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# HUNGARIAN AGRICULTURAL RESEARCH

December 2019

**Environmental management, land use, biodiversity**

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# BIODEGRADABLE PLASTICS – AN INNOVATIVE GROWING MARKET

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## ABSTRACT

There has been a big boom in the production and application of biopolymers, but the utilization of biodegradable polymers is critical because current waste management systems in most cases are not suitable for treating these types of waste. The purpose of our research is to confirm the hypothesis that biopolymers are good feedstock (input materials) for anaerobic digestion and/or composting systems. We seek to strengthen with scientific data the claim that biopolymers must be collected source separated, and aerobic and/or anaerobic treatment is necessary for closing the organic loop. We therefore undertook the following related measurements: TS, VS, LOI, OM, pH, respiration intensity ($AT_{30}$), and biomethane potential (BMP). We found that biopolymers do have significant BMP. Moreover, we present a successful story about a project by Profikomp Inc. involving the on-site composting of biodegradable bioplastics wastes at the Sziget Festival in Hungary in 2019.

**Keywords: bioplastic, biopolymer, biodegradable, composting, biogas**

## INTRODUCTION

### *Definitions*

There are some misunderstandings and uncertainties concerning the definition of biopolymers, mainly due to the fact that biopolymer materials are relatively new. It is essential to clearly define the related categories and to distinguish them. Over past decades, intensive research has been carried out on this subject, which has led to the refinement of the original definitions. Another reason for misunderstanding originates from the two types of classification of biopolymers. We can distinguish biopolymers by origin (those derived from living organisms, including those that come from renewable energy sources, and those that come from fossil energy sources). With some biopolymers, both conditions (created from renewable energy, and potential for complete biodegradation) are fulfilled, while there are some other biopolymers for which only one of these conditions is fulfilled. The illustration below shows a classification of bioplastics and their distinction from conventional plastics. In conclusion, the term bioplastic includes *bio-based and biodegradable*, *bio-based but not biodegradable*, and also *biodegradable plastics that do not come from renewable energy sources* [1], [2].

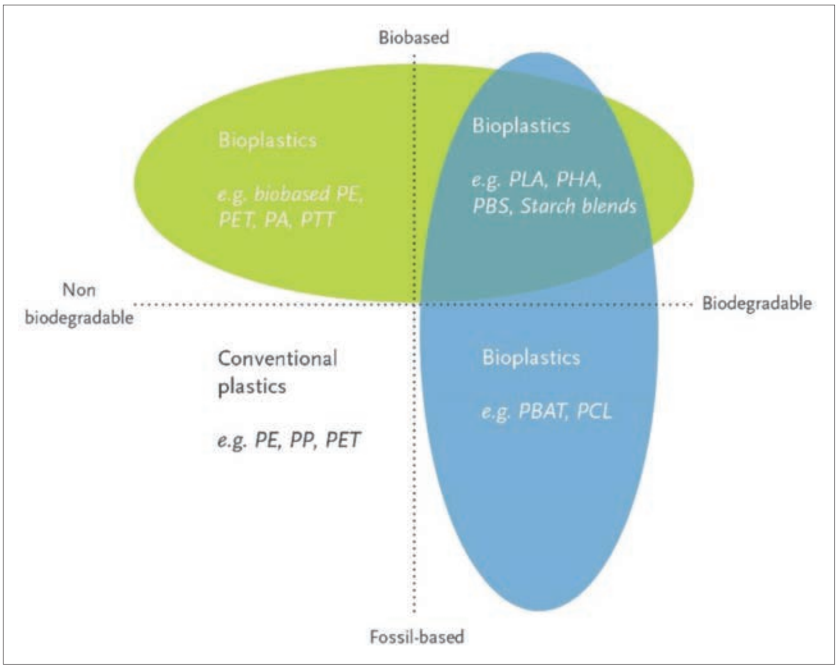


**Figure 1: Classification of plastics and bioplastics (*Source: https://www.european-bioplastics.org/bioplastics/*)**

It is very important to clarify that "oxo-degradable" plastics, which are unfortunately used nowadays as degradable plastics, are conventional plastics which have already been banned in many countries because of the related environmental problems such as the production of microplastics, their inability to be recycled, and the generation of impurities in composts. Oxo-degradable plastics, thanks to the use of additives, disintegrate quickly in the environment with the application of light, heat, or mechanical pressure. However, these materials do not biodegrade but only break down into smaller pieces (microplastics), thus they cannot be considered biodegradable.

### *Market situation*

Based on data from the European Bioplastics Association, bioplastics currently account for about one percent of the more than 359 million tonnes of plastic produced annually. But as demand is rising and more sophisticated biopolymers, applications, and products are emerging, the market for bioplastics is continuously growing and diversifying. According to the new EU Directive on Single-Use Plastics, when alternatives are easily available and affordable, single-use plastic products will be banned from the market. The new regulations indicate a new and growing market for bioplastic materials [3].

Regarding the material types of biopolymers, in the bio-based but non-biodegradable group polyethylene (PE), polyethylene-terephthalate (PET), and polyamide (PA) are represented in greatest proportions (11.8%, 9.8% and 11.6%, respectively), while in the biodegradable group starch blends, polybutylene adipate terephtalate (PBAT), and polylactic acid (PLA) are the types with the largest share (21.3%, 13.4% and 13.9%, respectively) (Figure 2).

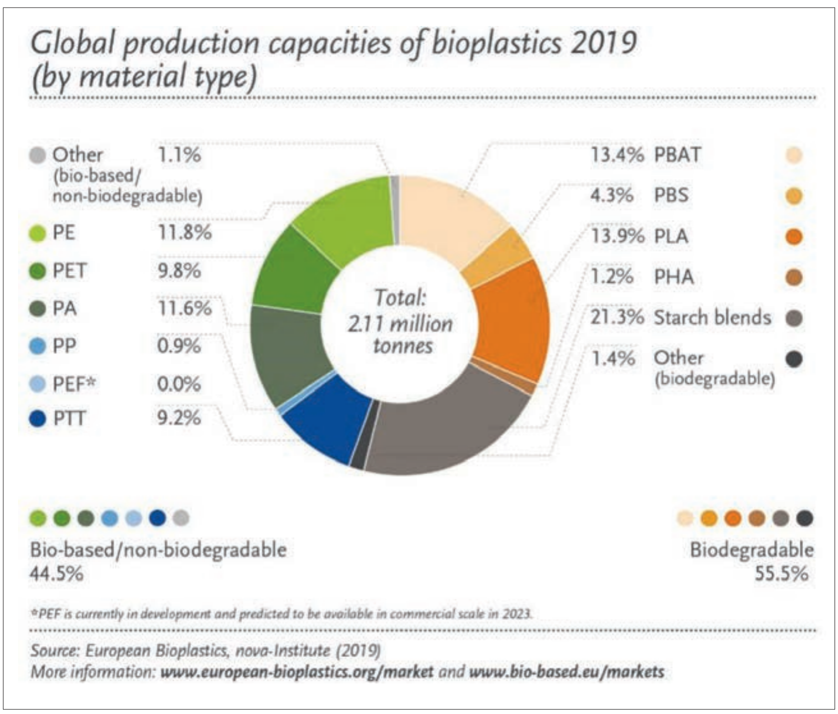


**Figure 2: Proportions of material types of biopolymers.** ***(Source: https://www.european-bioplastics.org/bioplastics/)***

Biodegradable plastics together, including PLA, PHA, starch blends and others, account for over 55.5% (over 1 million tonnes) of global bioplastic production capacity. The production of biodegradable plastics is expected to increase to 1.33 million tonnes in 2024, especially due to the significant growth rate of PHA [3].

The use of biodegradable plastics is greatest in the area of packaging materials (and within this, for the production of biowaste collection bags), agricultural and garden sheets and covers, textiles and single-use consumer goods, and in car production, but there are also other fields of use on the market. The materials most frequently used are biodegradable starch, PLA, polybutylene succinate (PBS), and PBAT [3].

The land used to grow the renewable feedstock for the production of bioplastics amounted to approximately 0.79 million hectares in 2019, accounting for less than 0.02% of global agricultural area, which clearly shows that there is no competition between renewable feedstock for food, feed, and the production of bioplastics [3].

However, biopolymers are also very important for agriculture, because the end products of the utilization of these materials such as composts and digestates may be applied to agricultural fields. If the degradation of biopolymers does not occur properly during composting or anaerobic fermentation, the related fertilizer and soil improving materials can cause serious contamination and environmental problems.

### *Biodegradability*

In the case of polymers, biodegradation is a two-step process. The first stage, which has a significant effect on the speed of degradation, is hydrolysis. During this process polymers disintegrate into smaller units. In the next step, these smaller, often water-soluble units decompose further through a process of mineralization within the cell and become part of the newly created biomass.

During examinations of the biodegradability of organic matter under aerobic conditions, carbon-dioxide emissions and oxygen consumption are meas-

ured, while under anaerobic conditions methane and carbon-dioxide emissions are evaluated. Such tests are conducted in laboratories under standardized conditions. As degradability is strongly dependent on environmental conditions, there are different standards (European, ISO and OECD) for different sectors (soil, compost, water, etc.).
It is relatively difficult to measure biodegradability using a standardized procedure as there are many standards available, while new methods are still in the process of being developed [4].

