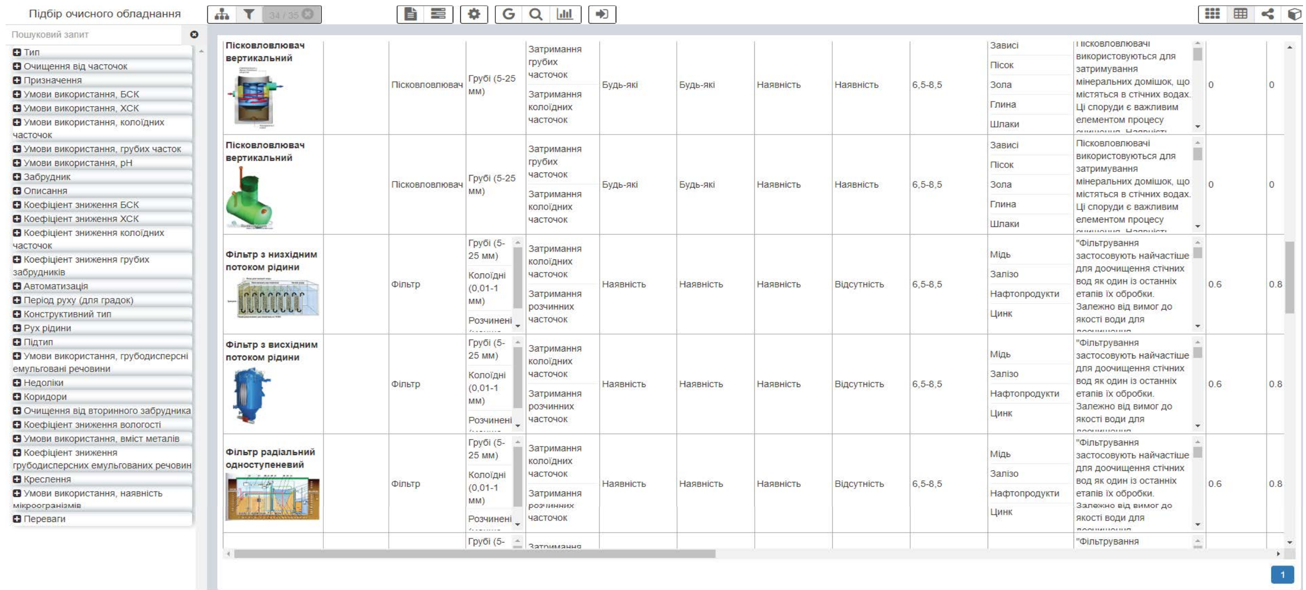


Fig. 2. Ontology of "waste treatment technology selection" in table view

Table 2
Examples of cases filtering usage

	Filters	Results
Case 1	COD = 2 g O_2/L, COD/BOD = 2	Anaerobic/aerobic digestion
Case 2	Pollutant = fats	Floatation, mechanical trapping, coagulation, flocculation, flotation under pressure, sorption, ozonation, electric, and membrane filtering methods.
Case 3	Maximum possible value of COD g O_2/L of the loaded substrate	Circulation reactor (IC), anaerobic baffled reactor (ABR), up-flow anaerobic sludge bed reactor (UASB), expanded granular sludge blanket (EGSB), anaerobic contact reactor (ACR), anaerobic fluidized bed reactor (AFBR), anaerobic filter reactor (AF)

