An Innovative Condition Assessment Method for Wastewater Treatment Facilities to Promote Long-Term Sustainability in Management and Operations

Ritiksha Danu
Department of Civil Engineering, Graphic Era Hill University, Dehradun, Uttarakhand, India 248002

Article Info
Page Number: 592-601
Publication Issue:
Vol. 71 No. 2 (2022)

Article History
Article Received: 25 December 2021
Revised: 20 January 2022
Accepted: 24 February 2022

Abstract: Conventionally, the success of a wastewater treatment plant is evaluated by the quantity of chemical oxygen demand (COD), dissolved organic matter (BOD), total suspended solids (TSS), and other consequences of wastewater treatment that are removed during the treatment process and thereafter. Environmental engineers consider a number of parameters at the plant's discharge, including pH, NH4-N, NTotal, fecal coliform, and others. The traditional approach to performance assessment fails because it does not directly compare the effluent's distribution of these characteristics throughout the output stage of the process to the standards or specification limits issued by the Central Pollution Control Board (CPCB). To fill this knowledge gap, we propose and implement the probability-based Process Capability Indices (PCIs) and Multi - variate Process Flow Indices (MPCIs) in this research. These indices measure the effectiveness of a wastewater treatment process by contrasting the observed results with the predicted ones. PCIs have been widely used as a baseline against which manufacturing processes may be evaluated and tweaked to increase efficiency. The focus of this effort is on PCIs and MPCIs from the standpoint of environmental engineers, with the hope that their use would grow. Using capacity indicators accurately measures the effectiveness of the process of wastewater treatment, which is essential for reducing pollution and permitting the reuse of treated water. This study provides an analysis of the treating wastewater process's capacity by applying appropriate capability indices, using additional information acquired from case studies via literature research. Findings suggest that appropriate capacity indices may allow for more precise assessments of sewage treatment system performance than are presently possible.

Keywords: Process capability indices; process distribution; process variation

Introduction

Untreated wastewater in India is a significant fraction of treated wastewater in industrialized nations [1]. Low-quality treatment plants and untreated wastewater is a major environmental pollutant. In light of this problem, it is crucial to rapidly expand the availability of the most effective, high-capacity wastewater treatment plants and to enhance the efficiency of already-existing facilities. Improving the quality of treated wastewater would help the environment and alleviate the water shortage to some extent. Improving the efficacy of the wastewater treatment process begins with conducting a process capability study utilizing relevant capability indicators. To learn how well a process operates in relation to process characteristics standards or specification constraints, statisticians use a technique called process capability analysis using capability indices. The perspective that a high-quality wastewater treatment process will adhere to Central Pollution Control Board-mandated standards for effluent discharge is important to the examination of wastewater treatment processes using capacity indices (CPCB) [2].

Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) removal rates are often used to evaluate the efficacy of a wastewater treatment facility. While evaluating the efficacy of a process, environmental engineers also look at variables like as pH, NH4-N, NTotal, fecal coliform, and so on at the outflow. The proportion of BOD, TSS, and other pollutants removed by a wastewater treatment facility is cited in a number of studies. [3, 4, 5, 6, 7 and 8].

Biochemical oxygen demand (BOD) removal efficiency was found to be 94.56%, and total suspended solids (TSS) removal efficiency was found to be 93.72%, in an assessment of the effectiveness of an activated sludge wastewater treatment plant [3]. The COD removal efficiency of the wastewater treatment facility was estimated at 69.39%, while the BOD removal efficiency was calculated at 62.78%. [5]. Wastewater treatment plants in India are required to ensure that the BOD and COD levels in their released effluent are "not more than 10" (mg/l) and "not more than 50" (mg/l), respectively. [2]. The equation used to determine BOD removal efficiency considers both the input and the final BOD concentrations. The removal efficiency of COD takes into account both the COD in the feeding phase as well as the COD in the output stage.

These calculations do not account for specific constraints when assessing wastewater treatment facility performance. As the effluent is not directly compared to CPCB's standards and specification limits for the characteristics measured at the output stage of the wastewater treatment process, the typical method of performance evaluation is faulty. Capacity indices, which compare the actual output of a wastewater treatment process to its intended output, are developed and implemented in this study to meet this demand.

