EXAMINATION OF THE DECOMPOSITION OF WILLOW, POPLAR AND MIXED LEAF LITTER WITH LITTERBAG TECHNIQUE

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Abstract

Leaf litter decomposition is one of the most important ecological material cycle processes. For saprophytic water organisms, allochtonous plant parts (especially leaves) represent the main source of energy and nutrients. As a consequence of their shredding activity, the organic nutrients of detritus can return into soil, and can be uptaken by plants again. In our study, decomposition rates of willow *(Salix* sp.*)*, poplar *(Populus* sp.*)* and mixed leaf litter were monitorized, with litterbag method in a class „A" evaporation pan. Litterbags were used with two different mesh sizes. With the 500 µm mesh-sized bag we were able to examine decomposition with the exclusion of macroinvertebrates, and with the 3 mm mesh-sized bag we got information in the presence of them. The study took place between 15. June 2019. and

24. October 2019. Based on our results, we did not notice any remarkable differences between the decomposition of willow, poplar and mixed leaf litter. All of them fell into „medium" decomposition category. Furthermore, we did not measure notable differences between the two different devices. During each and every sampling, water samples were also taken, and their pH, conductivity, NH_4^+, PO_4^{3-}, SO_4^{2-} and Cl^--ion content were determined. There weren't any considerable changes in the quality of water, during the experimental period. The main aim of the study was to examine the process of decomposition and the changes of water parameters, furthermore, to compare the evaporation of the modified experimental pan (sediment, decomposing leaf litter), with the standard class „A" evaporation pan's (control pan). From that, it was able to determine the effect of decomposing leaf litter on evaporation. From the results of this experiment, we found that, the presence of sludge, and decomposing leaf litter, placed in the modified pan, increased the rate of evaporation in 2019.

Keywords: decomposition, willow, poplar, litterbag, class „A" evaporation pan

Összefoglalás

Az avarlebontás egyike a legfontosabb ökológiai anyagkörforgalmi folyamatoknak. A szaprofita vízi élőlényeknek és a vízi szervezeteknek a külső forrásból érkező növényi részek (főleg falevelek) jelentik a fő energia és tápanyagforrást. Az aprító tevékenységük következtében a detritusz szerves anyagai visszajutnak a talajba és ismét felvehetővé válnak a producensek számára. Kutatásunkban a fűz *(Salix* sp.*)*, nyár *(Populus* sp.*)* és kevert avar lebontását vizsgáltuk, avarzsákos módszerrel, „A" típusú párolgásmérő kádban. Kétféle avarzsák típust használtunk. Az 500 µm lyukbőségű avarzsák segítségével ki tudtuk zárni a makrogerinctelen szervezeteket a rendszerből, míg a 3 mm lyukbőségű avarzsákkal ezek jelenlétében vizsgálhattuk a lebontást. A kutatás 2019. június 15. és 2019. október 24. között zajlott. Eredményeinket tekintve nem tapasztaltunk meghatározó különbségeket a fűz, nyár, és kevert avar lebontási ütemében. Továbbá nem tapasztaltunk kimagasló eltérést a 2 különböző eszköz esetében sem. A mintavételek alkalmával a vízminták vétele is minden esetben megtörtént, melyekből a pH-t, vezetőképességet, NH_4^+, PO_4^{3-}, SO_4^{2-} és Cl^--ion tartalmat határoztuk meg. A vízkémiai paraméterek tekintetében sem volt nagyobb mérvű változás a kísérleti időszak alatt. Kutatásunk fő célja az avarlebontás ütemének vizsgálata volt, emellett a vízkémiai paraméterek változásának figyelemmel kísérése, továbbá az avarlebontásnak helyet adó módosított kád (iszap, bomló avar), standard „A" típusú kád (kontroll kád) párolgásával való összehasonlítása. Ez utóbbiból meghatározhattuk a bomló avar párolgásra gyakorolt hatását is. Ennek a kísérletnek eredményeiből megállapítottuk, hogy a módosított kádba kihelyezett iszap, és bomló avar jelenléte növelte a párolgás ütemét 2019-ben.

