Ecological Cleaning and Reusing of Wastewater. Possibilities, Advantages and Proposals

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The historical view of sewage and rainwater cleaning, possibilities of applying it nowadays and newest experience in the world are analyzed in the article. The main advantages and disadvantages of the system were revealed after research. There were two parts of the analysis: personal cleaning and territorial planning. Biological and mechanical filtration were mostly used types of water cleaning. Main problems of ecological cleaning and reusing of wastewater were found: rather high price, possible permanent damage to the soil.

KEYWORDS: ecological cleaning, bioretention, ecological engineering, graywater, sewage farm, wastewater treatment.

Introduction

Only 1% of all water on Earth is usable freshwater. Today, we take clean, treated water, utilize it once and then flush it away. There are plenty of possibilities to clean wastewater, even more, reuse it ecologically. Applying natural ecologic processes to wastewater filtering is one of the most innovative solutions for common contamination problem. Ecological engineering is important not only for decreasing physical and chemical pollution, even more, it creates beneficial conditions for functioning of natural and anthropogenic eco-systems, moreover, it improves environmental quality (biodiversity, social value, aesthetical view, etc.). Although, not many of wastewater cleaning possibilities are being used in Lithuania and other countries.

One of the main ecological engineering principles is to solve problems by applying various models of eco-systems. Although similar projects and ideas were known even in the ancient times, the notion of ecological engineering and the main principles were formulated only in the middle of the 20th century. Around 1970 the huge wastewater cleaning projects, based on principles of ecological engineering, were started in America. (Kadlec, 2009, Bastian, 1993, The Arcata...) Applying ecological engineering technologies requires high qualification of the engineers and builders, because of that first projects received various reactions and discussions of citizens and specialists. Inappropriate evaluation of ecological risk (Jorgensen, 2014), incorrect technical decisions and a lot of other factors (Kangas, 2004, Etnier, 1996) can easily make a lot of unexpected problems (uncontrolled pollution flow, bad smell, ineffective cleaning process, etc.). Moreover, those problems cannot be easily solved – it requires a lot of effort and investment (Jorgensen, 2014). Even more, this kind of wastewater treatment occupies a relatively big area, which is designed for sedimenta-

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tion pools and filtration fields systems. This might be a reason which withholds the development of this kind of engineering systems.

Ecological engineering and its field of use is extremely important part of sustainable development (Campbell, 1999). In the time of rising life quality and society needs and consciousness, the attitude to usage of various engineering systems changes. Despite of these main causes, especially lightly contaminated wastewater, called greywater, cleaning by using treatment wetlands is one of the most perspective ecological engineering realms, which is now becoming widely used all over the world. Plenty of projects of this technology, evaluated with highest-level awards, such as ASLA *(American Society of Landscape Architects),* were established in China, USA, Canada, Netherlands and other well-developed countries these year. This technology only takes its first steps in Lithuania and it is not well-known between designers, engineers and architects. Although, there are few initiatives in small ecological engineering objects designing, such as eco-pools.

Ecological treatment of wastewater and rain water could completely or partially change common industrial wastewater cleaning equipment, which damages aesthetical view and it is declared as the objects of visual pollution. Ecological engineering and architecture, which connects various needs of community and nature into one system, could be the great example of applying sustainable development to everyday life. The aim of this article is to present various ways to clean the wastewater, their advantages, field of use; to research the examples from abroad and propose different areas and aspects of wastewater purification and potential of applying it in Lithuania. Furthermore, it is important to highlight the main problems of applying these systems, to understand, why these techniques are not widely used.

The method of this article is comparative literature analysis. The article is based on an overview of the historical development of the issue. Historical survey includes the origins of the water treatment method and discusses some typical cases of practice of this method in different historical periods. As well as touches upon the problems which have been encountered in the operation of such facilities or evaluating their impact on the environment. The second part analyses the latest wastewater treatment experience, discusses some examples of using modern technology in projects of varying scale and character, from huge areas to application of these principles in the level of local private facilities.