Biological methane potential (BMP) tests (i.e. anaerobic biodegradability assays) are used to determine the anaerobic biodegradability and ultimate methane potential of wastes or biomass, as well as the biodegradation rate under laboratory conditions. Anaerobic fermentation is an extremely complex process which is influenced significantly by biological-chemical factors, living and non-living agents, and the interactions between these [5], [6]. The more influential physical-chemical parameters are temperature, pH, the C/N ratio, OLR, alkalinity, and the concentration of volatile fatty acids (VFAs) [7], [8], [9]. Nevertheless, a new European interlaboratory assay is taking place and should soon yield new conclusions in this regard [10].

### *The examination of biodegradable biopolymers in practice*

In addition to examinations that have been carried out based on the relevant standards (MSZ, EN, ISO, ASTM) in the case of already certified and labeled products, it is important to carry out a practical examination of the biodegradability of products, and an analysis of final products. This can increase confidence concerning bioplastics, not only for the people who use them, but also for the waste sector.
Biopolymer-based biodegradable products can be biologically recovered after they have become waste. If biological waste treatment is the optimal solution, depending on the type of material the most appropriate type of waste treatment technology can be selected (industrial composting, garden composting, or anaerobic digestion in a biogas plant) and several different tests can be performed to determine the related biodegradability and quality parameters.
1. Above all, it is essential to examine the physical, chemical, and biological parameters of biopolymer wastes and by-products. These instrumental chemical and physical laboratory analyses are essential and necessary for furthering the understanding of biopolymers.
2. Investigation of the biodegradability of biopolymer wastes and by-products can take place during industrial composting or modeling in a bioreactor.
2.a.) During an industrial composting test, a sample is examined under realistic conditions using industrial composting technologies during a complete (12-week) or partial (4-week) composting cycle.
2.b.) The bioreactor test provides the opportunity to simulate the conditions of either an industrial composting or home composting environment, or anaerobic digestion, and thus gives an accurate picture of realistic biodegradability.
3. Examining the compost end product is also very important, as the usage (marketing) of compost made from biopolymer wastes must also comply with the legal requirements for compost products.
Since the biodegradation of biopolymers in most cases does not occur in nature but under artificial conditions (e.g. through industrial composting), it is important to study the related waste management systems and technologies.
Because the utilization of biodegradable, biopolymer-based products may require the modification of existing technologies or the application of new methods and technologies, it is also possible to study related waste treatment systems such as pre-treatment-, treatment-, and post-treatment technologies.
In relation to the above-mentioned facts and descriptions of the actual situation of biopolymers, we executed the following tests in order to determine the biodegradability of bioplastic products: biomethane potential (BMP), res-

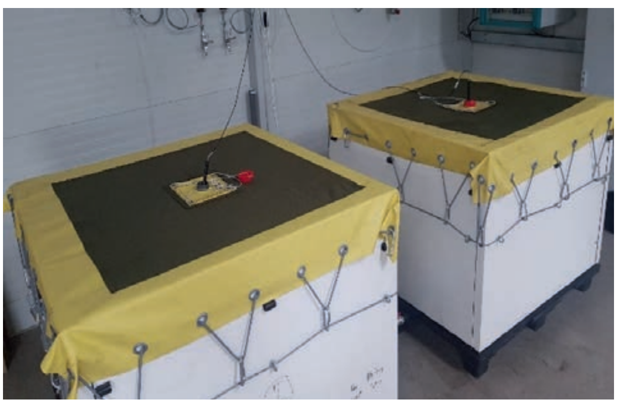

**Figure 3: Measurement of the biodegradability of bioplastics using respirometry and in bioreactors at Profikomp Inc**.

piration intensity ($AT_{30}$), total solid content (TS), volatile solid content (VS), loss on ignition (LOI), organic matter content (OM), and pH.

## MATERIALS AND METHODS FOR METHANEPOTENTIAL TESTS

### *Inoculum*

We obtained the inoculum from the mesophilic reactor of a plant operating in Hungary. The substrates of this plant are agricultural materials (animal manure and plant residue) and industrial food byproducts.

### *Samples*

Samples were certified and labeled (EN13432) bioplastic products available on the market. Samples were ground into pieces smaller than 5 mm.

### *Experimental methods:*

The anaerobic digestion study was carried out using the AMPTS II (Automatic Methane Potential Test System II) produced by Bioprocess Control AB (Figure 4).

The system consists of the following main parts:

• Water-bath with a capacity of 15 reactors of 600 ml each. Each reactor was connected to a mechanical agitator.

• Alkali solution: unit for chemically removing $CO_2$ and $H_2S$. The remaining gas (~methane) after scrubbing was transported to the next unit, the gas flow meter.

• Wet gas flow measuring device: the methane passing from the scrubbing unit enters the wet gas flow-measuring device which has 15 cells, one for each reactor. Data were recorded by the data acquisition system.

Before the tests, BMP reactors were purged with high purity nitrogen for three minutes to remove oxygen from the reactor head space. The exact weight of substrates and inoculum was calculated by software based on the VS and the inoculum-to-substrate ratio (I/S). The latter was always 2:1. The total volume of substrate and inoculum in the reactors was always 400 ml, therefore the volume of the gas that was produced was 200 ml.

Blanks and controls were measured in every sequence in parallels of 3-3, thus we could measure only three different substrates (also arrayed in 3-3 parallels) in one sequence. In the case of the measuring of blanks, only inoculum was entered into the reactors after weighing. In the case of controls, we used microcrystalline cellulose, a product made by Molar Chemicals Kft.

Controls were used as a reference with regard to identifying the biologically activity of the inoculum.

The length of time for one sequence was 30-77 days. Tests were stopped if the volume of methane produced in one day was less than 20 ml.

### *Further measurements*

Before starting the tests it was necessary to specify the TS and the OM content of the substrates and the inoculum; furthermore, to calculate VS content. These data were necessary for determining the exact weight of the substrates and the inoculum to be put into the reactors.

TS measurement was executed based on the standard MSZ EN 13040:2008.

Measurements of OM were based on the LOI method (MSZ EN 15935:2013).

Further analytical measurements were conducted: respiration intensity, and pH.

Respiration intensity values were determined by using OXITOP®. Originally, the procedure was standardized to measure the biological stability of wastes, although it has been confirmed that OXITOP® can be efficiently and reliably used for other purposes. The temperature at which measurement was taken was 20°C, and the duration of the tests was thirty days (accordingly, the abbreviation for this measurement in the following parts of the paper is $AT_{30}$). pH was measured according to the standard MSZ EN 13037:2012. All analytical measurements were executed in three iterations.

**Figure 4: Automatic Methane Potential Test System II.**

## RESULTS

### *Results of analytical and biodegradability measurement*

Total solid (TS), volatile solid (VS), loss on ignition (LOI), organic matter content (OM), and pH results for the substrates can be seen in Table 1. The values represented are the averages of three parallel measurements in every case. VS is a calculated parameter. Rel-

| Table 1: Chemical properties of the investigated substrates. | | | | | | |
|---|---|---|---|---|---|---|
| **Substrate** | **TS [%]** | **VS [%]** | **LOI [%]** | **OM [%]** | **pH** | **$AT_{30}$ [mg $O_2$/g d.m.]** |
| Product 1 | 92.8 | 92.0 | 0.9 | 99.1 | 7.3 | 14.57 |
| Product 2 | 93.3 | 88.3 | 5.3 | 64.7 | 7.2 | 16.44 |
| Product 3 | 95.2 | 73.9 | 22.4 | 77.6 | 7 | 15.86 |
| Product 4 | 91.9 | 90.5 | 1.7 | 98.5 | 7.5 | 8.91 |
| Product 5 | 99.2 | 99.1 | 0.0 | 100.0 | 6.9 | 3.36 |
| Product 6 | 95.9 | 95.7 | 0.2 | 99.8 | 7.2 | 9.87 |
| Product 7 | 94.5 | 64.6 | 22.9 | 68.4 | 7 | 10.29 |
| Product 8 | 92.5 | 89.0 | 4.1 | 96.2 | 7.3 | 11.34 |
| Product 9 | 85.0 | 82.7 | 12.5 | 97.3 | 6.8 | - |
| Product 10 (n=9) | 80.0 | 78.1 | 15.8 | 97.7 | 6.9 | - |

ative deviation is negligible in the case of TS, VS, LOI, OM and pH measurements. From the perspective of anaerobic digestion, the pH values for substrates were within the right range: they were neutral or weakly alkaline, therefore adjustment of pH was not necessary. Respiration intensity measurements represent home-composting processes.