Kulcsszavak: lebontás, fűz, nyár, avarzsák, „A" típusú párolgásmérő kád

Introduction

In the floodplain of rivers and highland and lowland streams the dominant plant communities are willow and poplar forests (Bagi et al., 1996). Plant parts can get into the water body from two main sources. The first and most important one is the allochtonous source which also contains branches, twigs, cones, crust, fruits etc., but depending on the vegetation, leaves represent 42-98% of it (Abelho, 2001). Leaf fall means approximately 1000 to 7000 kg dry weight per hectar, so it is obvious, that we speak about a significant amount (Mátyás, 1997). Autochtonous source means the inner source, which is the organic material, produced by aquatic plants. Leaf litter decomposition is a multifactorial process, in which a number of micro- and macroinvertebrates take part. It is a long-term period process, which can be separated into three main parts. The first part is leaching, where leaves may lose up to 25% of their soluble organic material content (Webster et al., 1986). The second section is microbial colonisation, in which bacteria and microbial fungi colonise leaves and tenderize their structure. In the third part macroinvertebrates play the main role as they shred leaves into smaller pieces (Abelho, 2001). As a consequence of mechanical and biological processing CPOM (Coarse Particulate Organic Matter) transforms into FPOM (Fine Particulate Organic Matter) (Wurzbacher et al., 2016). CPOM is the fraction, which is bigger than 1 mm. FPOM is between 1 mm and 5 µm, and there is also a further category, DOM (Dissolved Organic Matter) which is smaller than 5 µm (Allan and Castillo, 2007). With shredding CPOM into FPOM, decomposers prepare usage form of mineral nutrition for other organisms (Santonja et al., 2018). The speed of decomposition depends on many factors, such as environmental conditions, like water temperature and flow conditions, litter input, which is limited by the nearby vegetation, chemical composition of leaves and the concentration of chemical compounds in water. Fungi have a prominent role in decomposition, because they do the breakdown of large molecular polymers, such as cellulose, kitin and lignin (Moorhead and Reynolds, 1992). According to our knowledge, there are approximately 600 water fungi from which about 300 belong to Ingoldian hyphomycetes (Goh and Hyde, 1996). PH is also an important factor because most of the decomposers are narrow tolerant species, and prefer neutral pH value. Aquatic microbes are micro-algae, bacteria, viruses, fungi, protozoas and archeas in less than 200 µm size range (Sigee, 2005). Macroinvertebrates are bigger than 200 µm and the main taxons are snails, shells, leeches, crustaceans, dragonflies, bugs and water beetles. These listed creatures disengage the bonded organic compounds of dead plant material, so it can be consumable for the aquatic and terrestrial producers again. In natural waters their function is not only decomposing. They also serve as preys for fishes and other insectivorous aquatic animals (Ward et al., 1995). As time goes by, water parameters will also change with the progresses of decomposition, because more and more dissolved substances will be released into the water.

Materials and Methods

The usage of litterbag method

Our experiment was set up at the Agrometeorological Research Station at University of Pannonia, Keszthely (N: 46° 44’ 7.93”, E: 17° 14’ 16.65”). Leaf litter was collected from two different venues: willow from the lakeside of Lake Balaton and poplar from the area of Kis-Balaton. After that, it was let to dry to constant weight, then 10-10 g of willow, poplar and mixed leaf litter was filled into tiny litterbags. To examine decomposition rates we have chosen the litterbag technique, which is a widely acknowledged method, firstly described by Singh and Gupta (1977). The litterbags were made in two different mesh-sizes and were made out of non-biodegradable materials. It is expedient to use litterbags in the two different, upper mentioned mesh-size because with the exclusion of macroinvertebrates we can easily underestimate decomposition rates (Robertson et al., 1999). The experiment was launched in 05. 06. 2019. The size and arrangement of the pans fitted the world-wide accepted standards (inside and outside white, 120 cm diameter, 25 cm deep, layed on double wooden lattice, filled with tap water) (Gombos, 2011). The bottom of the modified class „A” evaporation pan was filled with sediment from Lake Balaton in 3 cm layer, in order to let decomposers in the system, then it was filled up with tap water. (In this research, tap water was used, instead of water from Lake Balaton, because we had to compare the evaporation of the experimental pan with the standard evaporation pan's.) The litterbags were tied to storage bins and were weighted to the bottom of the pan with greater stones to avoid their displacement *(Figure 1).*

