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IMPACT OF COVID-19 PANDEMIC ON AMOUNT OF MUNICIPAL WASTE GENERATION – A CASE STUDY

This paper presents the results of research of the impact of the COVID-19 pandemic on the amount of municipal waste generated in the Sieniawa community (region of south-eastern Poland). The basic assessment was conducted in relation to restrictions and limitations introduced in Poland in order to limit the transmission of the SARS-CoV-2 virus. The pandemic affected almost every sector of the economy and disrupted the existing social life, including the functioning of the waste management system. The analysis shows that in the study area during the COVID-19 pandemic, the level of waste generated changed significantly. It has been shown that in the study area, the introduction of various types of restrictions (including working and/or studying remotely, "national quarantine", restrictions on free movement, etc.) contributed to a clear reduction in the amount of waste generated in households, business entities, educational institutions, commercial and service facilities, among others. It turned out that the results of our observations are opposed with the generally formulated theses in this aspect. Nevertheless, an undeniable and unintended (indirect) effect of the actions taken to combat COVID-19 was the reduction of negative human pressure on the environment (reduction of the amount of waste generated). It follows that, in the current state of knowledge, there are no unambiguous patterns developed which would make it possible to predict the mechanisms responsible for the amount of waste generated during a crisis situation.

Keywords: municipal waste, waste generation, COVID-19 outbreak, environmental impact of SARS-CoV-2, social distancing policies

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1. Introduction

Every human activity involves the generation of waste, generally understood as things that are useless and/or undesirable due to the loss of their original properties [1, 2]. The ever-increasing amount of goods is closely related to the lifestyle and/or quality of life and the scale of consumerism in society, which ultimately translates into the amount of waste generated. In turn, increasing amounts of waste can have a negative impact on the state of the environment, including water quality, air quality or landscape. As the world's population continues to grow, waste management issues are becoming a priority. Currently, the global transmission of the SARS-CoV-2 virus (commonly referred to as the COVID-19 pandemic) is putting additional pressure on existing waste management systems [3, 4]. It is indisputable that the waste generated during the pandemic poses a serious threat not only to public health but also to the environment [5, 6]. A study by Garlasco et al. [7] found that due to the COVID-19 outbreak, there was a significant increase in medical waste generated between 2020 and 2021. Consequently, the authors point to the global challenge of disposing of the huge amount of medical waste and personal protective equipment (masks, gloves, disinfectant packaging, etc.). There is no doubt that medical waste increases exponentially during every infectious disease outbreak [8, 9], but the issues related to other waste groups are not so obvious. The use of personal protective equipment is estimated to increase in the long term [3], while various types of containment and isolation measures can reduce the generation of other solid waste, especially in tourist areas [10]. In response to the declaration of a pandemic state by the World Health Organization (WHO), many international organizations and countries implemented different types of strategies to combat the crisis. Considering the range of measures (restrictions, strictures and limitations) introduced to counteract the transmission of SARS-CoV-2 and, above all, their impact on changing the lifestyle of the population, particular attention is paid to the issues related to the waste generated during this time [6].

The main objective of the study was to assess the impact of the COVID-19 pandemic on the amount of municipal waste generated in the area of the selected administrative unit (municipality). The evaluation was carried out in relation to restrictions, limitations and recommendations introduced in Poland in order to limit the transmission of the SARS-CoV-2 virus. The intention of the study was to find out whether the restrictions introduced had an impact on the level of waste generated at that time.

2. Materials and methods

2.1. Study area

The study was conducted on the territory of the Sieniawa community located in the Podkarpackie voivodeship (region of south-eastern Poland). It is an urban-rural municipality covering an area of 127.7 km², of which 52% is agricultural land and 38% is forest land. Despite favorable conditions for agriculture and a well-developed farming economy, farms are fragmented, concentrated on traditional forms of farming. The commune area includes the town of Sieniawa and the villages [11]: Czerce, Czerwona Wola, Dobra, Dybków, Leżachów, Paluchy, Pigany, Rudka and Wylewa (Fig. 1). According to publicly available (public) data from the Sieniawa Community Office [12], in 2020 the community area was inhabited by 7022 inhabitants. Moreover, there were 444 registered business entities, 13 of which were of agricultural, forestry, hunting and fishing character. Further, 162 industrial and construction enterprises and 269 entities of a different nature (service activities, in particular trade) operated in the study area. In turn, according to the Central Statistical Office in Rzeszów [13], there were 13 educational institutions (including kindergartens, primary and lower secondary schools) in Sieniawa community in 2019. On the other hand, the health care of the inhabitants was provided by 4 clinics (there are no hospitals or other kind of specialized emergency facilities in the municipality).

