EVALUATION OF BIODEGRADABILITY AND ENVIRONMENTAL IMPACT OF BIOWASTE LEACHATE

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ABSTRACT

As the world's population and urbanization have significantly increased in the past few decades, the generation of municipal solid waste has accelerated on global scale. The biowaste disposal, which is an integral part of municipal waste, leads to leachate production. These kinds of wastewater are characterized by complex composition with very high concentrations of organic and inorganic pollution substances and toxicity, which may have harmful impact on the environment. This study investigated the physico-chemical and biological characterization of leachate from biowaste. The experiments were conducted in batch performance with initial concentration of leachate, expressed as chemical oxygen demand, 12.21 ± 0.46 g O_2/L and pH value 4.05 ± 0.13. Obtained results showed that leachate from biowaste have high value of chemical oxygen demand, toxicity and low pH. Overall efficiency of the process of aerobic biodegradation was 89 %. The abundance of viable bacterial cells and development of activated sludge flocs during the experiment confirmed the biodegradability of leachate from biowaste.

***Keywords**: leachate, biowaste, biodegradation*

INTRODUCTION

As a result of rapid industrialization, population growth and urbanization, the trend of generation in municipal solid waste per person have significantly increased on global scale [1]. Primary disposal approach worldwide for this type of waste is landfilling [2]. Many developed countries have legal obligation to reduce the quantity of municipal waste sent to landfill, with particular emphasis on biodegradable waste. One of the main reasons for reduction of biodegradable waste in landfill is the leachate formation which represents significant pollution problems if it is not adequately controlled [3, 4]. Biodegradable municipal waste mainly comprises of biowaste which includes kitchen, garden or green waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants [5]. Composition of the leachate depends on the constituents of the wastes, moisture content, stage of biodegradation reached by the waste, the microbiota type, climatic conditions and the age of the landfill or operational procedures [6, 7]. It is characterized by high organic load expressed as chemical oxygen demand (COD) value, toxicity, unfavourable odour and yellowish to dark brown colour [8].

Biological treatment is relatively simple, reliable, cost-effective and environmentally friendly method which can be used for treating wastewater with high organic loads [9]. Most commonly used biological treatment for wastewater is aerobic process with activated sludge, where microorganisms appear in flocs, mainly composed of bacteria [10]. Because of its origin, biowaste leachate is potential source of microorganisms. Thus, biological treatment with autochthonous microorganisms can be applied for the leachate contaminants degradation.

The aim of this research was to study physico-chemical characterization of leachate from biowaste and to investigate its biodegradation potential by indigenous microorganisms which are naturally present in the leachate.

EXPERIMENTAL

In order to characterize the biowaste the laboratory simulation of leachate preparation was used. The biowaste consisted of 9 different biodegradable wastes (substrates) commonly found in households, as previously reported [11]. According to European standard EN 12457-4:2002 [12], the leachate from each individual substrate and biowaste was prepared by adding the material into distilled water in ratio 1/10 and mixing it at 100 rpm for 24 hours.

The biowaste for biodegradation process was mixed in mass ratios optimal for composting process [13]. Initial values of C/N ratio, pH value and moisture content of biowaste mixture were 34/1, 5.93 and 57 %, respectively.

In order to assess the biodegradation process by the leachate's indigenous microorganisms, biodegradation experiments were carried out in batch performance on a rotary shaker at 160 rpm for 8 days, at room temperature (23 ± 1°C). The experiments were conducted in 1000 mL Erlenmeyer flasks which contained 500 mL of biowaste leachate. Initial concentration of organic matter of leachate was 12.21 ± 0.46 g O_2/L expressed as chemical oxygen demand (COD). During the experiment, COD, biochemical oxygen demand (BOD), pH value, toxicity, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS) and colony forming units (CFU) were monitored.