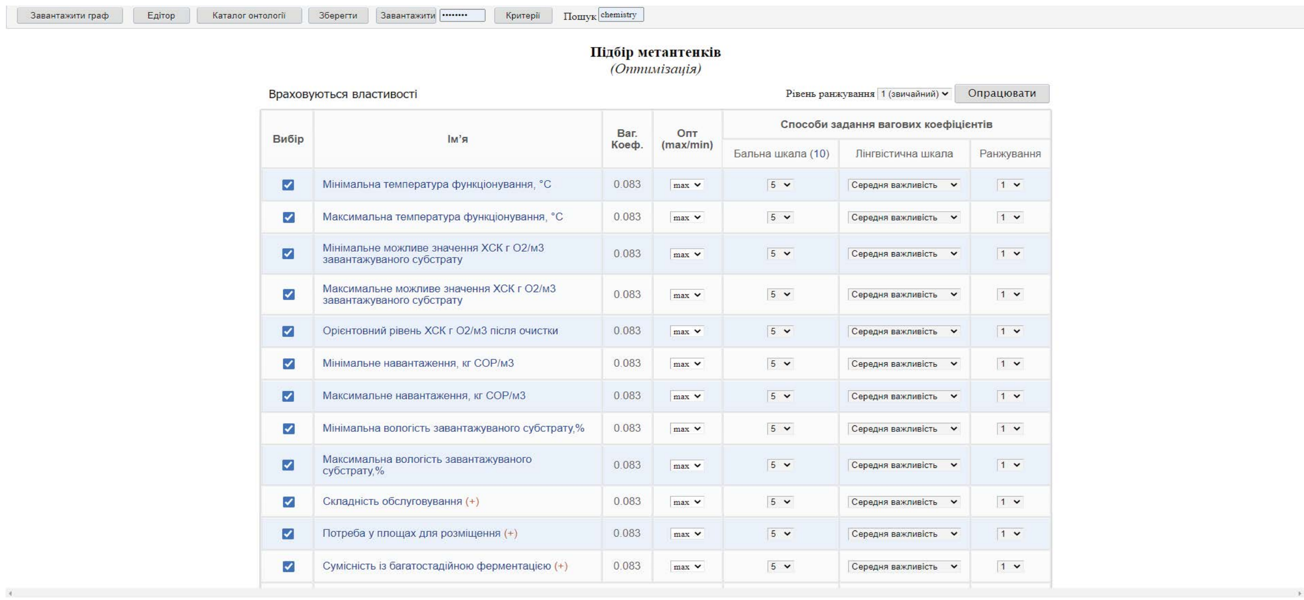


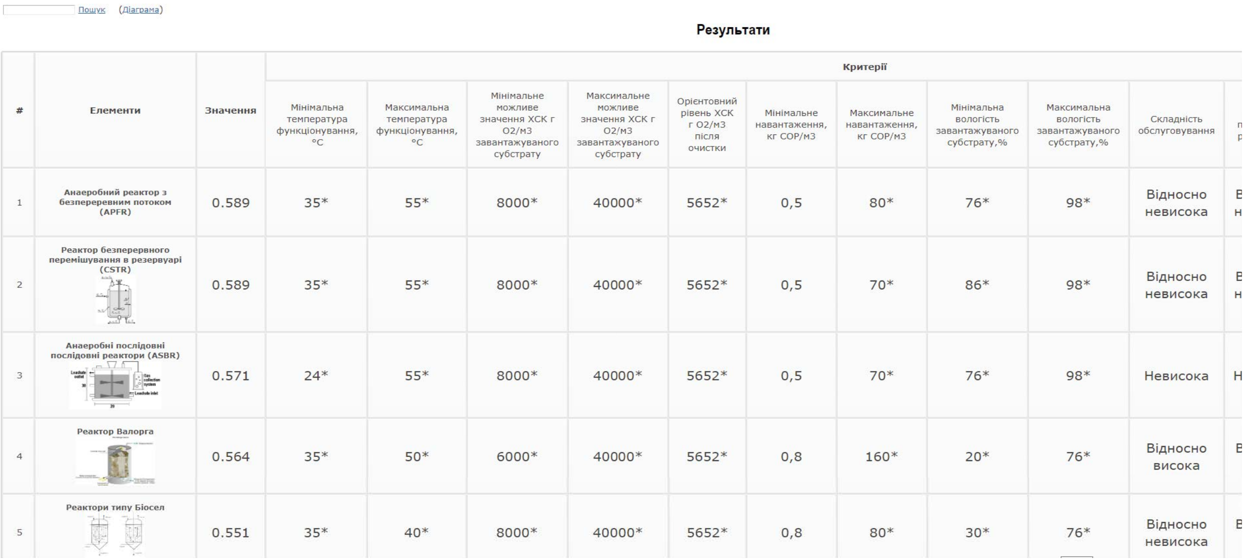
Fig. 3. General view of the input parameters priorities for "waste treatment equipment selection" on anaerobic digesters.

direction (to maximum or to a minimum for each parameter) For example, users can choose importance 8 and direction to maximum on COD g O_2/L of the loaded substrate. Users can choose multiple priorities for different parameters of anaerobic digesters. The ranking list based on his request will be shown after processing. An example of the ranking result of the processing is shown in Fig. 4.

As it is shown in Fig. 4, the anaerobic digestors which provide for the maximum possible value of COD g O_2/L of the loaded substrate are internal circulation reactors (IC), anaerobic baffled reactors (ABR), up-flow anaerobic sludge bed reactors (UASB), expanded granular sludge blanket (EGSB) reactors, anaerobic contact reactor (ACR), anaerobic fluidized bed reactor (AFBR), anaerobic filter reactor (AF). A list of examples of several queries is given in Table 2. The user can also use the filtering mechanism directly as was used for the "system of selection of anaerobic digestors". The general view of the filter system in the table form is shown in Fig. 5.

3.3. Use of ontologies for the analysis of scientific publications on the example of solid-phase anerobic digestion

All the works were divided according to certain key criteria which became the parent nodes of the ontology. Such criteria were: process temperature, (t°, °C) working volume (L), type of co-substrate content of chicken manure (%), humidity (%), the content of activated sludge relative to the substrate (%), final total solids content (TS, %) of methane output (CH_4^+, mL/mL substrate), biogas output (mL/mL