BMP values can be seen in Table 2. The number of parallel measurements was also three. except in the case of Product 10 because of its heterogeneity (n=9). The repeatability of AD tests was not acceptable in several cases. AMPTS II equipment saves data in continuously cumulated form, although separately and on a daily basis. The standard deviation of the blank measurements was acceptable in every measuring sequence. Controls measurements also confirmed the microbiological activity of the inoculum in every measuring sequence.

| Table 2: BMP of substrates and relative standard deviations. | | |
|---|---|---|
| **Substrate** | **Average BMP [Nml/gVS] (n=3)** | **Rel. St. Dev. [%]** |
| Product 1 | 437.42 | 12.4 |
| Product 2 | 447.41 | 4.6 |
| Product 3 | 333.71 | 6.1 |
| Product 4 | 567.4 | 19.1 |
| Product 5 | 367.7 | 7.2 |
| Product 6 | 443.8 | 4.9 |
| Product 7 | 359.6 | 3.8 |
| Product 8 | 322.6 | 4.7 |
| Product 9 | 56.2 | 13.9 |
| Product 10 (n=9) | 177.1 | 14.9 |

## DISCUSSION

The methanepotential of the biodegradable polymers under investigation was widely variable, although high in most cases. Eight of the ten bioplastic products produced methane in greater amounts than traditional biowaste (green waste or kitchen waste). Nevertheless, there were big differences in the process of methane production of the substrates. We can divide these differences into three groups: the initial intensity of methane production, the final BMP value, and the time period needed for degradation. In the case of Product 9, biological degradation barely occurred. Product 5 took two weeks before it started producing methane, but after this phase a high final BMP value was achieved with a moderate but continuous gradient. In the case of the other substrates, the initial intensity of methane production (the initial gradient of the curve) was regular. However, in the cases of Products 1, 2, 4, 7, and 8, the curve indicated saturation before the twentieth day, while Product 6 responded differently. After a very intensive first seven days, Product 6 produced methane continuously at a moderate intensity, and the test was stopped on the 77th day of the experiment. The methane production of Product 10 included a crash, low intensity, and also low final BMP. Thus, based on time required for biological degradation, two products (Products 5 and 6) took 77 days to reach the final BMP, while 21 days would have been enough for the other 8 products. Moreover, we recorded outstanding BMP in the case of Products 1, 2, and 4. These important observations are illustrated in the average methanepotential curves of the substrates in Figure 5.

The most important message from the observations described here concerns the significant differences between the biodegradability of biopolymers, proving that there is a need for the preliminary measurement of biodegradability. In addition, it is very important to highlight that biopolymers may have significant methanepotential.

## CASE STUDY

On-site composting of source-separated bioplastics wastes for the first time at Sziget Festival 2019 – one of the world's largest festivals

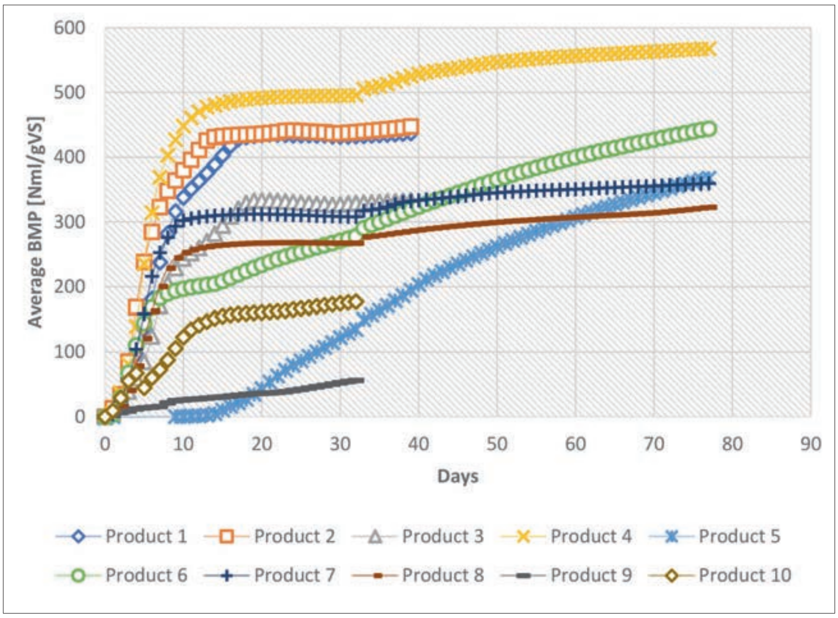


**Figure 5: Average MP curves for products.**

**Figure 6: On-site composting of food-contaminated tableware at Sziget Festival in 2019 using ProfiKomp® technology.**

Single-use biodegradable tableware (cups, bowls, and cutlery) are increasingly popular at large festivals at which these products cannot be substituted. In 2019, ProfiKomp Inc. partnered with Sziget Festival and successfully completed an on-site composting project which represented a viable solution to managing separately collected compostable biopolymer wastes.

The project started with an examination of biopolymer products, because for successful composting all tableware was required to meet the criteria of industrial compostability based on relevant standards (European norms). At Sziget Festival, compostable biopolymer waste (food packaging) contaminated with food leftovers was collected and treated separately. With its analytical and research capabilities, ProfiKomp was able to provide expert services in the field of investigating the biodegradability of raw materials, products, and wastes. By guaranteeing the compostability of the input material, and by using a tailored, on-site mobile composting technological solution and pre-treatment technology with special additives and the mixing of input materials, biopolymer wastes were made suitable for composting.

Due to the appropriate technology and optimal mixing of raw materials, a high quality compost free of impurities was produced from biopolymer waste. Quality biopolymer-derived compost end-products can meet the criteria applicable to compost products.

## CONCLUSIONS

There is a growing market for bioplastics, mainly because of the environmental damage caused by conventional plastic (and microplastic) wastes in nature, along with new regulations – for example, the forthcoming ban on single-use plastics from 2021. There is thus a need to obtain more scientific and practical experience with these new materials. The purpose of our research was to confirm the hypothesis that biopolymers represent good feedstock (input materials) for anaerobic digestion or aerobic composting systems. We collected a significant amount of scientific data that proves that it is useful to collect bioplastic waste source separated, and that anaerobic and/or aerobic treatment is required to close the organic loop. We proved that bioplastics may have significant methanepotential, but there are significant differences between the biodegradability of different biopolymers. This proves that there is a need for the preliminary measurement of biodegradability before biological waste treatment takes place. Moreover, we describe how we successfully implemented an on-site composting project involving biodegradable bioplastics wastes at the Sziget Festival in 2019.

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# LANDSCAPE CHARACTER AND HISTORICAL FUNCTIONS OF THE KURGAN FIELD NEAR KÉTEGYHÁZA

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## ABSTRACT

The burial mounds (kurgans) from the Late Copper Age are anthropogenic geomorphologic objects in the Great Hungarian Plain. These earth monuments have archaeological, cultural, landscape and nature conservational values. In the Kígyósi-puszta natural parkland research area located 75 kurgans (between Kétegyháza, Gyula, Szabadkígyós and Újkígyós settlements). We completed a complex conditional survey, morphological examination, and landscape historical description of the mounds. Many kurgans of the mound field near Kétegyháza were excavated by a scientific cooperation of Gyula Gazdapusztai archaeologist and the local agricultural producing corporation between 1966 and 1968. Some mounds were destroyed almost completely (e.g. the Török-halom), others show the sings of disturbance as landscape gashes. The Török-halom kurgan was already rebuilt in 2011 by the Körös-Maros National Park Directorate.
Kurgans can be found on their own, in pairs (double mounds), or in rows or groups, and their location shows a close correlation with natural geomorphology (they were built along banks of creeks, on loess ridges). During the millennia, their surfaces were intensively used by local communities; they were subjects of various forms of landscape exploitation (ploughing, forest management and tree planting, digging water canals, etc.), and both natural (fox holes, weed and shrub expansion) and anthropogenic processes (treasure hunting, boundary points, triangulation stations, soil removal, archaeological excavation) had their impact on them.

**Keywords: kurgan field, landscape and cultural values, landscape character, historical functions**

## INTRODUCTION

These thousands of burial mounds (kurgans) are the heritage of the so-called Yamnaya group, who arrived in multiple waves to the Carpathian Basin – east of the Tisza River, to the Danube-Tisza interfluve and the Transylvanian Maros River Valley – between the Middle Copper Age and the beginning of the Bronze Age. These barrows still stand high in the plain, even if in a somewhat damaged state and diminished numbers (Pető & Barczi 2011, Tóth & Tóth 2011, Bede 2016, Rákóczi 2016, Deák et al. 2016). These animal breeding, nomadic pastoral groups of eastern origin raised these mounds for burial purposes (Figure 1), with a sacral function (Ecsedy 1979, Dani & Horváth 2012).
Among the mounds of the plain, the barrow cemetery near Kétegyháza is of outstanding significance. The number, density, character and topography of the mounds all indicate that this must have been some kind of religious or tribal centre or sacred place of the kurgan builders (Bede 2016).
In the following, I will describe the landscape character

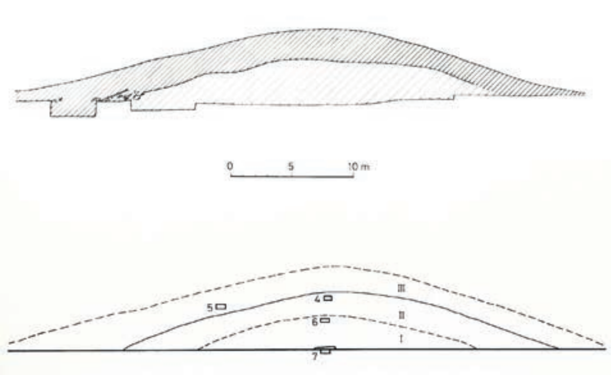


**Figure 1: The excavated Late Copper Age burials in the Török-halom kurgan and the structure of the mound (Ecsedy 1979: 24, Fig. 13–14)**

(main archaeogeographic-topographic traits) and historical functions (types of disturbances) of this field of mounds.

## MATERIAL AND METHODS

Our study was carried out in the Körös-Maros National Park, in the area called Kigyósi-puszta, which belongs to four different parishes (Gyula, Kétegyháza, Szabadkígyós, Újkígyós). The detailed morphological survey was carried out with a high-definition RTK (Topcon HiPer SR GNSS, FC336), and the evaluation and presentation of the recorded points was carried out with the appropriate GIS software (ArcGIS 10 és AutoCAD Map 3D 2010).
Information on landscape history were collected primarily from manuscript and printed maps, archival sources (e.g. parish charters), manuscripts and local historical and scientific literature.
Disturbances and other changes were recorded during the onsite assessment and survey of each mound, and a photographic documentation was also prepared in all cases.