Figure 1.: Class „A" evaporation pan with litterbags

Sampling and processing of the samples

The first sampling happened 64 days after the launch of the experiment, then further samplings took place every 2 weeks. On each occasion 12 samples were processed: 2 willow, 2 poplar, 2 mixed samples with 3 mm and 500 µm mesh sized litterbags. The bags weren't put into natural water, however, we could have assumed that, macroinvertebrates get into the system from the sediment or from the air. That is the reason, why we used 2 different mesh sizes. With the litterbags, water samples were also taken for subsequent water analytical tests. Under laboratory conditions, litter samples were unwrapped and depurated from contaminations with laboratory sieve and tap water *(Figure 2)*, then they were left to dry until their constant weight, for usually 2 weeks.

Figure 2.: Depurate of leaf litter samples

In the next step, we measured the remaining dry weights on digital analytical scales, and got information about weight loss. To define the decomposition rates, Graca et al's. (2005) widely acknowledged and used exponential decay model was applied:

$$\mathbf{Mt = M_0 \cdot e^{-kt}}, \qquad (1)$$

where „Mt" (g) is the mass at time, „M_0" (g) is the mass at time 0, „k" (day^{-1}) is the exponential decay coefficient and „t" (day) is time. With the exponential decay coefficient decomposition can be classified into three speed categories. If k<0.005 it is slow, if k=0.005-0.01 it is medium, and if k>0.01, we can speak about fast decomposition (Graca et al., 2005). The halving times were also measured, based on another formula of Graca el al. (2005):

$$\mathbf{TH = \ln 2 \cdot k^{-1}} \qquad (2)$$

It shows that how many days does it take for the samples to lose the half of their weight.

Measurement of water physical and chemical parameters

To define pH, conductivity and NH_4^+, PO_4^{3-}, SO_4^{2-} and Cl^- -ion-content of the water samples Adwa AD110 pH and thermometer, Adwa AD310 conductivity-temp portable meter and Lovibond Multidirect Spectrophotometer were used.

Measurement of evaporation

Next to the modified evaporation pan, a standard „A" pan was also settled, to compare their evaporation results. The water level of the pans had to be 5 centimetres under the edge of the pan, and it wasn't allowed to go 7.5 centimetres under it (Brouwer & Heibloem 1986). It is extremely important to maintain the water level, because if it falls 10 centimetres under the required level, measurement errors can be as high as 15 percent (Brouwer & Heibloem 1986). Wire mesh was stretched around the class „A" evaporation pans to prevent animals (birds and smaller mammals) from drinking the pan's water. It could have increased the measured values by up to 7% (Gifford et al. 2005). The measurement was performed according to the meteorological practice, during which the hole of the measuring cylinder placed in the tub was opened with a screw, and then, following the law of the moving vessels, the water level in the cylinder stopped at the level, that was in the tub. After the water level had levelled off, to determine the height of the water column, the hole was closed, then water was filled into 0.1 mm scaled glass measuring cylinder. After the measurement, it was filled back to the pan. The amount of daily evaporation was given by the difference in water column heights, measured on two consecutive days. During the experiment, actual evaporation was determined by subtracting the daily precipitation. The measurement was performed at the usual 7 a.m. observation time, in the morning (WMO, 1966, 1976). Tap water was used to replace evaporated water. It was stored in 120 l white tanks, in order to replace evaporated water, with water of the same temperature (Anda et al., 2016, 2018). Daily evaporation of the treatments was analyzed by paired t-test at the significance level of 0.05.