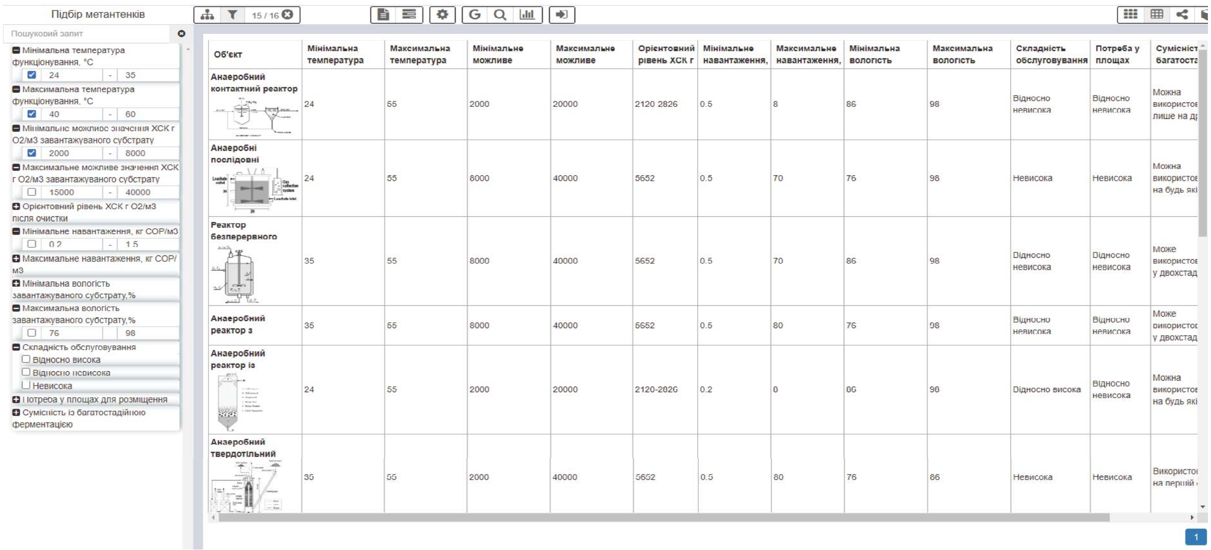


Пошук (Діаграма)

Результати

#	Елементи	Значення	Критерії									
			Мінімальна температура функціонування, °C	Максимальна температура функціонування, °C	Мінімальне можливе значення ХСК г О2/м3 завантажуваного субстрату	Максимальне можливе значення ХСК г О2/м3 завантажуваного субстрату	Орієнтовний рівень ХСК г О2/м3 після очистки	Мінімальне навантаження, кг СОР/м3	Максимальне навантаження, кг СОР/м3	Мінімальна вологість завантажуваного субстрату,%	Максимальна вологість завантажуваного субстрату,%	Складність обслуговування
1	Анаеробний реактор з безперервним потоком (APFR)	0.589	35*	55*	8000*	40000*	5652*	0,5	80*	76*	98*	Відносно невисока
2	Реактор безперервного перемішування в резервуарі (CSTR)	0.589	35*	55*	8000*	40000*	5652*	0,5	70*	86*	98*	Відносно невисока
3	Анаеробні послідовні послідовні реактори (ASBR)	0.571	24*	55*	8000*	40000*	5652*	0,5	70*	76*	98*	Невисока
4	Реактор Валорга	0.564	35*	50*	6000*	40000*	5652*	0,8	160*	20*	76*	Відносно висока
5	Реактори типу Біосел	0.551	35*	40*	8000*	40000*	5652*	0,8	80*	30*	76*	Відносно невисока

Fig. 4. Ranking results in "waste treatment equipment selection" on anaerobic digesters ontology.



Об'єкт	Мінімальна температура	Максимальна температура	Мінімальне можливе	Максимальне можливе	Орієнтовний рівень ХСК г	Мінімальне навантаження,	Максимальне навантаження,	Мінімальна вологість	Максимальна вологість	Складність обслуговування	Потреба у площах	Сумісніст багатоста
Анаеробний контактний реактор	24	55	2000	20000	2120 2826	0.5	8	86	98	Відносно невисока	Відносно невисока	Можна використов лише на д
Анаеробні послідовні	24	55	8000	40000	5652	0.5	70	76	98	Невисока	Невисока	Можна використов на будь які
Реактор безперервного	35	55	8000	40000	5652	0.5	70	86	98	Відносно невисока	Відносно невисока	Може використов у двохстад
Анаеробний реактор з	35	55	8000	40000	5652	0.5	80	76	98	Відносно невисока	Відносно невисока	Може використов у двохстад
Анаеробний реактор із	24	55	2000	20000	2120-2826	0.2	8	86	98	Відносно висока	Відносно невисока	Можна використов на будь які
Анаеробний твердотільний	35	55	2000	40000	5652	0.5	80	76	86	Невисока	Невисока	Використо на перший

Fig. 5. The general view of filtering input system of selection of anaerobic digestors on the table form.

substrate), methane content in biogas (%), year of publication, the result obtained, authors, content ammonium (NH_4^+, mg/L) content of volatile fatty acids (VFA, mg/L) and other.

The system incorporates an algorithm for the summation of factors and after processing a final coefficient is obtained, according to which the units are ranked. Accordingly, the numerical values of each bioreactor will participate in the formation of the final coefficient. The user of this ranking ontology can filter these works according to the priority of the indicators he presets. For example, the user needs the technology with the highest methane and biogas yield (mg/mg of the substrate) and ontology can provide ranking using the user request (Fig. 6). In the result of information processing, you will see ranking as shown in Fig. 7. Some cases of choosing parameters and the ranking results are presented in Table 3.