For each individual substrate physico-chemical characterization was conducted in means of determining COD and pH values. Physico-chemical characterization of biowaste leachate was carried out at the beginning and at the end of biodegradation experiment. The pH value was measured by WTW Multi 340i set. COD was determined spectrophotometrically (Hach model DR/2400), MLSS and MLVSS were determined gravimetrically using Standard methods [14]. MLSS is an indirect measure of sludge concentration which is commonly used to characterize the biological mass in the activated sludge. MLVSS is a measure of the amount of volatile suspended solids found in a sample of MLSS. Variations in the concentration of MLVSS indicate a change in the amount of biomass share [9]. Biochemical oxygen demand (BOD) was determined by Winkler method and toxicity using bioluminescent bacteria *Vibrio fischeri* [15]. Bioluminescence inhibition assay has been widely used in determining toxicity of leachates [16]. Toxicity is expressed as the effective concentration of compound that affects 50 % of bioluminescence inhibition (EC_{50}). When the sample is constituted by a mixture of compounds or contains unknown compounds, the result is expressed as percentage of sample that affects EC_{50} [17].

In order to monitor changes in biomass development, determination of CFU and microscopic analysis were applied. CFU of mesophilic bacteria and fungi were determined through preparation of decimal dilutions [11].

Microscopic analysis was performed using optical microscope (Olympus BX50) equipped with system for taking photographs (Olympus DP10 camera). Samples were microscopically examined under 100× total magnification.

RESULTS AND DISCUSSION

The results of physico-chemical characterisation of leachate from each individual substrate are shown in Figure 1. Average COD value of all biowaste leachate was 16.2 ± 8.6 g O_2/L, which correlates with the published results [18]. The highest COD value of 34.9 g O_2/L was obtained from leachate from apple peel, which consists of sugars (glucose, fructose and sucrose), cellulose and lignin [19]. pH value for all biodegradable leachates ranged between 4 and 7, with average value of 5.5 ± 1.0.

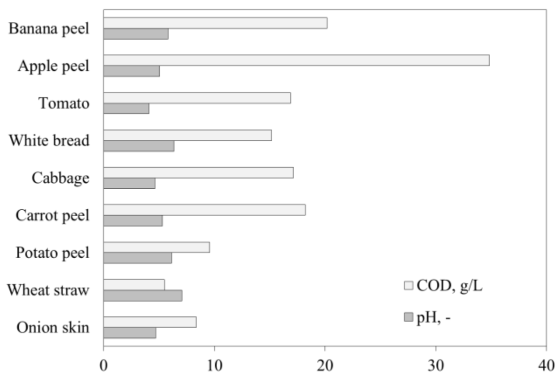


Figure 1. Physico-chemical characterization of leachate from each individual substrate

A biodegradation experiment was conducted for 8 days, in order to study the biodegradability of leachate from biowaste. At the beginning of the experiment BOD_5/COD was 0.65, which means that leachate is biodegradable and biological treatment can be applied.

Homogenizing and stirring conditions can promote microbial growth and enhance microbial degradation activity on pollutants from leachate [20]. According to Aktaş (2012) the ratio of initial COD to initial MLSS concentration is relevant in biodegradation process of organic compounds which are not easily biodegradable because of their inhibition effect. At the beginning of the experiment COD/MLSS value was 5.62 which correlates to the values found in literature [21]. From Figure 2 it can be seen that in 2nd day of the experiment, value of COD/MLSS decreased for 46.7 %. High decrease of COD/MLSS value points out the major changes in COD and MLSS value, meaning the rapid growth of biomass due to utilization of dissolved organic matter from leachate. During the biodegradation experiment, COD gradually decreased while MLSS increased, indicating the development of activated sludge. MLSS/MLVSS ratio is a value often considered for evaluation of activated sludge activity [22]. Through biodegradation experiment MLVSS/MLSS ratio maintained relatively high with value of 0.89 ± 0.02 implicating that the amount of viable biomass in developed activated sludge is high. As the values of COD/MLSS ratio started to decrease from the day 6 to the end of experiment, the changes in MLVSS/MLSS values slightly followed the abatement trend. These changes occurred because of biomass decay due to decreased concentration of COD.