Results and Discussions

Water chemical parameters

The parameters, and dissolved material-, and ion-content of the pan's water were slowly, but constantly changing as time went by. Nevertheless, we did not notice any outstanding changes during the experimental period. Only conductivity and NH_4^+ content has shown less variability.

Table 1. Water quality parameters during the experimental period

pH	7.93±0.35
Conductivity (µS/cm)	325.93±218.45
NH_4^+ (mg/l)	0.367±0.16
SO_4^{2-} (mg/l)	14.71±8.62
PO_4^{3-} (mg/l)	0.187±0.121
Cl^- (mg/l)	8.24±1.099

The pH of the pan's water (7,93±0,35) was slightly alkaline, which is favourable for most of the saprophytes. In an experiment after the well-known red mud catastrophe, Hubai et al., (2007) were carrying out research by the Torna-stream. They reported that on strongly alkaline pH each and every evincible creature have disappeared, and they emerged only after the decrease of pH value again. In their study, Tripole et al. (2008) examined the tolerance spectrum of aquatic macroinvertebrates, depending on acidity, in the Grande-river. Their results have shown that there weren't any macroinvertebrates under 5.5 pH. The increase in conductivity can be traced back to leaching, in which more and more ions were released as time passed (Hasanuzzaman and Hossain, 2014). From that, it is obvious that leaf litter decomposition depends on a number of influencing factors. For example, Ágoston-Szabó et al., (2014) documented 69% mass loss by willow leaf litter, also in a 140 day experimental period. It is more than our 57.3%, and the reason of the difference could be the diversity of environmental, water temperature and flow conditions. In the absence of drift, degraded materials and sediments may accumulate in litterbags which, if not flushed or removed, may reduce colonisation of microorganisms, thereby reducing the rate of degradation (Chauvet, 1987). Meentemeyer (1978) mentioned water temperature as the main influencing factor in leaf litter decomposition. Other researchers, such as Liu and Sun (2013) emphasises C:N ratio of leaves as the main factor. I believe that, all of these mentioned factors take part in decomposition and their influencing force depends on the local environmental conditions, and human interventions.