3.4. Using the internal search function in providing of technological approach

To solve the problem of searching for certain information, the user can use the mechanism which calls internal search. For example, of a request, he needed the value of the COD of wastewater. The user of the polyhedron IT system has an opportunity to use an internal search function that has more perspective compared to the external because

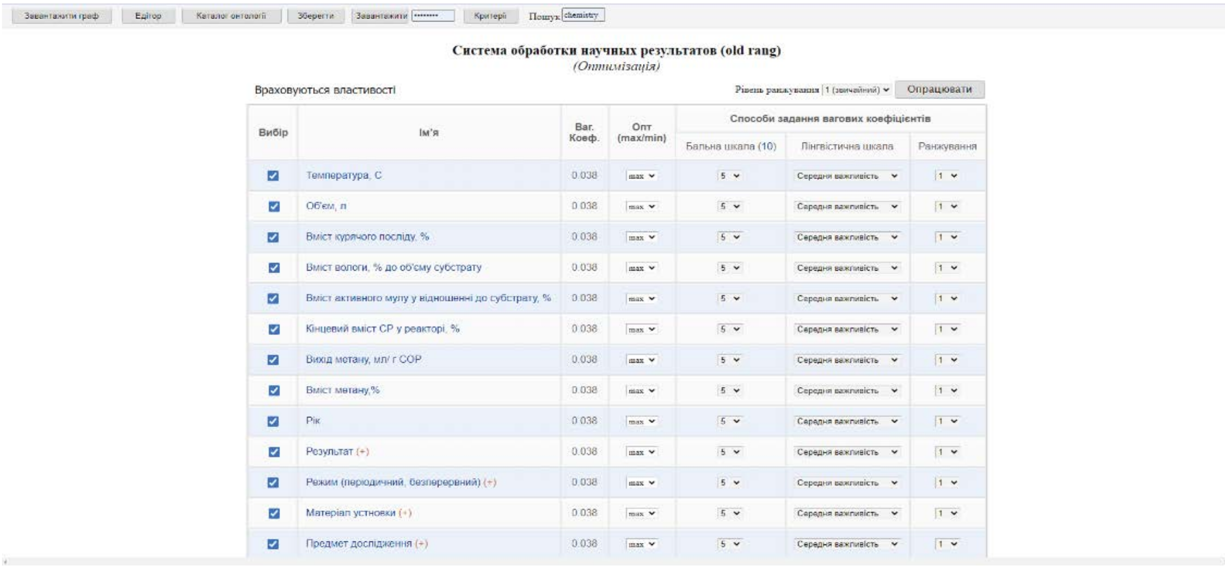


Fig. 6. General view of the input system interfaces.

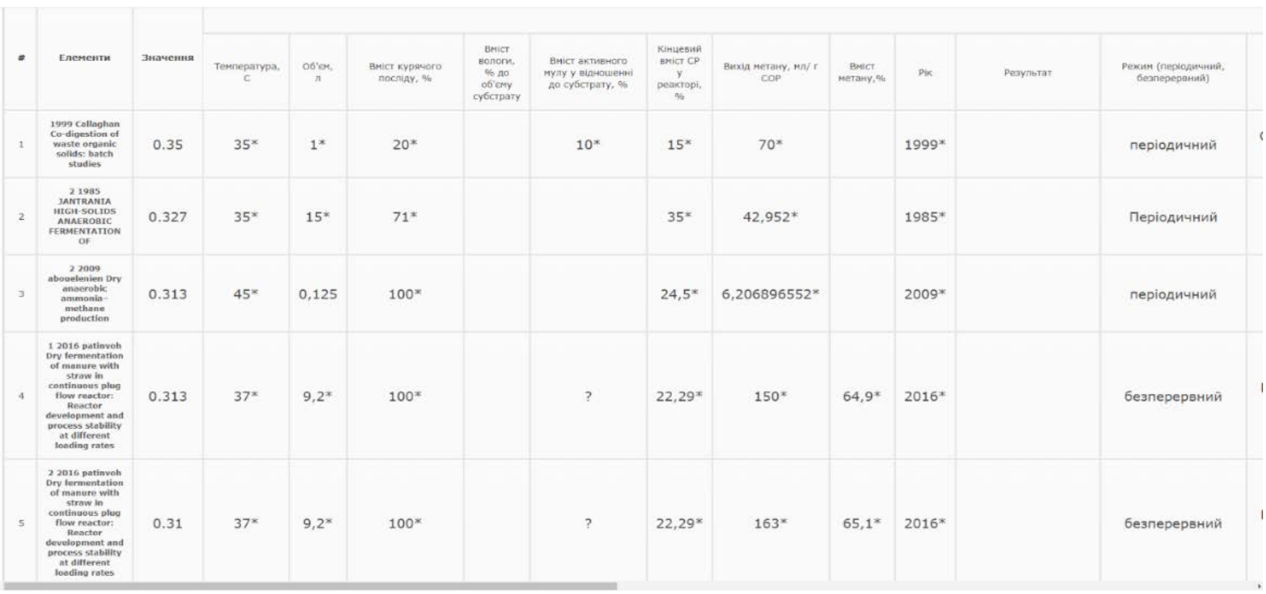


Fig. 7. Ranking results in ontology for the analysis of scientific publications.

it provides information created by experts. To provide a search, it is necessary to select word users looking for and use the internal search button (Fig. 8) or copy the word into the search bar of the polyhedron. The mechanism of the internal search for semantic characteristics is illustrated in Fig. 8 and the results of it in Fig. 9.