Historical experience

Even in prehistoric times there were three main aspects people had to deal with to be able to grow plants: how to concentrate desirable plants into one convenient place; to prevent unwanted weeds from growing there; and to find the best solution to encourage the plants to thrive. In short, people had to learn how to plant, weed, and water or drain crops. Although, there was no such thing as wastewater treatment, it gave a fundament to its development in the future.

Irrigation based agriculture has been the technology created by many of the world's greatest civilizations, although it was used in many different ways (Angelakis 2015, Wiesmann... 2006, Pescod, 1992). One of them was application of its principles to the waste water treatment. But invention like this is not easy to develop. Usually, ancient irrigation schemes require a lot of investment or labor or both, moreover, it depends on physical geography and geology of the area and requires a lot of engineering skills. Most known irrigation systems were developed in ancient Egypt, Mesopotamia (Coven, 1999), but one of the oldest and most developed centralized sewage management system examples were set in Mohenjo - Daro culture. Furthermore a similar cases can be found all over the world (Angelakis 2015).

In Middle Ages the facility of water cleaning was forgotten. The change of morals and social habits had a huge influence on everyday life. Privacy of the family and household became essential, because of that the public lavatories that were used in Roman Empire were no more appropriate. Although monasteries tried to solve this problem by creating some internal and common lavato-

ries, the idea was ignored by the communities. The main solution was to throw sewage straight to the street and let it flow away to the nearest pond or river. (Angelakis, Rose, 2014).

After the industrial revolution and the rapid growth of the cities sanitation problems became vital. Therefore it was searched for various ways of solving them. Among those decisions was an attempt to adapt the ancient water management methods based on the principles of irrigation. Ancient experience was taken as a base for these days needs and improved for a different specialization. The irrigation system was applied to wastewater filtering. The main similarity between these water using systems is water ponds, sometimes in different levels, where water flows naturally.

Berlin example

Sewage farm in Berlin is one of the earliest examples of wastewater treatment. It was designed using J. Hobrechts dewatering concept. The base of Hobrechts system was to divide the city into 12 districts, called radial systems, each of it had a pumping station. Domestic, commercial and industrial wastewater flew into these stations as well as precipitation water through gravity flow pipelines. The main purpose of pumping stations was to collect wastewater from districts and to redirect it to sewage farms located outside the city. Wastewater is first collected in sedimentation basins, where water flows through the tank and most sediments settle to the bottom. Dewatered sludge had been used as a soil conditioner for agriculture and horticulture in early years.

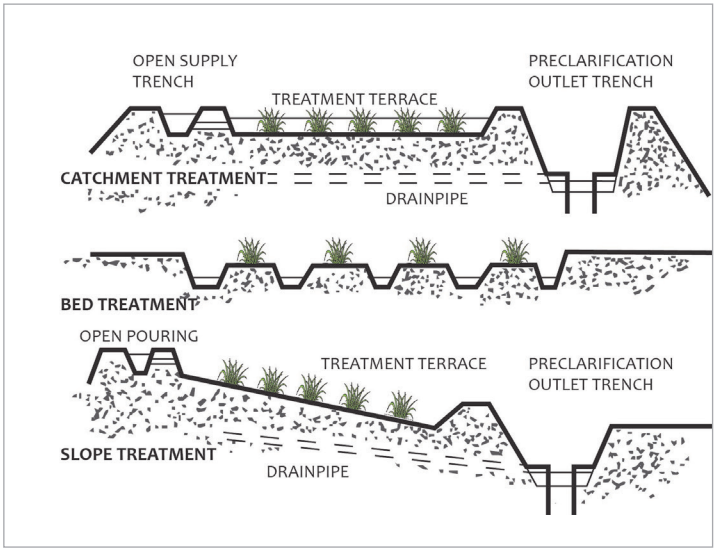

Fig. 1

Types of sewage farms (with reference to Berlin environmental atlas...2016, Ehrhardt S. et al. 1991)

There were three types of sewage farm (Fig. 1) treatments in Berlin: catchment (horizontal), bed and slope. Each of them are applied depending on surface. "Horizontal terraces are flooded by surrounding distribution ditches. For slope terraces, sewage water overflows the upper bank and irrigates the sloped terrace. Bed terraces with ditch irrigation were also initially used. Waste water flowed through bed terraces in connected parallel furrows, about one meter apart. Only plant roots received water." (Goedecke, Welsch, Zweer, 2000)

After using this system for a long time, it was realized that by cleaning hardly contaminated water all the harmful sedimentations stay in the soil. Hence this system would be better for graywater (lightly contaminated used water) cleaning (Goedecke, Welsch, Zweer, 2000).