## GEOMORPHOLOGIC BACKGROUND

The landscape itself, which is outstanding from the point of view of natural protection as well, is varied and sometimes quite mosaic-like (Figure 2). Parallel ancient channels of the Maros River (Vizes-völgy, Apáti-ér, Szabadkai-ér, Nagy-Csattogó, Hajdú-völgy) cut through the terrain (Gazdag 1960), with larger ridges and Pleistocene remnant surfaces between them (Rónai & Fehérvári 1960, Rónai 1981, Rakonczai 1986a). In the central area of the plain, there are large salinized steppe and marshes (alluvial basins), smaller loess grasslands, in the periphery scattered arable lands, forests and smaller grasslands (Rakonczai 1986b, Kertész 2006, Molnár & Biró 2017).

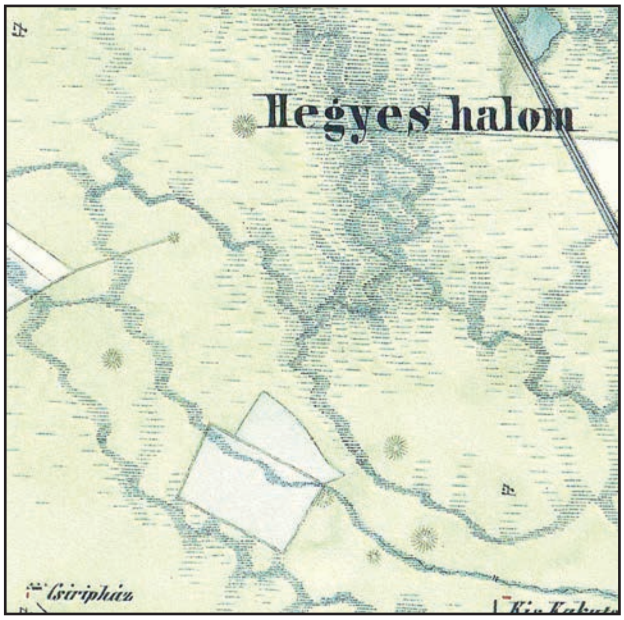


**Figure 3: Kurgans on the Second Military Ordnance Map, 1860**

Natural geological and geomorphological conditions must have played a crucial role in the selection and construction of the barrow field (Dövényi et al. 1977). The mounds are usually lined up along the banks of former riverbeds and on the ridges that accompany them (Figure 3).

## RESULTS AND DISCUSSION

### *Landscape character*

An archaeogeographic survey was carried out within the Kígyósi puszta area of the Körös-Maros National Park. In this area of 4,779 hectares, we registered 75 kurgans, seven of which had already been destroyed, the others suffered small (arable), medium (ditch, elevation point) or larger (canal, excavation, demolition) disturbances, especially during the last century. Since most of the mounds here do not have

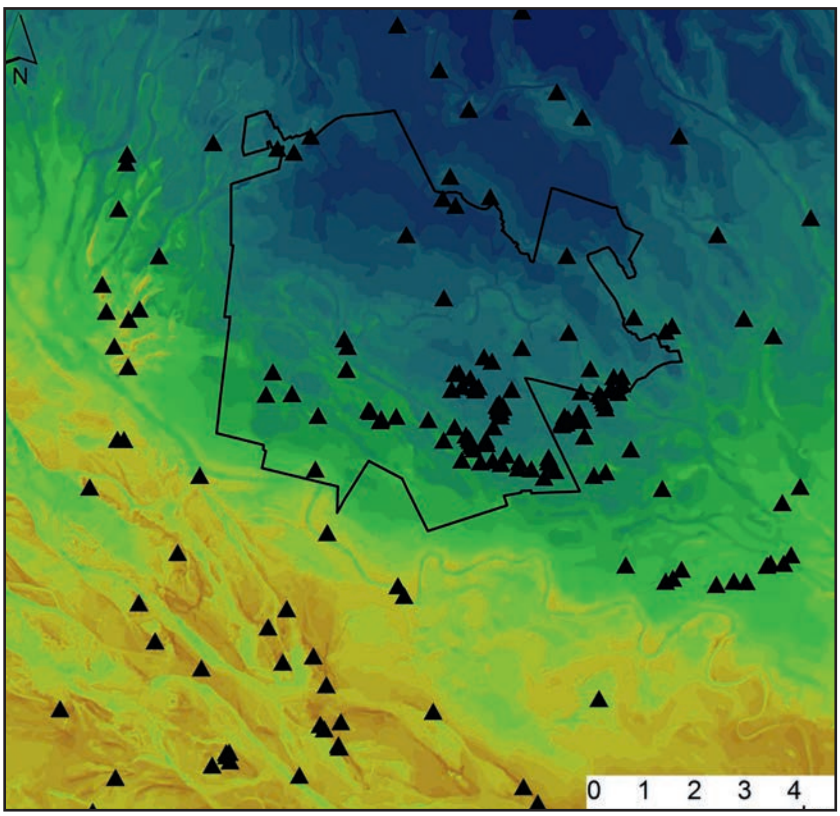


**Figure 2: The mounds of the Kígyósi-puszta and its vicinity on a geomorphologic relief map**

a traditional, historical name (anonymous), we provided them with a numbered code according to each settlement (administrative area): Gy (Gyula), K (Kétegyháza), Sz (Szabadkígyós), Ú (Újkígyós) and a combination of these. Figure 4 summarizes the mounds of the barrow field and the individual codes.

There are mounds outside the national park as well that form an integral part of the kurgan field, especially the kurgans located just north of the inner area of Kétegyháza and the group of mounds east of the railway line between Szabadkígyós and Lökösháza. Their approximate number is 30. However, we were not able to include the latter in the study because due to the short-term planning strategy (available tenders) and the intent to rebuild the damaged mounds, we surveyed only the hills of the central protected area at the request of the National Park Directorate; we undertook only the detailed description of their state and the planning of their realistic reconstruction.

The morphology and topographic position of the mounds of the kurgan field was investigated by Gyula Gazdapusztai and József Tóth in 1966 (Gazdapusztai & Tóth 1966, 1967, Ecsedy 1979: 20, Fig. 7), while in the 1970s Zoltán Dövényi and his associates analysed several mounds from a geomorphological. micro-relief, and climatological point of view (Dövényi et al. 1977).

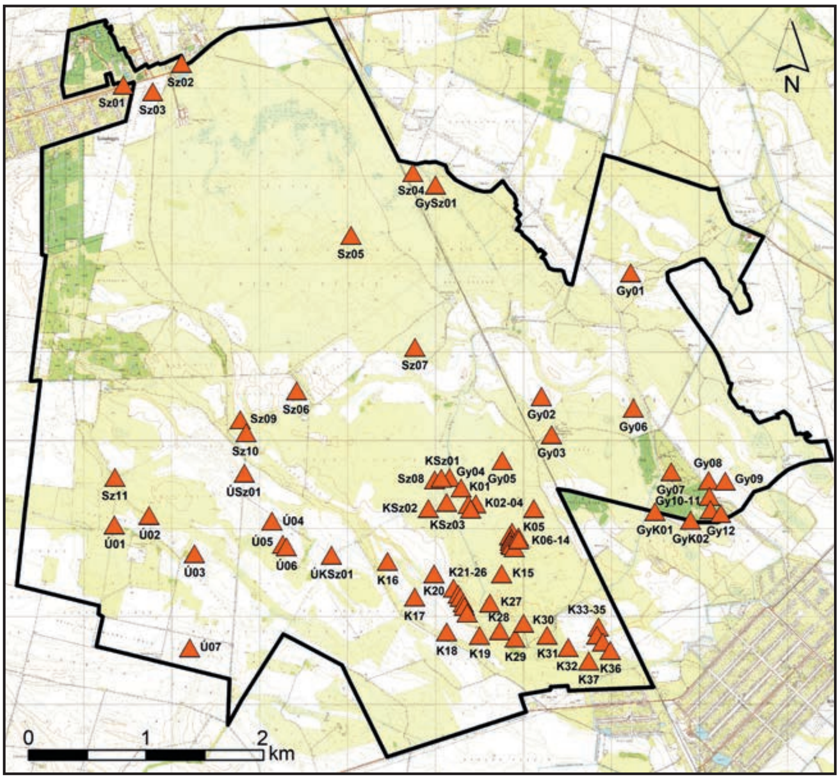


Figure 4: General map of the kurgan field with the surveyed mounds (EOTR, 1979–1980)

a) Isolated mounds. The most common occurrence when a mound is isolated (Gy01, Gy06, Sz5, Sz7, Ú07 stb.), though this is less common in our sample area because of the density of the kurgan field (Figure 5).

b) Double mounds. A typical case when two roughly equal (K27–28, Sz09–10, Ú05–06) or one larger and one smaller mound are standing side by side (GySz01–Sz04) relatively close to each other (Figure 6). It can be assumed that the people buried in the mounds had been related by kinship.

(c) Rows of mounds. This form of appearance is also very common in the Great Hungarian Plain, because mounds are often located along a riverbed, at a certain distance from each other. There are both denser (K16–19) and sparser (K21–26, K33–36) rows of mounds in our sample area, each with 3 to 7 members (Figure 7).