Researchers first looked at the steady-state process distribution vs the product specification presented as minimum and maximum values while exploring univariate process capacity analysis. The histogram was one of the first and most important statistical tools for assessing throughput. Tool for Keeping the Peace. Due to the limitations of the histogram as a capacity assessment tool, practitioners needed a process capability metric promptly. That's why we have the PCI as a measure of computer efficiency. There has been a lot of study on PCIs, particularly their estimators, distributional properties, and inferential abilities [9, 10]. PCIs are widely used to evaluate the quality of a production line, and they also give valuable insight into the efficiency with which a facility manages its environmental impact [11, 12]. Many factors influence many real-world processes.

In order to evaluate the effectiveness of multivariate processes, scientists have developed multivariate process capacity indices (MPCIs) in the last three decades [13,14]. Due to their multivariate statistical foundations, MPCIs can simultaneously account for both the variables

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2139
and their correlation structure. Recently, the advantages of PCIs and MPCIs were contrasted and compared[16]. It is almost difficult to meet the requirements of households, farms, and factories with the current distribution of water. Desalinating ocean water or recycling treated wastewater are two common methods used across the globe to provide the necessary quantities of potable water. Water pollution may come from both discrete and diffuse sources. Industrial effluents, sewage discharge, and industrial strom water discharge are all examples of point source contamination, while improper waste dumping, resource mismanagement, pesticide use, agricultural runoff, accidental spillage of toxic substances, etc., are all examples of non-point source contamination. Strict laws may be used to curb contamination from point sources, but non-point source contamination must be addressed via consumer education and awareness campaigns. Effective management of water resources requires addressing both point and non-point causes of pollution, although only the latter can be eliminated or greatly reduced.

Major Water Consuming Industries

Significant toxins that poison water bodies to a major level come from point source contamination, such as effluent or waste from factories. All process industries rely heavily on water. Water may be softened, dealkalized, deionized, purified, apyrogenic, high purity, or ultrapure, depending on how much impurity it contains (Judd & Jefferson 2003). Fresh water (1.5 g/L Total Dissolved Solids [TDS]), brackish water (1.5 g/L TDS]), and saltwater (10 g/L TDS]) are the three categories used to describe the salinity of naturally occurring water. The greatest way to fulfill process needs is with the help of desalination technology. Many desalination processes need a lot of power, including reverse osmosis, distillation, and electrodialysis. While several unique approaches have been developed for combating energy guzzler concerns, such as deionization or electrosorption, backward osmosis, and freeze distillation, these methods are still in the experimental stages. The water recovery rate of desalination methods is poor, and there is also the issue of how to properly dispose of both the concentrated brine that is a byproduct of the process. The predicted water requirement of certain important process industries is shown in Table 1.

Table 1.Water demand for large process industries

Industry		Water demand (m^3)
Power	Per MWh for steam	2
	Per MWh for cooling	58
Dying (per tonne of fabric processed)		110
Paper (per tonne of paper produced)		30
Newspaper (per tonne of paper produced)		12
Brewing (per m^3 beer)		20
Dairy (per m^3 milk)		180
Sugar (per tonne of sugar)		12
Automotive (per car)	Metal production	500
	Tyre production	800
Soap (per tonne of soap)		5

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2139

Literature Review

Edward R. Jones et.al.,(2021) Sustainable development and the shift toward a circular economy may be bolstered by implementing cost-effective wastewater management practices that reduce pollution and increase the availability of clean water. The goal of this research is to provide the first worldwide perspective on the current condition of wastewater production, collection, treatment, and reuse in both residential and industrial settings. We use a data-driven strategy by collecting, comparing, and standardizing wastewater data from different countries throughout the world. When necessary, multiple linear regression is used to estimate missing data. Wastewater information at the national level is then downscaled and verified at a resolution of 5 arcmin (10 km). The research found that 63% (225.6109 m3 yr1) of the world's wastewater is collected, while 52% (188.1109 m3 yr1) is treated. Hence, we conclude that, compared to earlier estimates of 80%, only 48% of worldwide wastewater output is discharged to the environment untreated. Intentional reuse of treated wastewater accounts for an estimated 40,7 109 m3 per year. Wastewater output, collection, and treatment on a per capita basis vary considerably from one location or economic development level to another. In high-income nations, where just 16 percent of the world's population resides, 41 percent of the wastewater is generated. Although though they only make up 5.8% and 5.7% of the world's population, the Middle East and North Africa have some of the highest rates of treated-wastewater reuse (15%) and western Europe have some of the highest rates (16%). South and Southeast Asia, in particular, are hotspots for the flow of untreated wastewater into the environment, and our database will help you locate these areas. Our findings are also useful as a reference point for gauging the success of various policy initiatives that have some bearing on wastewater management. For further in-depth hydrological investigations, such water quality modeling and large-scale water resource evaluations, our spatially explicit findings accessible at 5 arcmin resolution are an excellent choice.