Sydney example

Before intermittent downward filtration was used in Sydney, it was widely applied in towns and cities of the Great Britain and the United States of America, where land was often scarce and the ocean distant. Hence situation was a bit different in the newly established city of Sydney. Australian method used land as a filter through which the sewage drained, because of this the land became richer and crops could be grown. Although, this was only secondary consideration since the main purpose was to purify wastewater before it reached the ocean (Wastewater network...). Now the wastewater network in Sidney consists of 30 separate systems; 24 000 kilometres of

pipes; 16 wastewater treatment plants and 680 pumping stations. Most of the work is done by a gravity – it makes wastewater flow naturally through catchment drainage lines to a wastewater treatment plant (Beder, 1993).

After long time of using filtration fields, it was noticed that a lot of toxic sedimentations stay in approximately small area, which cannot be cleaned for a long time. It was decided that this kind of filtration system should be applied only for low-polluted wastewater, called graywater.

Lithuanian case

In terms of application experience in Lithuania of this type of technology, should be mentioned practices of filtration fields development that have been introduced in some advanced farms during interwar period. But then lack of experience and knowledge and the insufficient perception of processes of natural environment and human impact on them in most cases had a negative impact on the surrounding environment (filtering fields were installed in grounds which were not suitable for that or too close to the surface water bodies, etc.). Even the larger effects on the environment were caused by the use of filtration fields in the Soviet period. Then not only domestic but also industrial waste were treated in this way. At this industrial period the extra precautions had not been taken and thus it caused to recover not only large but also very dangerous quantities of waste that has accumulated in certain limited areas, which is currently very difficult to use. This causes the questions for the liquidation of negative consequences even today (Panevėžys...2011). For these reasons and negative experiences quite a negative view of the open-type wastewater treatment methods is formed in Lithuania and their application in practice is very limited.

Common technologies of biological wastewater cleaning

These days wastewater treatment technology became widely used in more fields and countries. As it has improved, it became necessary to divide sedimentations into individual groups to increase cleaning effectivity. Generally, wastewater treatment could be categorized into levels (including preliminary, primary, secondary and tertiary or advanced treatment criterions), based on activities made in these stages. In *preliminary* treatment stage, only debris (paper, plastic materials, rags, etc.), which can be taken away even physically, are being cleaned from the wastewater. *Primary* stage involves the partial elimination of suspended solids and organic materials from wastewater physically by screening and sedimentation. The main purpose of *secondary* treatment is to get rid of organic solid material using bacterial decomposition. *Tertiary* treatment eliminates inorganic components from the wastewater (Orukpe Otaigbe, 2010). Nowadays wide used *alternative wastewater cleaning technology* is based on water cleaning, when plants are used as a filter, has some similarities to a simple biological cleaning. It is based on each plant having its own sewage treatment area. This type of water cleaning should be called filtering as sedimentations area cleaned by roots of the plants and this process is absolutely natural and self-contained.

At the moment the method of wastewater treatment, imitating the principles of natural processes occurring in the natural environment it is rapidly becoming popular. It has some positive aspects, which contribute to the anthropogenic activities in the natural environment and might implement sustainable development strategies.

These different alternative wastewater treatment method application areas can also be distinguished:

Landscape as a living system. Simulation of natural processes in anthropogenic geotechsystems is currently widely applied in spatial planning. It helps to organize the complex of human activities in large, heavily used territories or to eliminate of the negative effects of human activities in the affected environment. *Industrial area by the Huangpu River in Shanghai* was remade to demonstrate ecological culture for Expo 2010. Houton Park is a regenerative landscape and was designed to treat polluted river water and recover degraded river waterfront in an attractive way. Moreover, wetland not only filters river water, it even protects the area from the flood. This kind of ecology attracts people to visit

and to take a walk around the area by well-developed pedestrian paths.