Leaf litter decomposition

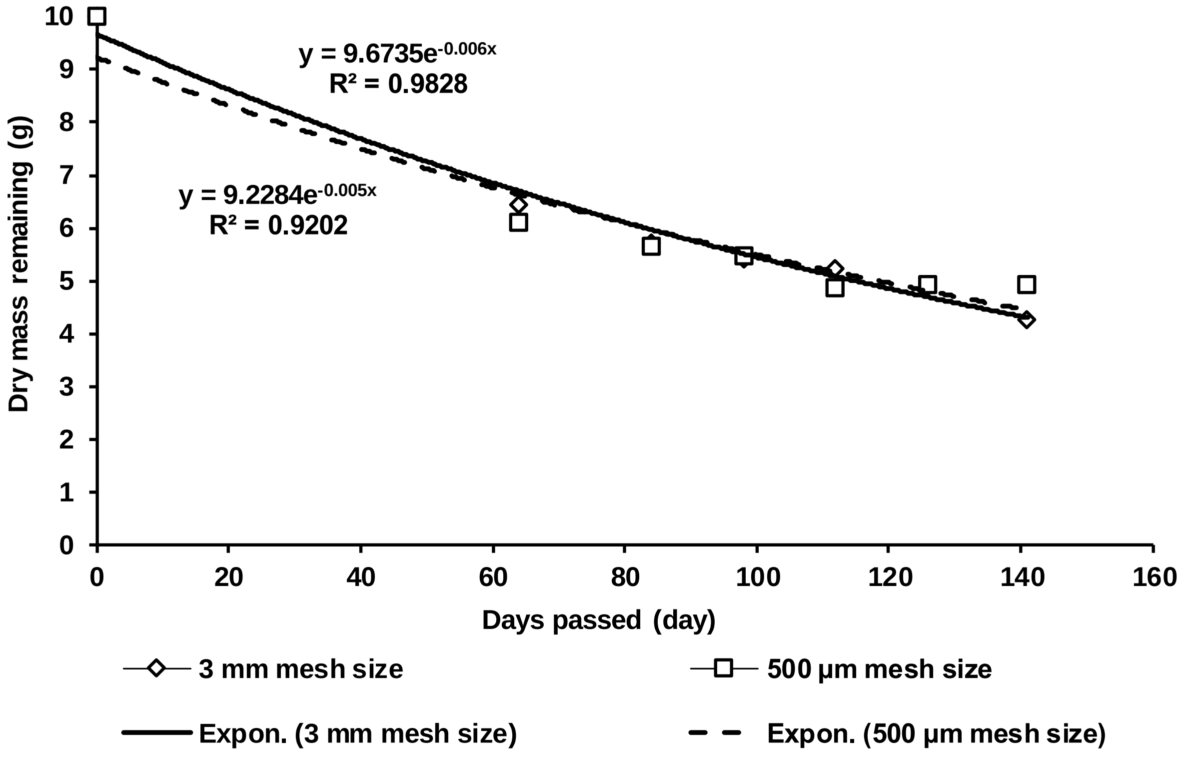

Figure 3. Decomposition rate of willow (Salix sp.*) in class ,,A'' evaporation pan*