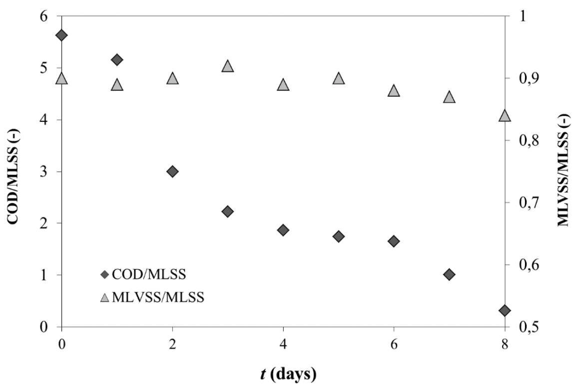


Figure 2. Changes in COD/MLSS and MLVSS/MLSS during 8 days in biodegradation process of leachate from biowaste

During the biodegradation experiment, changes in number of viable cells of bacteria and fungi were observed (Figure 3). The number of bacteria and fungi in 1 mL of biowaste leachate at the beginning of the experiment was 3.1×10^8 and 1.2×10^5, respectively. From the beginning to the third day of the experiment, the phase of exponential growth was observed, where the highest value of CFU/mL of leachate 3.7×10^8 for fungi was obtained. The viable number of bacterial cells maintained till the end of the experiment with average value 3.4×10^9 while the number of fungi decreased to 1.7×10^7 CFU/mL. During the biodegradation process the total number of bacteria was in range of 10^9 CFU/mL, while in landfill leachate without biostimulation the number rages between 10^3 and 10^6 CFU/mL [23].

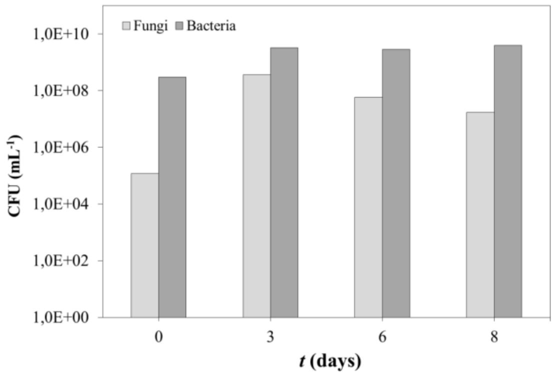


Figure 3. Changes in CFU for bacteria and fungi during 8 days in biodegradation process of leachate from biowaste

Physico-chemical characteristics of leachate from biowaste at the beginning and after the biodegradation experiment are summarized in Table 1. Biodegradable organic matter, in terms of BOD5/COD ratio, indicated high biodegradability of leachate from biowaste. As a result of biodegradation process, biomass developed and biodegradability decreased by 80 %, while overall removal efficiency of dissolved organic matter was 89 % at the end of biodegradation process.