Fig. 2

Potsdam square, Berlin. Rainwater management (Photo by J.Vitkuvienė)

Potsdam square. Hobrecht's sewage farm was not the only example of wastewater treatment systems in Berlin. This idea was improved and newly established in Potsdamer Platz (Potsdam square) (**Fig. 2**). The aim of this project is to collect rainwater and to filter it through percolation beds which include aquatic plantings. All the water of the system circulates through filtration beds every third day. "Regular monitoring of key parameters such as ammonia nitrogen, nitrites, nitrates and phosphorus shows a high level of water quality quite suitable for fish and other wildlife" (Overstrom, 2008).

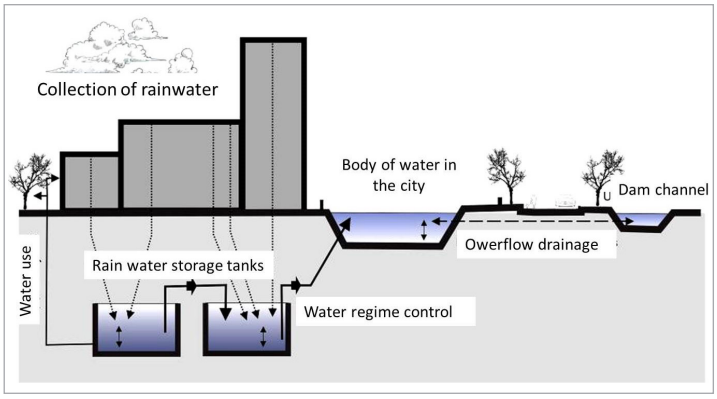

Fig. 3

Scheme of water collection, storage and use of the Daimler Crystler center in Potsdam square (according to Glücklich, 2013)

This project is not only ecological, it even increases aesthetical view of this square. The water flows through shallow ponds and watercourses along the square, moreover, people can cross them by stepping on stones and enjoy the nature view in the city centre (Overstrom, 2008).

The main idea of this urban project is that the rainwater is used where it falls. To achieve that, water is collected from the roofs of 19 buildings in this area, most of them are covered by grass.

Greenest neighbourhood. The application of modern environmental uses is important not only for the sustainability and preservation of the natural environment and protection of anthropoecosystems, but also for improvement of the quality of living environment and aesthetic.

Neighbourhood in Victoria, British Columbia (Canada) is sometimes called the greenest neighbourhood in the world – it is carbon-neutral and it is achieved by using on-building windmills, solar panels and, the most important, biomass gasification plant. Moreover, it has established its own sewage treatment system and graywater recycling facilities. The technological process of the water cleaning is used to make this neighbourhood look more attractive – the stream is running through the development and it makes an illusion that everything is built on the water (Benfield, 2011).

Gulbinų district in Vilnius. This is one of the first examples of non-traditional storm water management technology implemented in Lithuania. The main purpose in this district nearby Vilnius was to increase recreational potential and to design ponds for rainwater cleaning. The area was 1 ha (with 55 percent of urbanisation), so it would require to have 190 m^3 reservoir to collect rainwater. The main purpose of this design was to find an alternative between filtration pond and device. The result was a scheme of rainwater management network and places of ponds in this neighbourhood. These ponds are cleaning rainwater both ways – biologically and mechanically. The main idea of this type of cleaning is water transportation from bigger manifold to the leading pond

through periodically suffused bay, which is distinguished from leading pond by a dam.

Technology of cleaning by ponds is based on water gathering in lower parts of territory. From there it starts to go deeper into the soil and it is collected in underground reservoirs. After that, water is lead to the surface ponds. By the time water filters through the soil, it gets treated mechanically, later on surface it is cleaned biologically by plants.

In this kind of ponds, it is hard to remove oil products from rainwater – this is the reason, why it was necessary to place oil - catchers near large parking lots. Moreover, it requires a lot of attention – lowland needs to be cleaned up periodically (Januška, 2015).