Kavindra Kumar Kesari et.al.,(2021) One of the world's most pressing issues is the lack of access to clean water for millions of people. Several nations routinely utilize wastewater that has not been treated for agricultural purposes. This is a major problem that affects people's health and the environment all around the globe. Treated wastewater has been discovered to be a more practical and environmentally-friendly alternative to utilizing raw sewage. Environmental toxicity from solid waste exposures is also a major cause for worry.

Vinayakam Jothiprakash et.al.,(2020). Many variables, including but not limited to As a consequence of urbanization and industrialization, people from the countryside increasingly relocate to metropolitan centers in quest of a better standard of living. The wastewater collecting network, treatment by sewage treatment plants (STPs), sewage disposal system, and reuse distribution system are all placed under a great deal of stress when large numbers of people move to a city in a rapidly expanding country like India. This results in the conversion of nearly 80% of the current consumption of drinking water into effluent. Services have been inadequate or badly administered in a number of instances. Just 10% of India's sewage is cleaned before being discharged into waterways or the soil, as reported by Kulkarni, Wanjule, and Shinde (2018). Most urban areas have lax regulations for wastewater, which has led to widespread contamination of both surface and subsurface water sources.

Use of Water is Categorized by following

Motels, hotels, restaurants, offices, and other commercial structures, as well as government and military installations, all consume enormous quantities of fresh water. The majority of people's daily water use goes toward domestic uses. Water used for routine household activities such as drinking, cooking, bathing, laundry, dishwashing, flushing toilets, and watering lawns and gardens is considered domestic usage. Manufacturing facilities rely on water for a variety of functions, including processing, cleaning, transporting, diluting, and chilling. Steel, chemicals, papers, and petroleum refining are major water consumers. Water is often recycled for several uses in industrial settings. Water used for irrigation includes water used to hydrate pastures, to protect crops from frost and freeze, to apply chemicals, to chill crops before harvest, and to leach salts from the root zone of crops. Water is used in the mining industry for the extraction of a wide variety of materials, from coal and ores to crude petroleum and natural gas. All processes associated with mining fall under this umbrella, from quarrying through milling (including crushing, screening, washing, and flotation). Around 32% of the water utilized in mining operations is saltwater. The term "public supply water usage" refers to the delivery of water for residential, commercial, and industrial applications that is extracted and distributed by public and private water providers such as county and municipal water works. Over 225 million Americans, or 84% of the total population, relied on public water systems in 1995.

Use of Waste water and its Disposal

1.Cereals: Wastewater from Hyderabad is used to irrigate 2100 hectares of land along a 10 km section of the Musi River (Hyderabad, Andhra Pradesh) to grow rice. In Ahmedabad and Kanpur, wheat is watered using sewage water.

2. Vegetables: At the Keshopur and Okhla sewage treatment plants in New Delhi, 1700 hectares of land are used to grow a wide variety of vegetables using wastewater as irrigation. Summertime finds the soil fertilized with cucurbits, eggplant, okra, and coriander; wintertime brings spinach, mustard, cauliflower, and cabbage. Spinach, amaranths, mint, coriander, and other herbs and vegetables are cultivated in the Musi river basin in Hyderabad all year round.

3. Flowers: Roses and marigolds are grown using wastewater by farmers in Kanpur. Farmers in Hyderabad are using treated sewage water to grow Jasmine. Public parks & avenue trees in Hyderabad are irrigated with secondary processed effluent.

Environmental Impact Assessment (EIA)-

Analyzing the Environment (EA) Impacts on human health, ecological health, and risk connected with a project, as well as the presence of changes in nature's services, are only some of the things that may be evaluated by an EIA. [1]. It's the process of weighing the potential benefits and drawbacks to the environment of a plan, policy, program, or physical project before making a final decision to implement it. Although "environmental impact assessment" (EIA) is more often used when referring to specific projects undertaken by people or businesses, "strategic environmental assessment" (SEA) is more commonly used

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2139

when referring to proposed government policies, plans, and programs (Fischer, 2016). Rules of administrative process involving public engagement and record of decision making, as well as judicial review, may apply to environmental impact assessments.