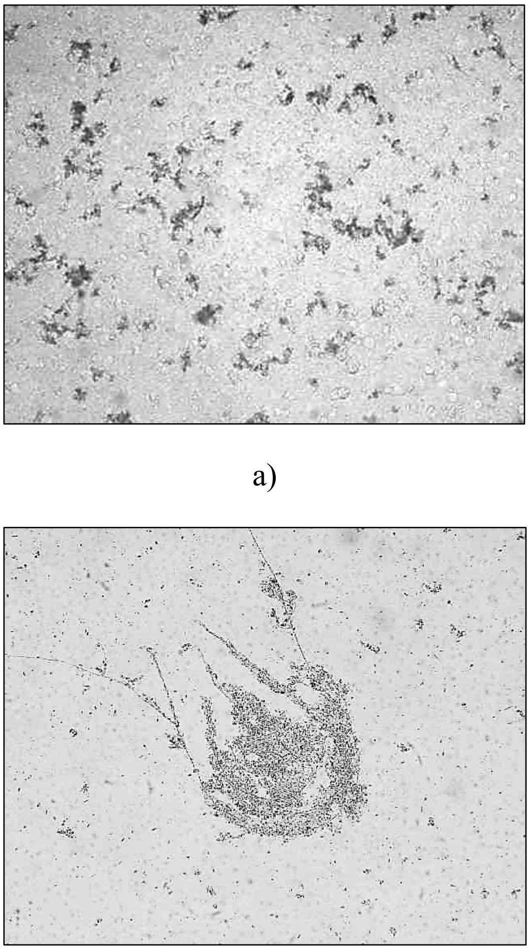
Table 1. Physico-chemical characteristics of leachate from biowaste at the beginning and at the end of biodegradation experiment

Parameters	Initial values	Final values
COD (g O_2/L)	12.21 ± 0.46	1.39 ± 0.24
BOD_5 (g O_2/L)	7.94 ± 0.98	0.18 ± 0.02
BOD_5/COD (-)	0.65 ± 0.76	0.13 ± 0.11
pH (-)	4.05 ± 0.13	8.45 ± 0.06
EC_{50} (%)	6.45 ± 0.17	25.33 ± 0.88

While biological wastewater treatment generally occurs at neutral pH, in conducted experiment pH value changed from 4.05 to 8.45. Due to the decomposition of organic nitrogen in biodegradation process ammonium is released. Hence, the concentration of NH_4^+ is increased and pH value increases to alkaline range [24]. Optimum pH for bacterial growth is neutral pH area to slightly basic pH, while optimal growth of fungi is in acidic environments [25].

In conducted experiment, leachate from biowaste was considered toxic according to EC_{50} values [16]. From Table 1 it can be observed that at the beginning of the experiment value EC_{50} was 3.93 times lower than the EC_{50} value at the end of experiment. This means that leachate at the beginning of the experiment consist of more toxic compounds than at the end of experiment. Despite its toxicity, biodegradation treatment was successfully used. Major changes in colour and odour appeared at the end of biodegradation process. Unpleasant, slightly acidic odour, correlates with low pH value at the beginning of the experiment. As the process was near to its end, the odour became more pleasant, because of the removal of organic matter, which also increased pH value. Due to development of activated sludge and degradation of organic matter the colour of leachate became darker.

Microscopic analysis was conducted in order to give insight in the course of the biodegradation process. The results of microscopic examination are shown in Figure 4. At the 2nd day of the experiment, the flocs started to form. A great number of small sludge flocs, irregularly shaped, with open floc structure which is specific for young sludge [26] can be seen in Figure 4a. Transparent and loose flocs indicate development of new biomass during the biodegradation process [9]. In the biodegradation process, as a result of degradation of organic matter, microbial growth appears. From Figure 4b it can be seen that in the 6th day of the experiment the formed and compact flocs appeared, with floc shape specific for biodegradation process of biowaste leachate in batch conditions.



a)

b)

Figure 4. Microscopic photographs of developed activated sludge flocs in biodegradation process of leachate from biowaste, magnification 100×: a) 2nd day, b) 6th day

CONCLUSION

Biowaste leachate is characterized by high organic load, toxicity and acidic pH value, thus treatment of leachate needs to be applied before its disposal to environment. The high value of biodegradability of biowaste leachate supported the concept of biological treatment application, which can also correlate to the application of composting process for treatment of solid biowaste. The process of leachate biodegradation was induced by aerobic conditions which led to removal of dissolved organic matter from biowaste leachate by naturally occurring microorganisms where COD/MLSS ratio was reduced for 94 %. As green technologies have gained more attention in field of environmental protection in recent years, biological treatment can be considered environmental friendly and cost effective technology.

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