Results are displayed on all ontologies which contain inputted keywords (Fig. 9). Thus, the use of this mechanism allowed the user to navigate quickly throughout the system. Therefore, the cognitive IT Polyhedron information system allows an obtaining system of decision-making for specific technological processes.

Table 3
Examples list of the system of decision-making using an ontology-based approach

	Requested value by user				
	TS	to	CH_4	NH_4^+	Top results
Case 1	Low	Low	Abs.	Low	Callaghan et al. [30]: Co-digestion of waste organic solids: batch studies; Jantrania [37]: High-solids anaerobic fermentation of poultry manure; Patinvoh et al. [29]: Dry fermentation of manure with straw in continuous plug flow reactor: reactor development and process stability at different loading rates.
Case 2	Abs.	Low	Low	Low	Callaghan et al. [30]: Dry anaerobic ammonia–methane production from chicken manure; Markou [32]: Improved anaerobic digestion performance and biogas production from poultry litter after lowering its nitrogen content
Case 3	Low	Abs.	Low	Low	Abouelenien et al. [33]: Dry Co-digestion of poultry manure with agriculture wastes; Abouelenien et al. [34]: Simultaneous ammonia removal and methane production from chicken manure under dry thermophilic condition.
Case 4	Low	Low	Abs.	Low	Patinvoh et al. [29]: Dry fermentation of manure with straw in continuous plug flow reactor: reactor development and process stability at different loading rates; Abouelenien et al.: Simultaneous ammonia removal and methane production from chicken manure under dry thermophilic condition; Abouelenien et al. [33]: Dry co-digestion of poultry manure with agriculture wastes.
Case 5	Low	Low	Low	Abs.	Rajagopal and Massé [35]: Start-up of dry anaerobic digestion system for processing solid poultry litter using adapted liquid inoculum; Böjti et al. [36]: Pretreatment of poultry manure for efficient biogas production as monosubstrate or co-fermentation with maize silage and corn stover; Abouelenien et al. [33]: Dry co-digestion of poultry manure with agriculture wastes

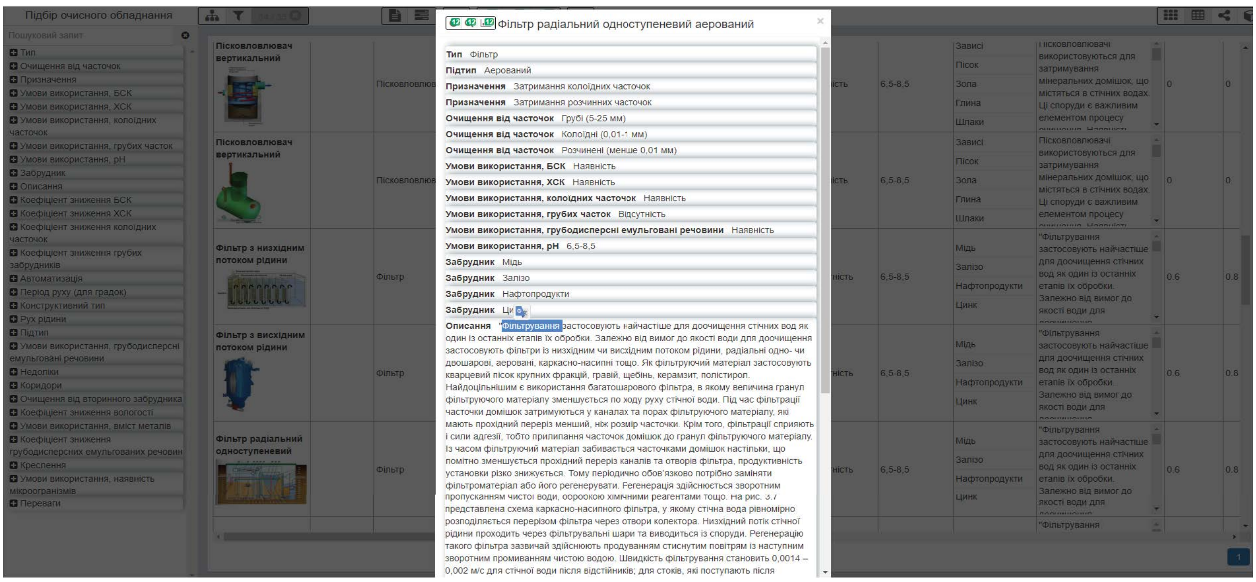


Fig. 8. The general overview of semantic characteristics in the selected node.

4. Discussion

4.1. Transdisciplinary using of scientific results in ecobiotechological education.

Nowadays web-based learning used both as a tool to support formal education programs and for distance education. Web-based programs may, for example, encourage more independent and active learning and are often an efficient means of delivering course materials [39–42]. Online learning has always been concerned with the provision of access to an educational experience that is, at the least, more flexible in time and space than campus-based education. Online learning can be more effective if we use it in pair with ontology-based systems. For example, students can interact with material directly, they investigate it necessary by themselves. The learner could target the information needed and only review that exact particle of knowledge necessary for the skill building at hand. A common core of standards-based ontology can aid with the design of online tutoring systems and can reduce the ambiguity of terminology by encoding explicit computer and human-understandable definitions [39,43]. The ontology-based system can be used to provide integration and transdisciplinary using internal sources. Current day access to learning resources, including teaching materials, literature, and lesson plans, are often limited to students who are part of an academic institution. Other authors predicted the expansion and improvement of remote access to learning resources [44]. That knowledge can be used by a huge amount of people.