Evaluating the positive and negative effects that a project or development may have on the environment is what EIA is all about.

It's a helpful tool for integrating the study of a project's costs and benefits with consideration of environmental, social, cultural, and aesthetic factors, which is essential for making well-informed decisions.

In order to pick environmentally friendly locations, process technologies, and other environmental protections, this activity should begin early in the planning stage of projects.

All industrial initiatives probably have some environmental effects, although those effects may not be large enough to need extensive evaluation methods. Decisions on whether or not such drills are necessary will need to be made following a preliminary assessment of the potential effects of a certain project and also its location. The following are examples of projects that may benefit from a thorough EIA: The techniques and procedures used this to treat wastewater that is a byproduct of a business or industrial activity fall within the purview of "industrial wastewater treatment." Treated effluent from an industry may be recycled or discharged into a sewage system or body of water for environmental usage. Despite recent advances in the industrialized world to minimize wastewater output or recycle such effluent within the manufacturing process, most businesses still generate some wastewater. Yet, many sectors continue to rely on wastewater-generating technologies.

Below are some examples of wastewater treatment processes, including ETPs, STPs, and CETPs::

1. Effluent Treatment Plants (ETP)

2. Sewage Treatment Plants (STP)

3. Common and Combined Effluent Treatment Plants (CETPWaterborne infections are responsible for the deaths of an estimated 1.8 million people annually. The lack of basic sanitation is likely to blame for many of these fatalities. We need to take wastewater treatment more seriously for the sake of the future of our civilization. The goal of wastewater treatment is to convert wastewater and domestic sewage into a waste stream or solid waste that can then be safely discharged or reused.

Traditional Ground-Water Treatment

The water-table is the main reservoir for groundwater. The water that is lost via evapotranspiration eventually returns to the planet in the form of rain. Aquifers are used to preserve this water for later use. Water's flavor and aroma may be affected by a wide variety of minerals, including iron, manganese, salt, and fluoride, that dissolve into it from the soil. Water treatment is performed because the unwanted substances present are useless trash. Both confined and unconfined acquifers exist. There is a connection between the unconfined

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2139

acquifer and the surface, maybe in the form of a stream. When animals drinking from these outlets ingest various kinds of fertilizers used in agricultural areas, the water they provide may be contaminated with bacteria and pathogens, rendering it unfit for human consumption. Water is able to dissolve the contaminants. When only minimal amounts of manganese are present, aeration may be used to remove the black sediments that accumulate in a sand filter. Unremovable compounds like fluoride are subjected to chemical treatments like sedimentation, chlorination, etc., which involve the division of complicated sectors [6]. But, these methods may eventually be used for progress in rural regions, where access to such chemicals is limited.

Conventional Surface Water Treatment

The traditional approach is the gold standard for treating surface water. The majority of the world's industrialized nations and major cities adopt this technique. Multipurpose water treatment is necessary because of the variety of uses for which it is needed. Most infectious illnesses are spread via contaminated water, making it obvious that lowering water standards is a bad idea. Water should undergo quick blending, flocculation, sedimentation, filtration, and disinfection as unit operations [7]. The first step in the standard water treatment procedure is to filter out any larger particles by using a screening technique. The water is first pre-sedimented, and then it is sent to the coagulate tank. Coagulants bind to the suspended particles, creating dense clumps that may be separated out of the solution by sedimentation and filtering. Large masses occur in the water as it is gently churned, and these masses eventually fall to the bottom, where they are eliminated by sedimentation. Chlorination or other methods are then used to kill any remaining bacteria in the water. It is possible to design all three of the aforementioned processes—coagulation, flocculation, and sedimentation—into a single tank, which would be called the clarity tank, or to construct coagulation and flocculation into separate tanks.