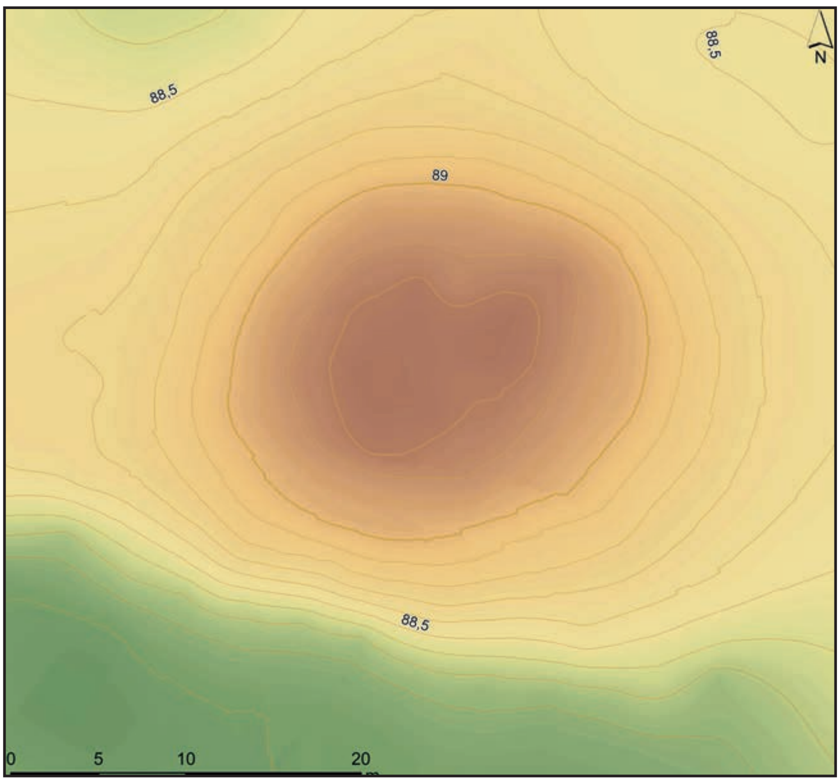


Figure 5: Solitary kurgan (Sz07) in Szabadkígyós, visualized on contour map

Figure 6: Two unnamed kurgan in pair (Ú06 and Ú05) in Újkígyós (photo by Á. Bede, 2015)

Figure 7: Kurgan line with six mounds (K21–26) on a 3D model in Kétegyháza

d) Mound groups. Groups of mounds with 3 to 9 members have a significant landscape character within the sample area. There are both sparser (Gy04, Sz08, K01–04, KSz01–03) and denser clusters (K6–14; Figure 8). A special feature of the group comprised of the K6–14 kurgans is that the mounds surround a crescent-shaped saline swamp.

The largest (tallest) kurgans of the field of mounds are the two Török-halom (means "Turkish mound"; K28 and K27; 6,7 m and 5 m), the Hegyes-halom (means "Pointed mound"; KSz01; 4,9 m), the Nagy-halom (menas "Great mound"; GyK02; 2,9 m) and the Fekete-halom (means "Black mound"; Sz11; 2,5 m). The rest of the mounds all have a height of less than 2 m, but mostly they do not reach 1 m. The largest mounds (over 4 m) have up to three layers or mantles, while medium ones (2 to 4 m) typically have two, and the lowest (below 2 m) have one.

### *Natural impacts and anthropogenic functions*

In addition to the main topographic location, we can group the mounds according to the type of damage they had suffered. Since the communities of later periods (from the Bronze Age to the Modern Age) used the mounds with different intensity and for different purposes, we can find smaller or larger traces of disturbances on almost all of them. Since disturbance as a form of intervention is essentially human (anthropogenic), and the construction of the mound itself is also connected to human activity, natural effects and disturbances are less prevalent on them and are less spectacular than the effects of humans.

a) Natural effects. In addition to anthropogenic disturbances, natural effects also have an impact on the mounds (and here we are not primarily concerned with environmental influences but with interactions within nature). In fact, we can also find disturbances, since foxes (*Vulpes vulpes*) often settle in and dug into less frequented mounds (Godó et al. 2018), typically in already disturbed places (such as ditch walls, canal banks; K18) or around triangulation points (KSz01). Pioneering, ruderal, or generalist associations, often with invasive elements, appear in the already disturbed areas and break down the original vegetation. In the case of undisturbed grasslands and loess-wall vegetation (KSz01, KSz02, GyK02), a severe natural pressure may be caused by the spread of shrub (especially blackthorn).

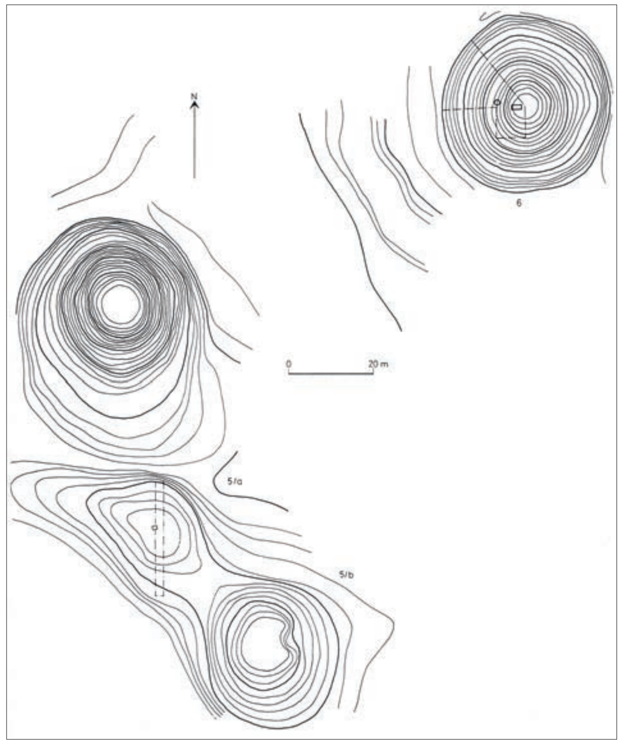


Figure 8: Archive contour map with a part of the kurgan group (K9–13) in Kétegyháza (Ecsedy 1979: 27, Fig. 17)

b) Ploughing. Maybe one of the oldest types of disturbances. Virtually all the smaller (flatter, lower) mounds have been ploughed in the past centuries. A few barrows are still being ploughed (K35, K36), however, cultivation has been abandoned on most of them due to the habitat treatments of the national park; grassland has reappeared on the surface of these mounds (typically spontaneously, naturally, in the place of medick) (e.g. K21–26).

c) Treasure hunt. In historical times, the mounds were often dug into in the hope of finding treasure. These holes and pits were later filled, but they can still be seen on the surface as dents (K27, KSz01, KSz02). Illegal metal detecting in the area is still ongoing.

d) Border points. The boundaries of late medieval (16th–17th-century) settlements and later of the grassland were reinforced in the early Modern Ages (18th–19th centuries), for which mounds were also used: a border hill was thrown on the top of the mounds, and border walls were dug into their sides. These features are cultural historical landscape elements to be preserved (GyK01, GyK02, KSz01, KSz02).

e) Forest and tree planting. Forests have been planted on the surface of some of the kurgans, changing the basic landscape character of the mound in the long run (Gy01, Gy07, Gy12, GyK02). In addition, the roots of trees change the structure and geochemical conditions of the layers. On other mounds, usually next to dirt roads, trees were installed, and naturally other woody shrubs (blackthorn, elder, hawthorn, etc.) appeared and formed dense stands (Sz01, ÚKSz01, ÚSz01 stb.).

**Figure 9: The damaged Határ-halom kurgan (GySz01) is a boundary point between Gyula and Szabadkígyós, cutted by a canal (photo by Á. Bede, 2015)**

**Figure 10: A 2 m high mound (K09) during the archaeological excavation in Kétegyháza (Gazdapusztai & Tóth 1967)**

f) Triangulation points. Official surveys often use mounds as a horizontal base point because they are very stable, reliable, long-term landscape localities. Measuring points are created (perpetuated) in the centre of the mound with disturbances at a depth of nearly 2 m, and several concrete points (columns, concrete slabs) are placed at the top of the barrow (K16, K27, KSz01, etc.).

g) Canals. Canals dug into mounds for water management purposes (typically for drainage) cause a high degree of destruction and deep scars in the landscape (Figure 9), as they relocate or remove much of the material of the mound (GySz01, KSz03).

h) Earth removal, archaeological excavation. At the beginning of the 1960s, the local cooperative began to mine the earth of the largest mound, Török-halom. Taking advantage of this situation, Gyula Gazdapusztai archaeologist carried out the excavation of several mounds between 1966 and 1968 (Gazdapusztai 1966, 1967, Ecsedy 1979), for which he also used the power of high-performance machines (Figure 10). Certain hills suffered relatively small interventions easier to repair (K15, K11), but others were almost completely destroyed (K06, K09, K13, K28, K29). The rebuilding of the Török-halom for landscape rehabilitation purposes was realized in 2011 (Nagy 2012), and the Directorate of the National Park plans to reconstruct the other damaged mounds soon as well.

## ACKNOWLEDGMENTS

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# EXPERIENCES OF THE REARING OF BURBOT *(LOTA LOTA)* IN HUNGARY

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## ABSTRACT

Study on the breeding and rearing of burbot in recirculation aquaculture system (RAS) revealed that ovulation and spermiation can be induced by thermal shock or hormonal induction. Comparing different rearing tanks, Zuger glass proved to be the most effective in early rearing phase. Finally oxygen demand of spawns was determined as $LC_{50}$ érték 1.02±0.43 mg/l. The above experiments created a solid base for the repopulation of burbot to Lake Balaton.