The proposed system will be very useful for students and young scientists who just start their research work. For instance, students in the ordinary learning process using methodical books that providing necessary and unnecessary information, and, also, students study only one topic, looking at only one technology, which may be not effective. The significantly higher effect may be archived by using the proposed model, where students can "research" the material. Moreover, learning with ontology systems involves, on a level with other modern approaches, such as augmented reality.

For example, students during learning of "Environmental engineering" will study specific technology aspects and will understand waste which can be utilized using this method. But, if the teacher will integrate his classes with ontology, students will provide informational "research" based on the type of waste or waste characteristics. Students will propose their hypothesis and after will input characteristics of waste into ontologies to test their hypothesis. It's worth note, that the highest effect will be achieved in case of using together with the classification of microorganisms [45]. Below we will present a list of proposed ontology tools that can be used during educational process, for example, at the University of the Food Technologies of Ukraine (Table 4).

Taking to account the information in Table 4, the usage of proposed ontology-based tools is relevant for a wide range of disciplines. And the methodology will be different for each case of usage. However, it is possible to provide an example. All proposed ontology tools can be used on "Biological processes of environmental technologies" course and it may be used both, to provide introduction classes and to systemize studied material at one of the final classes. For example, a general mechanism of providing classes for systemizing the obtained knowledge by students will be next:

- Teacher gives the real-life tasks to students to solve and ask them to choose the technology (or complex of the technologies) which fits the best to solve it;

Fig. 9. Internal search mechanism.

Table 4
Potential usage of an ontologies system in education

Ontology tool name	List of courses
"Waste treatment technologies selection"	"Environmental chemistry", "Ecology and environmental protection", "Ecological safety", "Landscape ecology", "Theoretical foundations of biotechnology", "Biological processes of environmental technologies"
"Waste treatment equipment selection"	"Ecology and environmental protection", "Ecological safety", "Landscape ecology", "Theoretical foundations of biotechnology", "Biological processes of environmental technologies"
"Ontology for the analysis of scientific publications"	"Methods for measuring environmental parameters", "Rationing and standardization in nature conservation activities", "Theoretical foundations of biotechnology", "Biological processes of environmental technologies"

- Teacher uses the "Waste treatment technologies selection" ontology tool and input task's input data (that was given to students before). The tool shows the technology that is proposed to use. The teacher discusses both, the versions of the students given previously and versions suggested by the ontology tool;
- Teacher gives the task to students to propose the construction for the equipment for chosen technology/technologies;
- Teacher uses the "Waste treatment equipment selection" tool and inputs required parameters. Teacher and group discuss both, equipment proposed by group and suggestions of the ontology tool;
- Teacher asks in student's group if someone knows innovations related to chosen technology. If yes, he discusses with a group such innovation; if not, he uses "Ontology for the analysis of scientific publications" tool to and inputs the lowest importance for conditions that decreases economical attractiveness (low temperature, lesser additives) and the highest importance for parameters that enhance the efficiency (the highest biogas yield and methane content; the highest energy production);
- Based on the found publications, the teacher gives homework to get acquainted with such innovation (studies) and propose the construction and the condition of such innovative technology;

The technology card of such a lesson is presented in Table 5.

4.2. Using of the proposed approach in engineering

Choosing technologies is a hard and very specific process. Especially due to it is multi-competency process [46]

Table 5
Technology card of proposed systemizing-knowledge lesson at "Biological processes of environmental technologies" course

Topic	Systemizing-knowledge lesson at "Biological processes of environmental technologies course"	
Aims	To systemize obtained knowledge on the "Biological processes of environmental technologies course" and to learn how to use automatized decision-making tools at biological processes of environmental technologies.	
Content	Providing the own expertise on the proposition of environmental technologies; Providing the own expertise on the proposition of environmental equipment; Providing the own expertise on the proposition of innovative approaches into industrial implementation; Using ontology-based decision-making tools to simplify all these steps.	
Equipment	PC, projector, Student's personal notebooks.	
Plan and scenario		Duration
Introduction	Welcome speech of the teacher and announcing of lesson.	2–3 min
Theory questionnaire	Teacher asks of the theoretical aspects of the taught material.	10 min
Practical tasks to select the technology to solve environmental tasks (including ontology tool)	Teacher gives the real-life tasks to students to solve and ask them to choose the technology (or complex of the technologies) which fits the best to solve it; Teacher uses the "Waste treatment technologies selection" ontology tool and input task's input data (that was given to students before). The tool shows the technology that is proposed to use. The teacher discusses both, the versions of the students given previously and versions suggested by the ontology tool.	20–30 min
Practical task to choose the equipment for suggested technology	Teacher gives the task to students to propose the construction for the equipment for chosen technology/technologies; Teacher uses the "Waste treatment equipment selection" tool and inputs required parameters. Teacher and group discuss both, equipment proposed by group and suggestions of the ontology tool.	20–30 min
Practical task to implement innovative environment biotechnology on the practice	Teacher asks in student's group if someone knows innovations related to chosen technology. If yes, he discusses with a group such innovation; if not, he uses "Ontology for the analysis of scientific publications" tool to and inputs the lowest importance for conditions that decreases economical attractiveness (low temperature, lesser additives) and the highest importance for parameters that enhance the efficiency (the highest biogas yield and methane content; the highest energy production); Based on the found publications, the teacher gives homework to get acquainted with such innovation (studies) and propose the construction and the condition of such innovative technology.	15–20 min
Summarizing and finishing	Teacher describes the best ideas proposed by students, the proposition how to enhance the student's competencies on the choice of technology and equipment, and summarizes the aspects of working with decision making ontology tools.	