Municipal Waste-Water Treatment

The activated sludge technique is the standard method for treating municipal wastewater. Biochemical Oxygen Demand (BOD) removal is used here. Suspended growth therapy is a biological procedure that may be used to get rid of BOD. Wastewater is oxygenated throughout this process, making it an aerobic one. Secondary clarifiers are used to get rid of the flotsam and jetsam that form as a result of bacterial growth. Aeration devices agitate the liquid, introducing oxygen to the matter and encouraging the development of additional bacteria under controlled circumstances. Depending on the BOD requirement, the amount of time waste-water is held might range from 3 to 8 hours. Secondary effluent is the cleared liquid that remains after the microorganisms have been separated via sedimentation. Some of the sludge that is produced is reused in the aeration basin, which keeps the concentration of mixed-liquor suspended solids (MLSS) at an optimal level. To keep the number of microorganisms in the tank stable, the leftovers have been collected and put back through the sludge processing system.

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2139

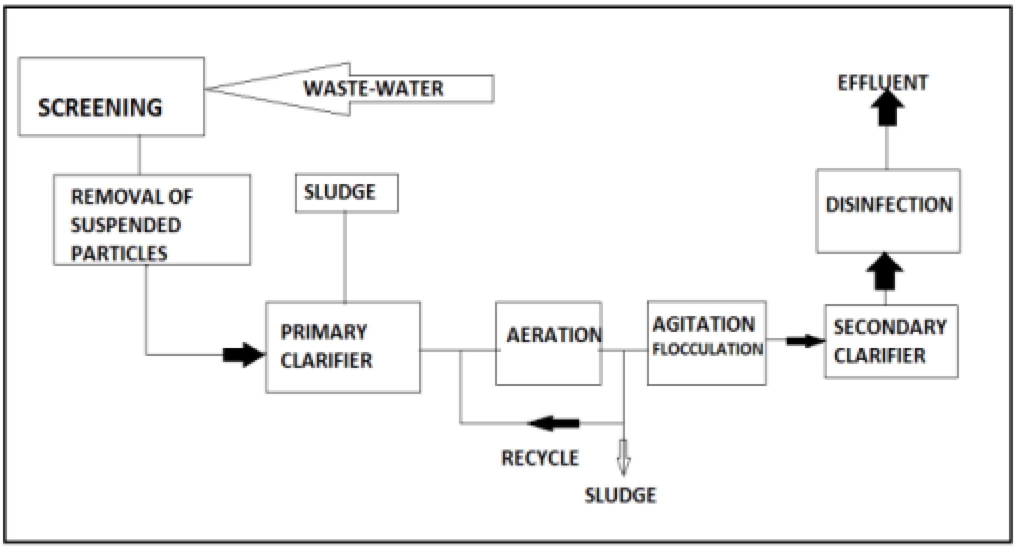

Figure. 1 Active sludge treatment

Another way that microorganisms may help break down the raw-waste paper is in facultative ponds. Despite the fact that anaerobic conditions for decomposition are optimal, aerobic decomposition predominates at the surface while anaerobic decomposition occurs at deeper depths. Bacteria that thrive in the presence of oxygen breakdown organic wastes and produce carbon dioxide (CO2), whereas methanoic action occurs in the absence of oxygen in the anaerobic zone.

UV-Filters In Waste-Water Treatment

Research shows that ultraviolet (UV) disinfection is an efficient way to clean water in remote locations like communities. As we've already established, water treatment chemicals are harder to come by in the countryside, but installing a self-contained system that can clean the water is always useful. This is the third and last stage in the water treatment process. UVfiltration eliminates microorganisms by exposing the feed to ultraviolet light of a certain wavelength (254 nm) that destroys their DNA [13]. By applying a voltage across the gas mixture, a UV lamp may be created that emits light at low pressure. The bulb, power supply, and electronic ballast are the three essential parts of a UV disinfection system. Quartz glass is utilized because it can be formed into a cover that allows UV light to flow through while also keeping water away from the light bulb during manufacturing. The ultraviolet (UV) disinfection procedure features an active mode that not only kills all target organisms but also removes the micro-organisms' capacity to multiply, hence blocking the path through which it may infect the host. Class A and Class B systems are created for the goal of providing effective therapy. Wastewater treatment plant effluent, sewage sludge, and microbiologically rich agricultural runoff are the primary contributors to the world's waste water problem. The UV treatment utilized has several drawbacks, such as the high brightness of feed and the reduced turbidity of feed, and the power of both the UV lamps also decreases with time [14].