## INTRODUCTION

Burbot (*Lota lota*) is an autochthonous species of sweet waters in the temperate and frigid zones of the northern hemisphere. The fish represents the only cod in the genus native in sweet water rivers and lakes (Pintér 2002). The species is valued by nature conservationists, however, it has economic importance in some countries (Poland, Russia and Canada). Besides natural water catches, experiments on the reproduction in RAS were also started (Żarski et al., 2010; Trabelsi et al., 2011; Lahnsteiner et al., 2012). Burbot is native in Hungary, present in most of the greater rivers (Danube, Tisza, Drava and Körös rivers) of the country, and was considered common in the Lake Balaton until 1961 (Harka & Sallai, 2004). In this water bulk introduction of eel (*Anguilla anguilla*), being a food and niche competitor of burbot, presumably led to the decrease of the species (Pintér, 2002). Development of the reproduction technology of the fish has been started with the co-operation of Balaton Fish Management Non-profit Ltd. and Szent István University, funded by Ministry of Agriculture. The aim of the project is not only the reintroduction of burbot populations to Lake Balaton but also to provide material for stocking of natural waters and a base for possible intensive fish rearing.

## MATERIAL AND METHODS

Reproduction and rearing experiments of burbot were carried out in the years of 2016 and 2017 in the RASs of Szent István University, Department of Aquaculture and the fish farm of Zoltán Szabó and István Ittzés in Nagykarácsony. Broodstock was originated from the Danube. Broodstock was kept on 4 °C for 6 weeks, then thermal shock (2 °C) and hormone induction (Ovopel, Interfish Ltd. 1pellet/body weight) were applied. Ovulation was checked daily. Egg was incubated in Zug and McDonald jars on 2 °C for 53 days. Larvae was reared at 8 °C then freshly reared, non-feeding larvae was kept on 14 °C. Larvae started to feed on the $10^{th}$ day. Ad libitum Artemia (*Artemia salina*) was used as feed after swim-up and start of feeding, three times a day until day 21, and twice a day afterwards (in the morning and in the evening). Frozen chironomidae larvae (*Chironomus spp.*) was used as feed from the $70^{th}$ day. Rearing was managed in 100 litre giant Zug jars (1.000 larvae/100 l) or larvae rearing tanks (2.000 larvae/500 l). Body weight data was recorded 50, 70 and 90 days from the starting of feeding and 28, 48 and 69 days, respectively, after the introduction of the two different rearing environments (large Zug jar and tank). Oxygen content (mg/l) and temperature (°C) were recorded during the whole rearing period.
Oxygen demand of burbot spawn was also measured by selecting 20 individuals (average body weight: 0,1 g ± 0,02) in five repeats and kept in a hermetically closed system (10 l water). Changes in oxygen level and spawn mortality were recorded and $LC_{50}$ was determined.

## RESULTS

Five female burbots were successfully striped and more than 500 000 pieces of eggs were gained during the 2 year study in two locations. Fertilization rate was measured between 60 and 90%. Feeding age was reached by

200 000 larvae. Different age groups of burbot was reintroduced to Lake Balaton in different time and location with the following numbers and fish sizes: small fry (0,05 g) 40.000 individuals, big fry (0,2 g): 4.000 individuals, one year old fingerling (20 g): 2.500 individuals.

The results of different water tanks on fish development can be summarized as following: the average body weight was measured 0.1003±0.0286 g; 0.1437±0.0201 g; 0.1670±0.0253 g in the large Zug jar, 0.0636±0.0205 g; 0.1600±0,0338 g; 0.2044±0,0470 g in the rearing tanks at the three measurement times, respectively (day 50; 70; 90 from the start of feeding, day 28; 48; 69 from the separation).

The results of burbot fry tolerance on oxygen shortage showed that dissolved oxygen concentration of 1.02±0.43 mg/l resulted in mortality of 50% of the experimental stock. Temperature during the experiment was 19.11±0.82 °C. In the Control group no mortality was recorded under 8,56 ± 0,17 mg/l oxygen level and a temperature of 19,13±1,12 °C during the whole experiment.

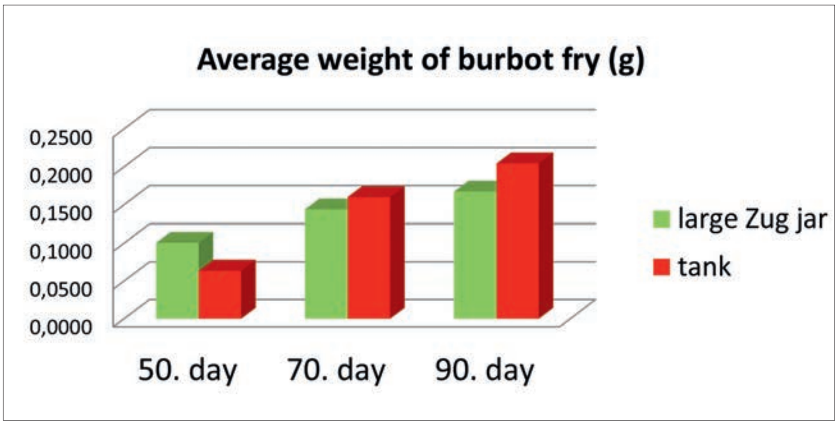


**Figure 1: Results of the fry rearing in different incubation jars.**

## DISCUSSION

Artificial reproduction of burbot was successfully managed by different authors (Kucska et al, 2002; Keresztessy & Rideg, 2001). Results of the above findings were fine-tuned and a reliable method for the production of stocking material was achieved. The study revealed that for hatching and rearing large Zug glass, generally suitable for any fish, was a proper choice for burbot, supplemented by dense mesh to prevent the washing out of *Artemia naupli* from the tanks. These above facts resulted in better nutrient utilization. Similarly important statement was that burbot larvae tolerate well oxygen shortage, meaning that high stocking density would not be a limiting factor.

Finally results of the experiment were exploited in practice as the fingerlings produced during the study was provide a good base for a launching of a reintroduction programme.

## ACKNOWLEDGEMENT


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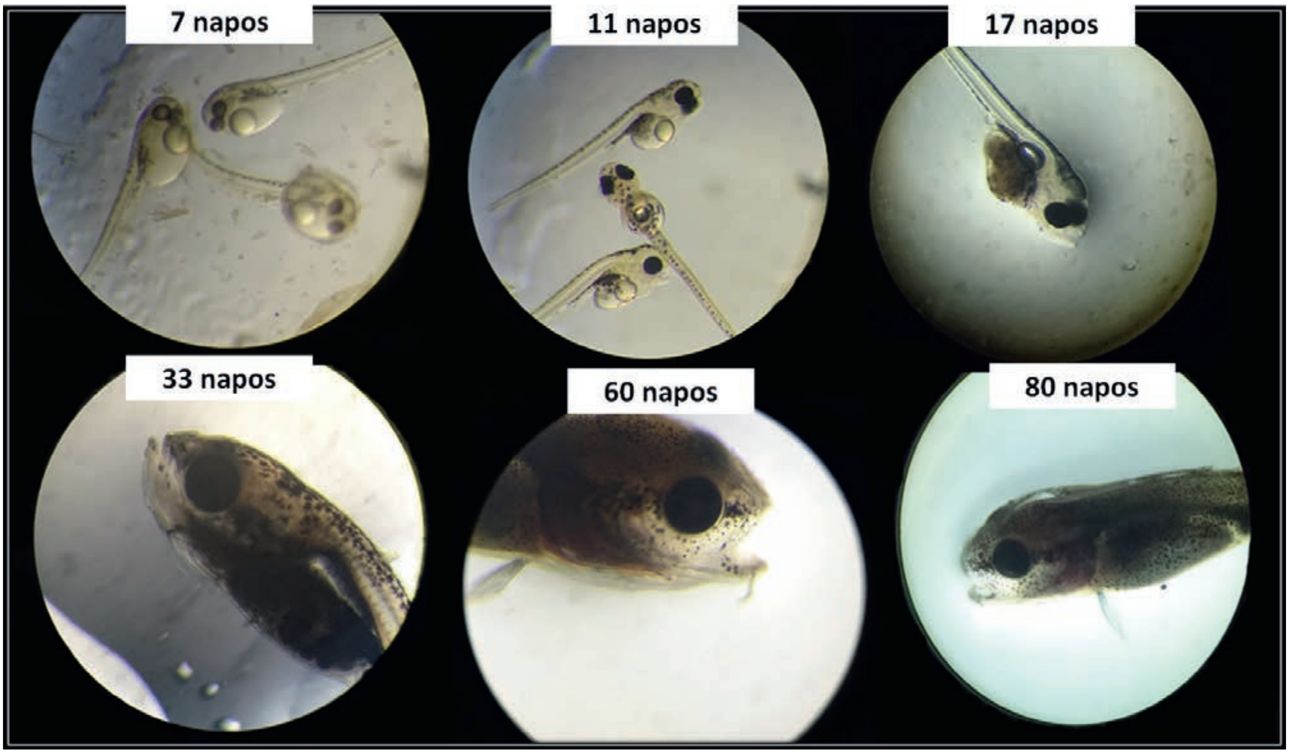
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# NEW REGULATION TO IMPROVE AIR QUALITY AND MAKING STEPS IN ENERGY EFFICIENCY

LÓRÁNT **RIESZ** – ANNA BOGLÁRKA **POMUCZ** – NÓRA **KOPLÁNYI –** ANDRÁS **BÉRES**

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## INTRODUCTION

Hungary can be classified as lagging behind the level of several European and other regions in terms of air quality, which can be explained with the terrain situation and with the emissions as well.
Due to the geographic conditions of the Carpathian-basin, and to the formation of frequent upstreamless flow and lack of mixing of inversion air layers, the dilution of the contamination does not take place often, so the emitted air pollutants can remain in the atmosphere of the settlements for longer periods.
The situation is further exacerbated by the fact that a significant proportion of Hungarian settlements are located in valleys, where this effect is enhanced. (The Danish Ecological Council, 2016)

The residential sector is significantly responsible for the air pollution in many regions because of the solid-fuel combustion habits. This is partly the consequence of the fact that due to the rise in the price of energy carriers, primarily natural gas, wood and coal consumption has increased among residents and in the case of coal, the use of lignite has significantly grown. (Magyarország Környezeti Állapota 2016)

**Keywords: air, air quality, residential heating, firewood, renewable energy, regulation**

## AIR QUALITY AND SOLID FUEL COMBUSTION

Significant amounts of air pollutants, small particulate matter (PM), carbon monoxide, nitrogen oxides, sulfur dioxide can be emitted, if the fuel, the combustion technology or the combustion equipment is inadequate.