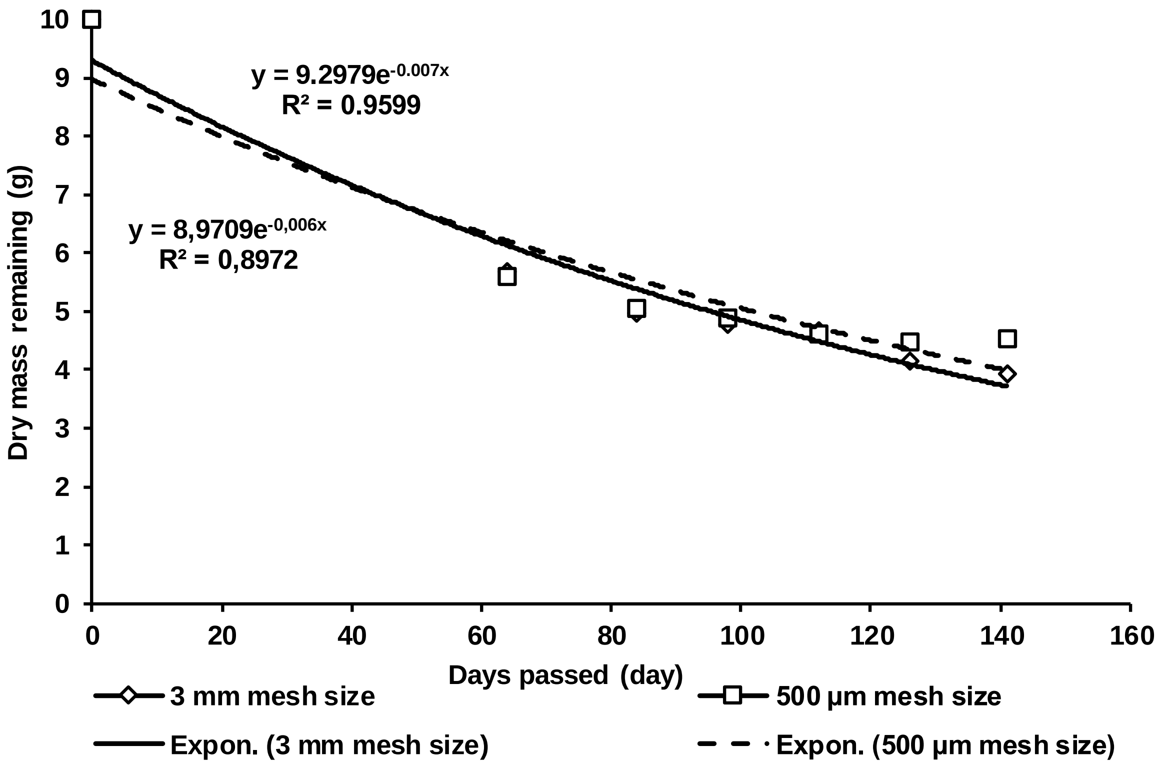

Figure 4. Decomposition rate of poplar (Populus sp.*) in class „A" evaporation pan*

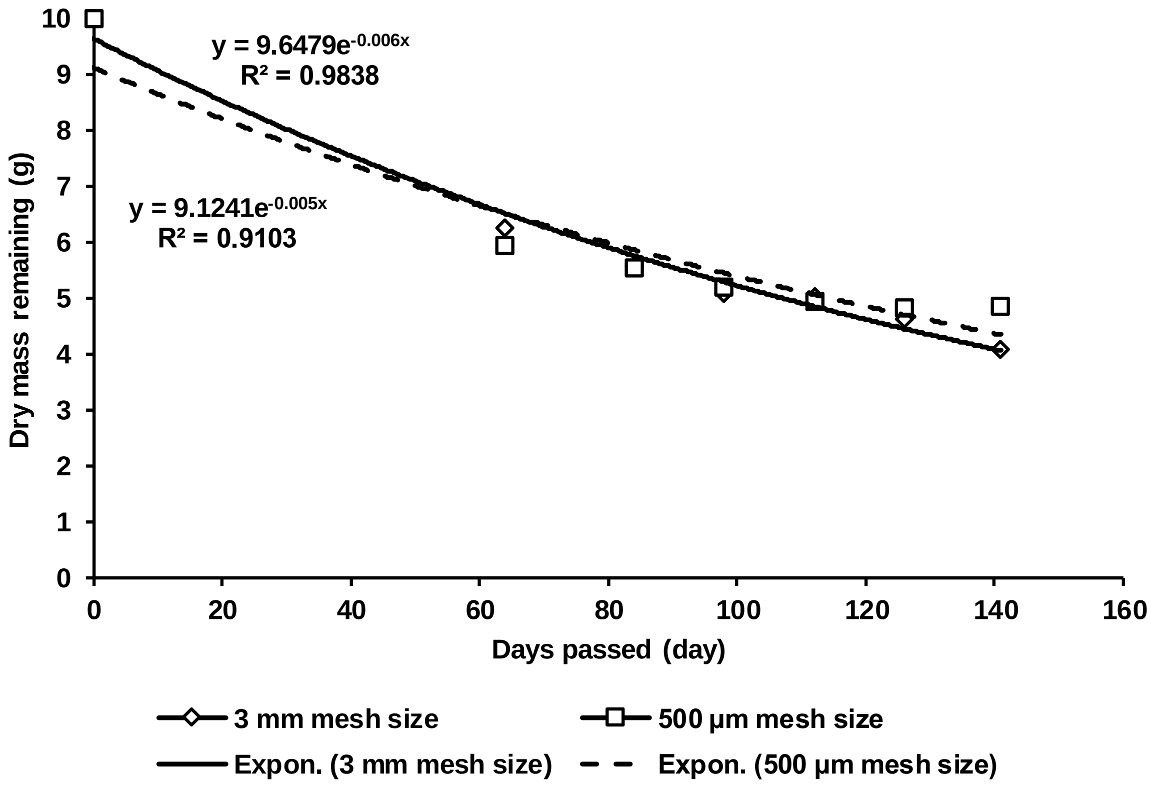

Figure 5. Decomposition rate of mixed leaves in class „A" evaporation pan

Decomposition followed exponential curve in every case (Figure 3-5). On the 112nd day the line of wide mesh-sized samples overcame the 500 µm mesh-sized litterbag's line by every litter type. The probably reason may be the hatching and shredding activity of macroinvertebrates.