and it is need to take into account factors of sustainable development, including economics, ecology, and social factors [47]. Common algorithm of technology choosing consists from stages of general technology selection taking to the account general waste parameters (the most general, for example, presence of large particles, COD and BOD), then engineer trying to find a solution in more specific dimension, in the technologies what he was chosen, and the final step is choosing of the apparatus type. A similar process is proposed with the usage of the ontology model. However, an engineer needs a huge amount of time to provide decision making. Besides, an engineer can forget some information and which is even more important is can do not know all modern approaches to provide an informed decision. This may be fixed by using the proposed method especially in case of constant information updates.

Traditionally accepted Engineering Design Process [48] that used to provide manual engineering decision making will be modified in case of usage developed ontology tools. It will consist of further traditional steps: "Define the problem", "Do background research", "Specify requirements", "Brainstorm, Evaluate, and Choose Solution", "Develop Prototype and Solution", "Test Solution", "Determining if the solution meets the requirement" (if no then back to "Specify requirements", "Brainstorm, Evaluate, and Choose Solution") and "Communicate Results". However, stage "Brainstorm, Evaluate, and Choose Solution" will be significantly simplified and automatized by using "Waste treatment technologies selection", "Waste treatment equipment selection", "Ontology for the analysis of scientific publications" ontology tools. The engineer will input the requirements (parameters of wastewater) into the ontology tool "Waste treatment technologies selection". At the current state, it is still necessary to provide manual decision-making, but the system will propose a systematic list of acceptable technologies. In further, with system development, it will be possible to provide automatic decision-making with only verification by engineers (this is relevant for all proposed tools). Then engineer uses a more specified ontology "Waste treatment equipment selection" to define the possible construction of reactors by more detailed request. Also, engineers manually calculate the parameters of the reactor but using of proposed tools significantly simplify the steps before. If there is a request to get the most optimized and novel process the engineer uses "Ontology for the analysis of scientific publications". Using of developed ontology tools under the traditionally accepted Engineering Design Process is shown in Fig. 10.

Below we will compare the classical approach an ontology-based approach for engineers (Table 6). The analysis was performed by the following criteria: qualification of personal, required time, amount of analyzed approaches, and integration of data from smart devices and the possibility to accommodate different software tools inside simultaneously.

As shown Table 6 classical approach of information processing and the decision making (the hereafter classic one) can be provided only by highly qualification users (only a specialist), while the use of an ontology-based approach for information processing and the decision (hereafter ontology-based approach) can be providing any person. Also required time is more in the classical one (up 100 man-h) approach in comparison with the ontology-based approach (up to 1 man-h). Therefore, the ontological-based approach is more effective than the classic one. Comparison parameters of usage of classical and ontological approach information processing during the engineering process is shown in Fig. 11.

5. Conclusions

- There're no ontologies which determine to waste treatment technologies
- We have created the ontology of "Waste treatment technologies selection", "Waste treatment equipment

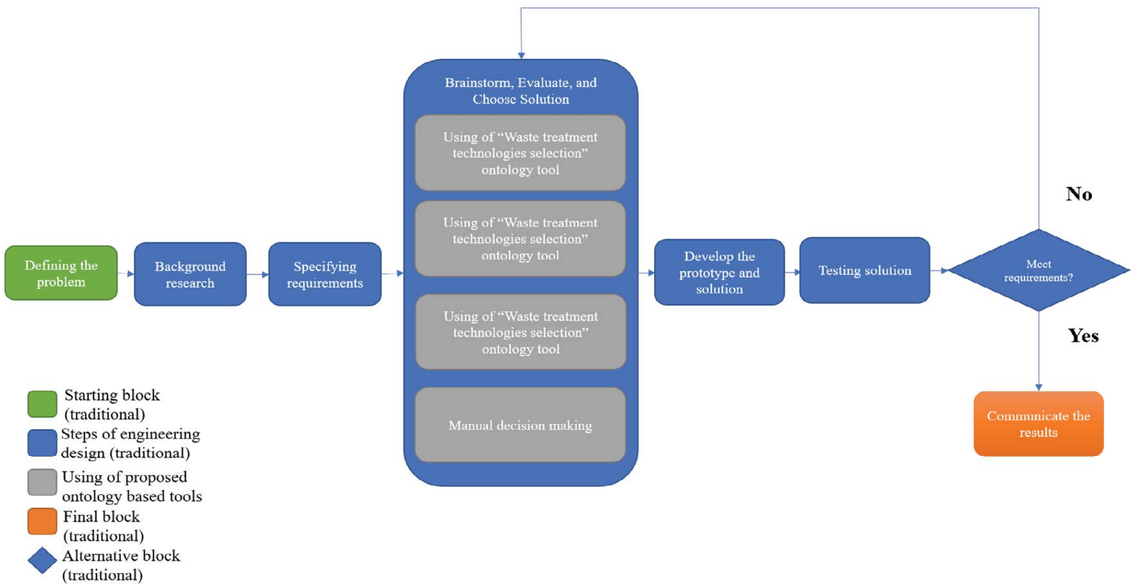


Fig. 10. Using of developed ontology tools under traditionally accepted Engineering Design Process.