Conclusion

Since fresh water supplies are rapidly depleting, there is an immediate need for water production from any and all possible sources. Supporting the Appreciable Technology requires more than simply drawing attention to the issue at hand, however; it also requires the creation of strategies and the implementation of various technologies. There has to be effective treatment of the many types of wastewater produced. It's not always the case that the results are pointless. Although all of the aforementioned systems' applications might be beneficial in some way, it's important to choose the right one in order to get the most bang for your buck from waste-water treatment. There are a variety of methods that may be used, depending on the norms of the local society. In a world where non-renewable resources are rapidly depleting, it makes more sense to switch to a renewable energy source. Although there is no doubt that harvesting renewable energy and utilizing it as a power source requires substantial financial backing, the primary benefit is that it has no negative effects on the environment. Given India's status as a developing nation and the fact that progress is driven by people's thoughts and ideas, there has to be concerted action to spur a transition to renewable energy that prioritizes long-term sustainability.

References

1. Jones, E. R., van Vliet, M. T. H., Qadir, M., & Bierkens, M. F. P. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth System Science Data, 13(2), 237–254. https://doi.org/10.5194/essd-13-237-2021
2. Kesari, K. K., Soni, R., Jamal, Q. M. S., Tripathi, P., Lal, J. A., Jha, N. K., Siddiqui, M. H., Kumar, P., Tripathi, V., & Ruokolainen, J. (2021). Wastewater Treatment and Reuse: a Review of its Applications and Health Implications. Water, Air, & Soil Pollution, 232(5). https://doi.org/10.1007/s11270-021-05154-8
3. Vinayakam Jothiprakash, Marcus Joseph Tobias (2020) Study Of The Socioeconomic Spillovers Of Sanitation: Sewage Treatment Plants In Navi Mumbai, India” Asian Development Bank Institute ADBI Development Case Study No. 2020-1 (May)
4. Herrera Melián, J. A. (2020). Sustainable Wastewater Treatment Systems (2018–2019). Sustainability, 12(5), 1940. https://doi.org/10.3390/su12051940
5. Geem, Z. W., Chung, S. Y., & Kim, J.-H. (2018). Improved Optimization for Wastewater Treatment and Reuse System Using Computational Intelligence. Complexity, 2018, e2480365. https://doi.org/10.1155/2018/2480365
6. Angelakis, A. N., Asano, T., Bahri, A., Jimenez, B. E., & Tchobanoglous, G. (2018). Water Reuse: From Ancient to Modern Times and the Future. Frontiers in Environmental Science, 6. https://doi.org/10.3389/fenvs.2018.00026
7. Sapronova, Z., Sverguzova, S., Sulim, K., Svyatchenko, A., & Chebotaeva, E. (2018). Sewage treatment in megacities by modified chestnut tree waste. IOP Conference Series: Materials Science and Engineering, 365, 022058. https://doi.org/10.1088/1757-899x/365/2/022058
8. Finley, J. W., & Seiber, J. N. (2014). The Nexus of Food, Energy, and Water. Journal of Agricultural and Food Chemistry, 62(27), 6255–6262. https://doi.org/10.1021/jf501496r

9. Mangesh Gulhane, Ashwini Ingale, "Moving Bed Biofilm Reactor: A Best Option for Waste water Treatment", International Journal for Scientific Research & Development , Vol. 3, Issue 01, 2015
10. Ananth S Kodavasal, The STP Guide- Design Operation and Maintenece, Karnataka State Pollution Control Board, 2011.
11. Todoran, R. (2010). Modern Management Methods For Managing The Waste Water And Recovering The Heat From Waste Water. Annales Universitatis Apulensis Series Oeconomica, 2(12), 708–720. https://doi.org/10.29302/oeconomica.2010.12.2.23
12. Cossu, R. (2009). Driving forces in national waste management strategies. Waste Management, 29(11), 2797–2798. https://doi.org/10.1016/j.wasman.2009.08.002
13. Castaldi, P., Garau, G., & Melis, P. (2008). Maturity assessment of compost from municipal solid waste through the study of enzyme activities and water-soluble fractions. Waste Management, 28(3), 534–540. https://doi.org/10.1016/j.wasman.2007.02.002
14. Borghei, S. M., & Hosseini, S. H. (2004). The treatment of phenolic wastewater using a moving bed biofilm reactor. Process Biochemistry, 39(10), 1177–1181. https://doi.org/10.1016/s0032-9592(02)00195-4