Table 2.: The halving times of the investigated leaves from 15 June 2019. to 24 October 2019.

Leaf litter type	**Litterbag mesh-size**	**Halving times (day)**
Willow	3 mm	111.6
Willow	500 µm	110.3
Poplar	3 mm	92.3
Poplar	500 µm	95.9
Mixed	3 mm	104.62
Mixed	500 µm	106.5

Concerning to halving times, there weren't any considerable differences between the three litter types, and the two distinct litterbags. Zhai et al. (2019) also examined the decomposition of willow and poplar in the University of Bejing with litterbag technique, and in their results, there weren't significant differences in the speed of decomposition between the two different mesh-sized bags. The longest halving time was observed by willow, and the shortest by poplar. Mixed samples were between the two upper mentioned tree species.

The k values were expressed from the exponential decay model (Figure 6).

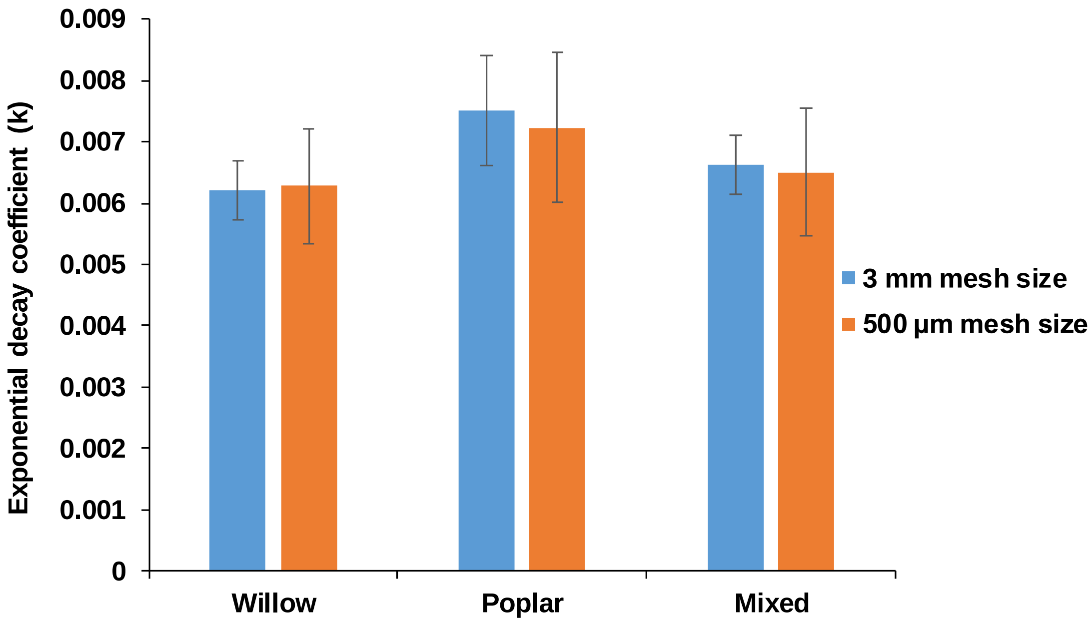

Figure 6. The distribution of exponential decay coefficient among our samples

On the diagram we can see that all „k" coefficients fell between 0.005 and 0.01 unit, so all of them were classified into „medium" decomposition category. Furthermore, there weren't any outstanding differences in the speed of decomposition, between the two different mesh-sized devices. In their study Markus and Gessner (2009) said, that the usage of mixed leaves tend to accelerate decomposition. The mixture of leaves containing more than one species could provide more homogenous nutrients for the decomposers, even species with narrow demands (Chapman and Koch, 2007). With our results, these statements cannot be proven. The highest value (k=0.0075±0.0009) was measured on poplar, with wide mesh-size, and the lowest value (k=0.0062±0.0005) on willow, also with wide mesh-sized bags. The results of mixed leaf litter were almost exactly the average of the two other litter types.