Heating with wet wood, coal and especially with waste cause serious health impact and environmental hazard, and its adverse air quality effects can be clearly shown in air quality measurement results. (Magyarország Környezeti Állapota 2016)
Figure 1, Figure 2, and Figure 3. shows the contribution of the residential sector to $PM_{2.5}$, $PM_{10}$ and $SO_2$ emissions. According to World Health Organization (WHO) particulate matter ($PM_{10}$ - 10 µm or smaller, $PM_{2.5}$ - 2.5 µm or smaller) is responsible for the biggest health risk among air pollutants. (WHO, 2010)
The residential energy use is the highest in Hungary, 35% of the final energy use. Most of the energy used by households is used for heating, approximately 74% (Figure 4.)
According to data of the 2016 microcensus, the use of wood for residential heating purposes in Hungary is nearly 32%, which varies by region and county, depending on the local infrastructure, conditions and social status of the population (Figure 5.)
Unfortunately there is no exact data on the proportion

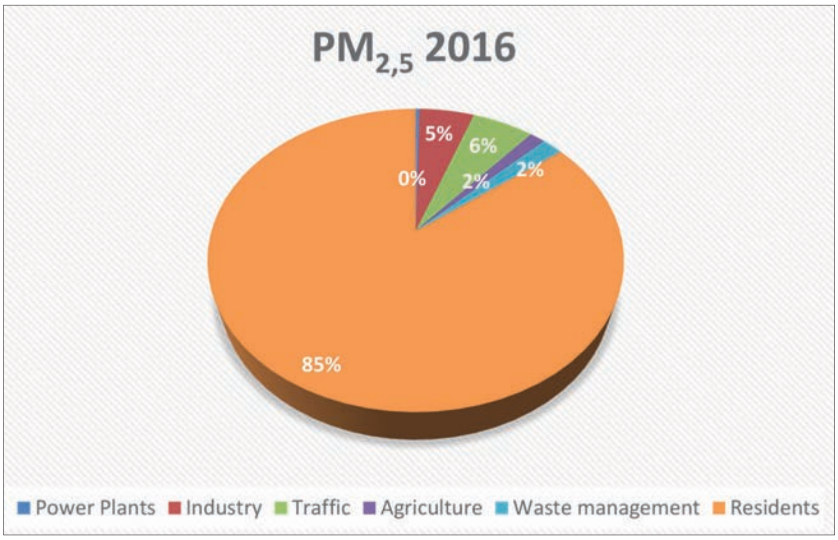


**Figure 1: Emission of $PM_{2,5}$ in 2016 (*Source: OMSZ*)**

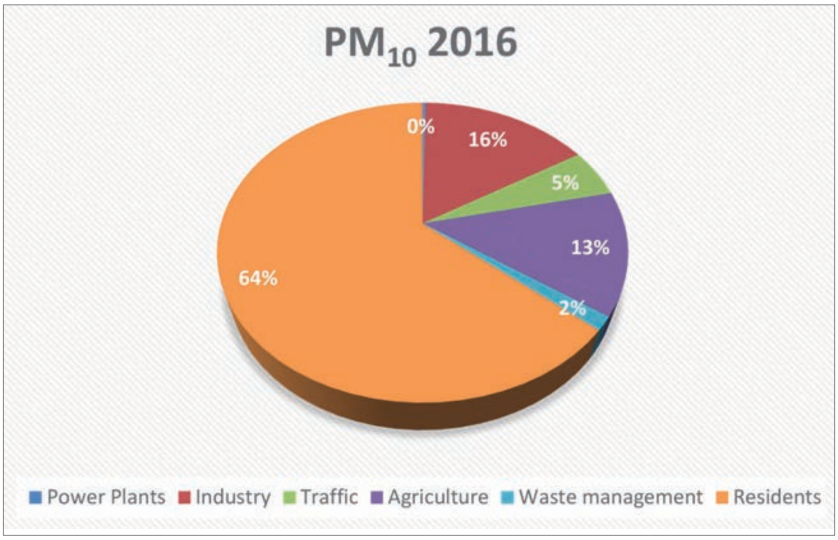


**Figure 2: Emission of $PM_{10}$ in 2016 *(Source: OMSZ)***

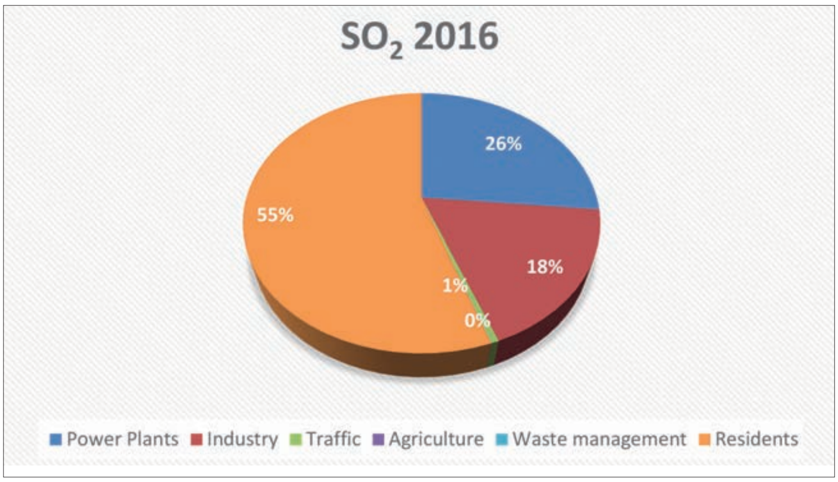


**Figure 3: Emission of $SO_2$ in 2016 *(Source: OMSZ)***

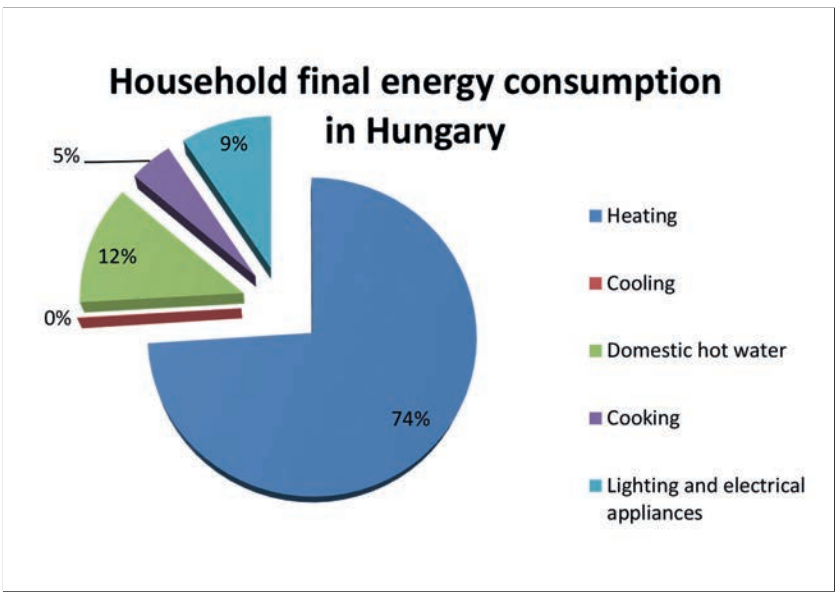


**Figure 4: Household final energy consumption in Hungary, 2016 *(Source: MEKH)***

of the different kinds of solid fuel combustion devices, how this huge amount of solid fire wood is combusted.

## RENEWABLE ENERGY IN THE EU

The goal of the European Union for 2020 was to satisfy 20% of the energy need from renewable sources. In 2017, based on the statistic of Eurostat (2019), this part was 17.5%. Some countries, like Hungary, have already reached the level they undertook (REKK, 2017) – in case of Hungary it was 13% - but each country has its own commitment (The European Parliament and the Council of the European Union, 2018).

Wind, different type of solar, hydro, tidal and geothermal energy, heat from heat pumps, biofuels and renewable part of waste are all renewable sources, that are able to meet a part of the energy needs. The use of energy from renewable sources has several potential benefits, e.g. reduction of greenhouse gas emission, diversification of energy supply and reduction of the dependence on fossil fuel (particularly oil and gas) and their strong influenced markets, use and development of new, green technology to produce renewable energy could also potentially stimulate employment (Eurostat, 2019a). In energy statistics, fuelwood belongs to the solid biofuels and as biofuel it is a renewable energy source as well (Eurostat, 2019b).