It is possible not only to take care of water cleaning globally (in districts, towns and cities), but also in small private areas. *Rain gardens and eco-pools* also can be used as instrument for improving the quality of living environment and solving the issues of wastewater and storm water management that are particularly relevant for Lithuanian cities. Eco-pools (natural swimming pools) are the alternative to widely used chlorine or salt pools. System of this pool is based on water flow circle: water is being pumped and flows through the roots of various plants – this is the way it gets cleaner. There are three different areas in this kind of pond: swimming area, plants area that filters water and slope shore area that makes water get warmer and regenerates it (**Fig. 4, 5**). The soil of plants area consists of these layers: well-drained planting soil, sand and gravel bed. All these layers are located on the foundation of the existing soil. Pool like this does not require a lot of attention and is completely natural.

Fig. 4
Work scheme of eco-pool

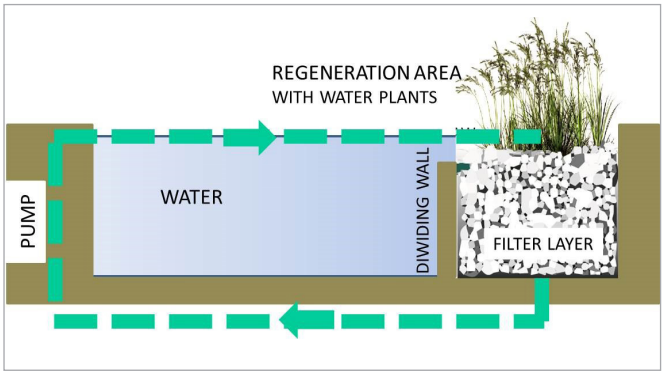

Fig. 5
Example of eco-pool in Potsdam square (Photo by J.Vitkuvienė)

Although it is more popular in abroad, there are a few examples of eco-pools in Lithuania. Specialist of landscape architecture G. Jablonskienė created one, matching all these criterions, in private house aside Vilnius. As a new technology, it is rather expensive, although, it is a good investment into future because of its natural circulation and self-cleaning abilities.

Results/main problems and possible proposals for Lithuania

Summarizing the examples, we can distinguish the following problems of the main alternative ways of water management practices:

- If not applied correctly, this kind of treatment could make damage to the soil and contaminate its deepest layers. Although it is possible to filter sewage water, it could leave permanent damage to the soil as Berlin example demonstrates.
- Proper application of these measures in practice requires a lot of theoretical preparedness, knowledge and systematic understanding of the principles of ecology, and their exact implementation in projects.

- It is quite expensive method, requiring investments.
- Districts, like in China (Houton Park) or Canada (Victoria, British Columbia), have to connect to a river or to be generally aside the water. Reorganization of abandoned industrial districts by the rivers is a noticeable problem in Lithuania. A newly formed district would have its own sewage system, which could make the whole district's wastewater treatment autonomic. Filtered graywater could be returned to the river or reused by households.

Nowadays in Lithuania there are many renovation projects in process which could be improved by wastewater treatment principle of the Potsdam square or rain gardens. The rain water could be collected from the roofs of apartment buildings and be treated in the system underground. Moreover, the filtration fields with fountains and flowing water streams could bring to life currently abandoned district yards. Collected rain water could be used for inside household usage, such as toilets, washing machines, etc. as well as to become a measure for improving the aesthetic quality.

Conclusions

1 Although wastewater usage technologies have old traditions, this kind of wastewater treatment is not widely used in Lithuania. Society should be introduced to possibilities of ecological engineering; its well-known problems and technological solutions.

2 Renovation projects in Lithuania could be improved by using the principles of ecological engineering in sewage systems.

3 Usage of ecological engineering principals would help to assimilate and make abandoned districts attractive, even more, to update ordinary renovation projects.

4 The application this kind of green idea would make a decent difference not only for a particular district but also for a whole city.

5 Rain gardens and eco-pools could be firstly designed in public spaces. Hence municipality of each town or city should be a good example for citizens. This kind of example would convince people to try something new. Even more, taking care of usual pools in Lithuania is quite a challenge for an owner. Hence the pool which is self-sufficient could be a free choice for every household.

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