Table 6
Comparison of classical and ontological approach information processing during the engineering process

	Classical approach of information processing and the decision making	An ontology-based approach for information processing and the decision making
Qualification of user	Only a specialist	Any person
Required time	Up 100 man-h	Up to 1 man-h
Amount of analyzed approaches	Depended on time use to the research; in general, up to 100 sources	Depended on the fullness of ontology; more than 400 sources
Integration of data from the PC, smart-phone, and other smart devices	Difficult for full integration	Can be easily fully integrated
The possibility to accommodate different software tools inside simultaneously	Only one software is selected and used at a time for solving certain tasks	It can contain many software tools at the same time in the links form

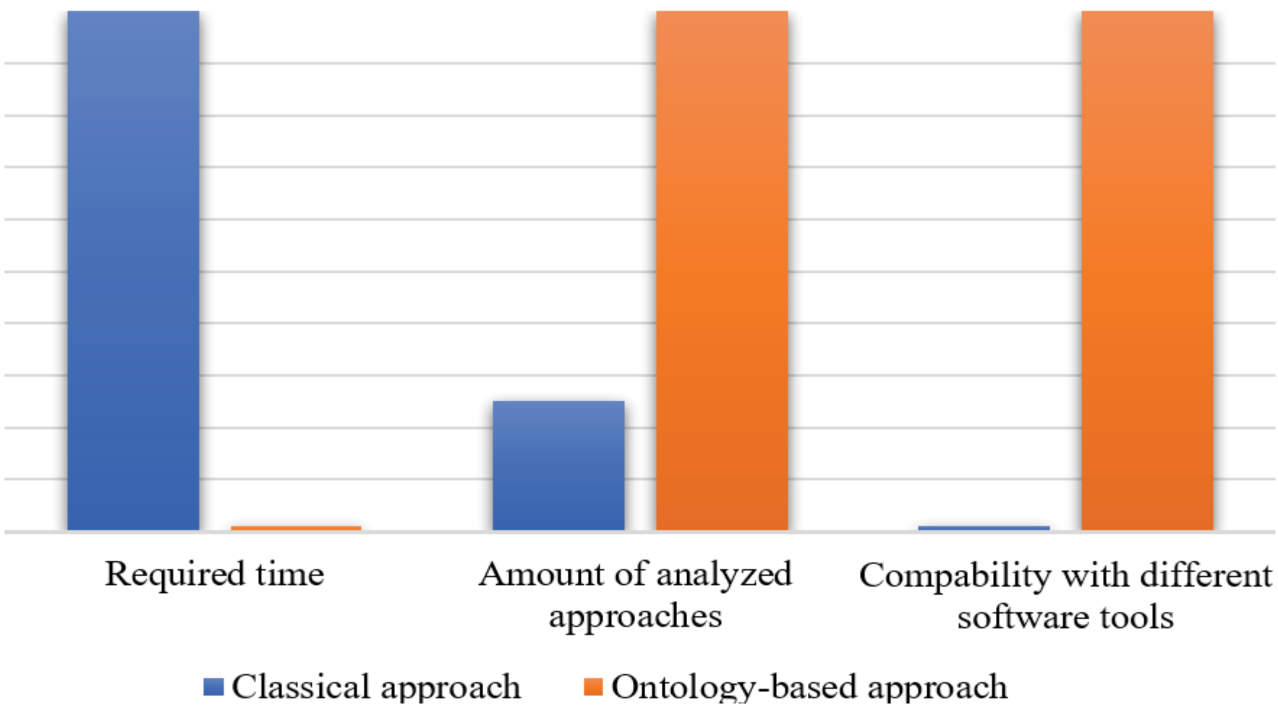


Fig. 11. Comparison parameters of usage of classical and ontological approach information processing during the engineering process.

selection" and "Ontology for the analysis of scientific publications".

- Firstly, was proposed using semantic characteristics of waste treatment equipment to create ontology and provide the ontological function of equipment selection
- We proposed an argument using ontological based models in the field of the treatment and disposal of organic waste both for educators and engineers.
- We compared both classical and ontological approaches in the field of use in environmental engineering.
- The system was proposed which allows the user to choose the priority of the indicators for selecting the technology and after processing they get the opportunity to familiarize themselves with the ranked list of these approaches, depending on how effective they are for solving a particular problem.

Author contributions

Conceptualization, Y.S., R.T. and S.U.; methodology, Y.S.A.DŚ, and V.S; formal analysis, Y.S, R.T. and V.S.F.A; investigation, Y.S., R.T., V.S. and S.U.; writing—original draft preparation, Y.S., S.U, R.T. supervision, Y.S., writing—review and editing, R.T., Y.S., V.S and F.A A.DŚ. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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