In the EU the composition of renewable energy consumption has changed slightly. While the share of the heat sector from the renewable energy use dropped nearly 10% in the last 15 years to 50.3%, the transport sector has increased the most, from 2.9% to about 8%. The share of the electricity sector has also increased – from 37.8% to 41.7%.

The analysis of the growth of renewable energy based on the utilized fuel in the European Union shows, that since 2004 the use of biomass has increased the most in absolute term. This is partly explained by the fact that in many countries, similarly to Hungary, the statistical methodology used to calculate household biomass use has been corrected. This correction resulted

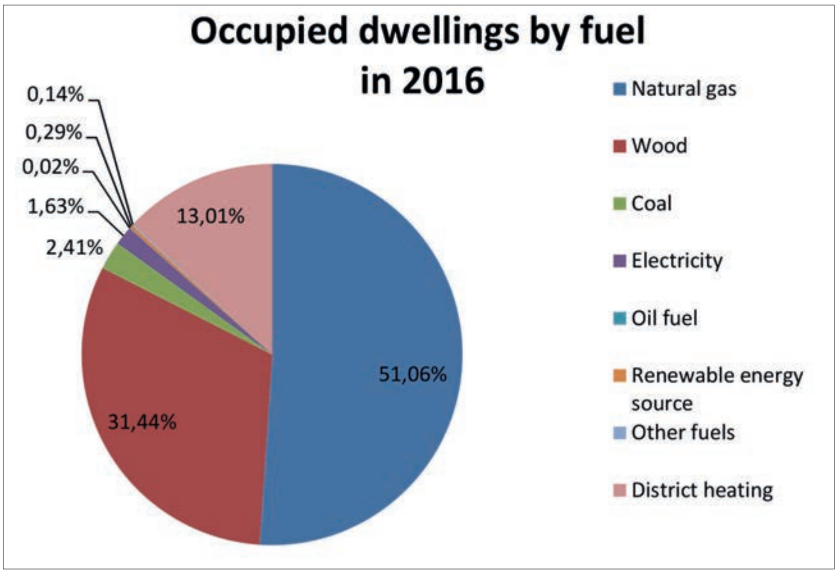


**Figure 5: Occupied dwellings by fuel, 2016** ***(Source: KSH Microcensus 2016)***

2-3 times growth and an overall at least 200 PJ increase. This increased use of biomass accounted for almost half (47%) of the total growth of renewable energy consumption (REKK, 2017).

## FIREWOOD CONSUMPTION AND STATISTICS OF HUNGARY

In Hungary the structure of the used renewable energy sources is notably one-sided, the solid biomass use of heating sector gives 81% of the total renewable consumption, this is mostly used by households (Bartek-Lesi et al., 2019), in heating sector the share of renewable sources is 20,8% (Shares, 2018).

Since 2015 new methodology is used to calculate the household solid biomass utilization data for the national energy balance in Hungary, it uses the results from the household data collection and building energy calculations. Based on this new methodology, solid biomass utilization data were recalculated in the energy balance back to the year 2005 (HEA, 2019) and this methodological change nearly doubled the firewood consumption in Hungary. But actually there is no real increase in usage of firewood, only the change of the statistical methodology resulted that significant rise (Bartek-Lesi et al., 2019).

Two different statistics are available based on the source data of firewood in Hungary, it is found that till 2008 these two - published by the Hungarian forestry authority and by EUROSTAT – are same, but after 2008 there is difference about half million cubic meter. The difference is stable 11-12%, which means that the EUROSTAT firewood data plus the 10% logging waste wood that used by the population is roughly the same as the official Hungarian firewood production data (NFCSO 2019) – calculation with import wood not necessary because (except the year 2010) Hungary is a net exporter of firewood (EUROSTAT, 2019c).

The most significant problem that there is a gap between the source and use data of firewood in Hungary, more than 50% of used firewood is not found in official source statistics. It is challenging to find the reason of that shortcoming, it can be caused by the methodological problems of the calculation of source and usage data.

If the source statistics are correct and the usage statistic accepted to be correct, than a large-scale of illegal wood have to be used that indicates the unreliability of the source data. If it is supposed that forestry statistics are correct, than methodological shortcomings have to be assumed in the usage data. There can be a problem in the methodology estimating the heating demand of households or the concept of solid combustible biomass can be unclear but the combination of all the former factors can affect the gap.

## NEW REGULATION ON SOLID FUEL BOILERS AND LOCAL SPACE HEATERS

New regulation has been taken into force for placing on the market and putting into service solid fuel boilers with a rated heat output of 500 kilowatt or less, including those integrated in packages of a solid fuel boiler, supplementary heaters, temperature controls and solar devices.

The new eco-design requirements that entered into force on January 1$^{st}$, 2020 shall not be applied to boilers generating heat exclusively for providing hot drinking or sanitary water; boilers for heating and distributing gaseous heat transfer media such as vapour or air; solid fuel co-generation boilers with a maximum electrical capacity of 50 kW or more and non-woody biomass boilers.

The Commission Regulation 2015/1189 is implementing Directive 2009/125/EC of the European Parliament and other Council with regard to eco-design requirements for solid fuel boilers.

The scope of the regulation are the solid fuel boilers meaning a device equipped with one or more solid fuel heat generators that provides heat to a water-based central heating system in order to reach and maintain at a desired level the indoor temperature of one or more enclosed spaces, with a heat loss to its surrounding environment of not more than 6 % of rated heat output.

From 1 January 2020 solid fuel boilers shall comply with the following requirements:

– seasonal space heating energy efficiency for boilers

with a rated heat output of 20 kW or less shall not be less than 75 %;
– seasonal space heating energy efficiency for boilers with a rated heat output of more than 20 kW shall not be less than 77 %;
– seasonal space heating emissions of particulate matter (PM) shall not be higher than 40 mg/m3 for automatically stoked boilers and not be higher than 60 mg/m3 for manually stoked boilers;
– seasonal space heating emissions of organic gaseous compounds (OGCs) shall not be higher than 20 mg/$m^3$ for automatically stoked boilers and not be higher than 30 mg/m3 for manually stoked boilers;
– seasonal space heating emissions of carbon monoxide (CO) shall not be higher than 500 mg/$m^3$ for automatically stoked boilers and not be higher than 700 mg/$m^3$ for manually stoked boilers;
– seasonal space heating emissions of nitrogen oxides ($NO_x$), expressed in nitrogen dioxide, shall not be higher than 200 mg/m3 for biomass boilers and not be higher than 350 mg/m3 for fossil fuel boilers;
These requirements shall be met for the preferred fuel and for any other suitable fuel for the solid fuel boiler.
From January 1st, 2020 the producers shall provide complementary information on solid fuel boilers such as the technical parameters measured and calculated in accordance with the obligations of the Directive, instructions on the proper way to operate the solid fuel boiler and the quality requirements for the preferred fuel and information on the proper disassembly, recycling and disposal at end-of-life.
The implementation of the Directive is going to result similar changes in the regulation of the solid fuel local space heaters from January 1st, 2022.
The Commission Regulation 2015/1185 establishes ecodesign requirements for the placing on the market and putting into service of solid fuel local space heaters with a nominal heat output of 50 kW or less. The regulation shall be not applied to several kinds of solid fuel local space heaters including those that are specified for outdoor use only and that are not factory assembled.
The scope of the future regulation are the space heating devices that emits heat by direct heat transfer or by direct heat transfer in combination with heat transfer to a fluid, in order to reach and maintain a certain level of human thermal comfort within an enclosed space in which the product is situated, possibly combined with a heat output to other spaces, and is equipped with one or more heat generators that convert solid fuel directly into heat.
Solid fuel local space heaters shall comply with the following requirements from 1 January 2022:
– seasonal space heating energy efficiency of open fronted solid fuel local space heaters shall not be less than 30 %;
– seasonal space heating energy efficiency of closed fronted solid fuel local space heaters using solid fuel other than compressed wood in the form of pellets shall not be less than 65 %;
– seasonal space heating energy efficiency of closed fronted solid fuel local space heaters using compressed wood in the form of pellets shall not be less than 79 %;
– seasonal space heating energy efficiency of cookers shall not be less than 65 %;
– up to 20 mg/$m^3$ emission limit of particulate matter (PM);
– up to 60 mg/$m^3$ emission limit of organic gaseous compounds (OGCs);
– up to 300 mg/$m^3$ emission limit of cabon monoxide (CO);
– up to 200 mg/mv emission limit of nitrogen oxides ($NO_x$).
Similar information obligations will be imposed on local space heaters as they are on solid fuel boilers.

## CONCLUSION

Due to the rising importance of the climate and energy targets set for 2020 and 2030 and the increase of the price of the natural gas, solid fuel consumption has significantly increased in Hungary. Heating with wood and coal can significantly impact the health and the environmental circumstances. In Hungary the residential sector is responsible for the majority of PM pollution, especially during the heating season.
As a  of the new regulation on solid fuel boilers and local space heaters, the emission will be decreased and the energy efficiency will be increased considerably from 2020 and 2022. However, there is no exact data on the present heating devices used and the source of more than half of the firewood is unknown. In addition, the replacements of the equipment can be only predicted so the impact of the new regulation on air quality can hardly be estimated.

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