Evaporation from the pans

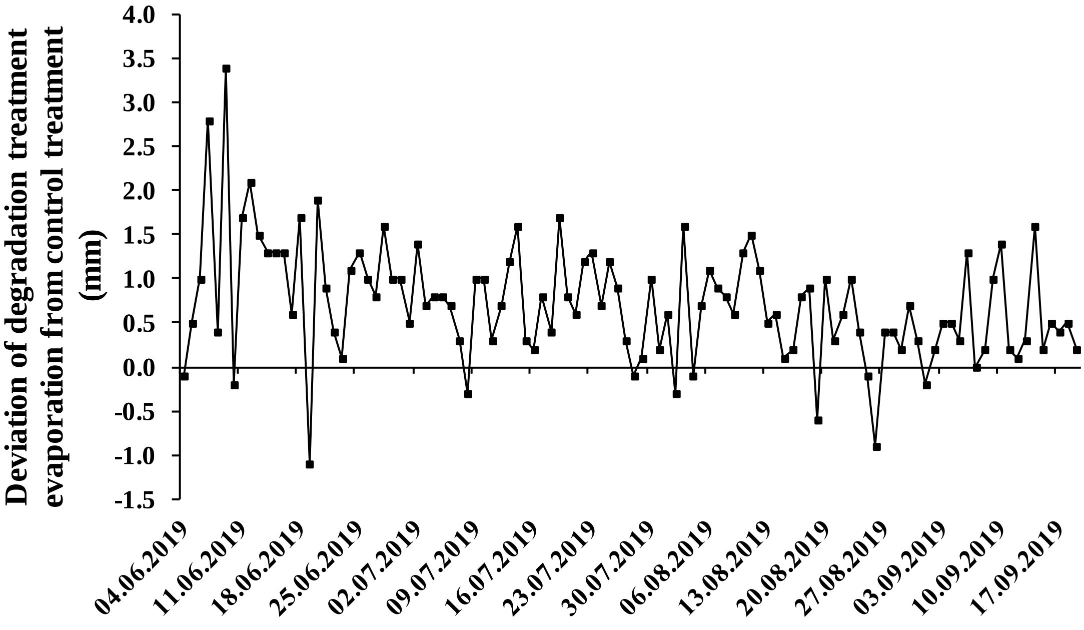

Figure 7. Differences in evaporation, between the modified and the control class „A" evaporation pans

The seasonal average daily evaporation of the control pan was 3.6±1.3 mm*day^{-1}, and the degradation treatment's result was 4.3±1.6 mm*day^{-1}. 19 % higher ($p<0.001$) evaporation rate in modified pan's evaporation was observed, which means that sediment and leaf litter placed in the pans increased the evaporation in 2019. The probably reason may be the higher energy absorption of filled pan, due to the darker color of the sediment (the standard tub is white), and the heat releases during the decomposition processes.

Conclusions

Taking everything into account, leaf litter decomposition is a complex multifactorial process, which is influenced by a number of natural and human factors. There are many other studies dealing with the decomposition of the same species, among different conditions. They all get conspicuously different results. Therefore, it can be stated, that the speed of decomposition is mostly influenced by water temperature, water quality (in connection with decomposers), the variety of saprophytes, decomposed plant species, and the chemical structure, and nutrient content of leaves. There are plenty of studies investigating decomposition rates in great lakes, rivers and disaster-weighted venues, but as far as I am concerned, it would be expedient to assess the decomposition rates of the Country's smaller streams too, to get a clearer picture about the condition of our waters, which could be useful to find out, if there is any deficiency, which may require human intervention. Temperature is also one of the main factors of decomposition, so global warming may bring unforeseen changes, so it would be advantageous to start researches examining the effects of global warming, on leaf litter decomposition. Furthermore, while leaf litter represent the main source of nutrients and energy for aquatic microorganisms, the protection of waterfront plant communities would also be inevitable.

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