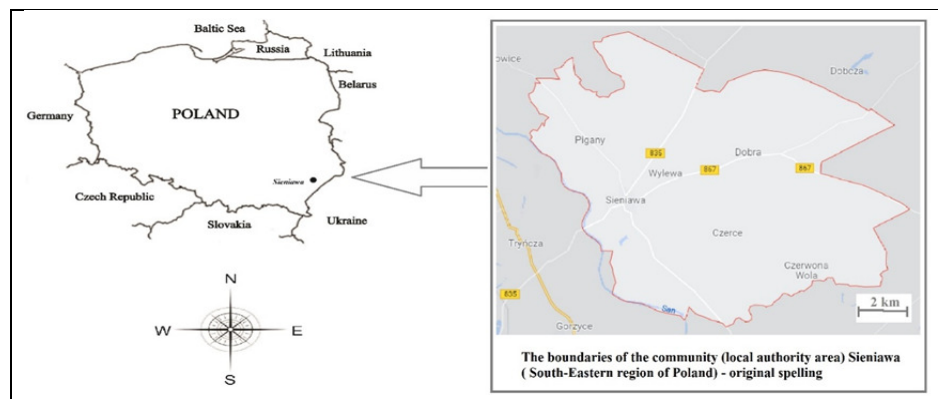


Fig. 1. Glocalization of Sieniawa commune

2.2. Research conception

In the analyzed area municipal solid waste (MSW) is temporarily collected at the place of its origin (stored by producers), from where it is further received in the form of separate waste collection (SWC) and mixed municipal waste

(MMW). Segregated waste is collected in appropriately marked colored bags. In single-family housing and rural areas it is allowed to manage bio-waste on your own (in home composting facilities). The municipality also collects waste electrical and electronic equipment and bulky waste (on average twice a year). In addition, a selective waste collection point (SWCP) has been operating in the community since December 2019, where you can deliver selectively collected waste yourself.

The analysis of generated municipal solid waste (MSW) in the area of the community of Sieniawa included the total amount of waste delivered/received in 2017-2020 (including waste from public facilities, commercial and service outlets, catering establishments, etc.). The analysis was broken down into separate waste collection (SWC), mixed municipal waste (MMW) and waste from selective waste collection point (SWCP). Data on the volume of waste generated were obtained from the administrator (head of the commune) of Sieniawa.

Information on the course of the pandemic in Poland comes from official data of the Ministry of Health published on the Government Information Domain [14].

In order to analyze the impact of COVID-19 on the amount of waste generated, data covering two years were compared, i.e. 2019 (as a base year before COVID-19) and 2020 (the first year of the pandemic in Poland). Then, the parameterization of introduced restrictions and recommendations aimed at counteracting the virus transmission was performed. The evaluation of introduced restrictions and recommendations was performed using a parametric (rank) rating scale ranging from 1 to 5 (Table 1). The method of parameterization of random factors used by Czaja and Preweda [15] and Barańska [16] was transferred to our study by analogy.

Table 1. Adopted parametric rating (rank) of the level of restrictions and limitations COVID-19

Restriction level	Rank
radical	5
high	4
moderate	3
low	2
none	1

2.3. Statistical analysis

Statistical analysis performed using Statistica 13.0 PL software included Kruskal Wallis ANOVA test (ANOVA KW) and Pearson linear correlation analysis (r). The Kruskal Wallis and Pearson analyses made it possible to assess whether correlations or differences between selected parameters were statistically significant. A significance level of $\alpha=0.05$ was used for the study.

3. Results and discussion

The transmission of the SARS-CoV-2 virus was and still is noticeable all over the world. As a consequence of the epidemiological situation, the relevant state administration bodies undertook a number of actions aimed at limiting the virus transmission. Many countries (including Poland) introduced a temporary almost complete freeze of the economy, the so-called "lockdown". Among others, educational institutions, commercial and service facilities, cultural and entertainment institutions were temporarily closed, and public transport and tourist traffic were restricted [17]. The economic crisis resulting from the declaration of the COVID-19 pandemic affected many countries worldwide [18, 4]. In Poland, in the second quarter of 2020, gross domestic product (GDP) fell by 8-9% compared to the previous quarter [19]. In Poland, the first market reaction after the introduction of the "lockdown" was an increase in the unemployment rate. A clear increase in unemployment was recorded in March and April 2020, which could be closely related to the proclamation of the epidemic and the introduction of a number of restrictions and limitations. It is also believed that the measures taken to contain the spread of the SARS-CoV-2 virus may have had a significant impact on the decline in economic activity observed in the country [17]. The most important events related to the course of the COVID-19 pandemic in Poland (including the introduced restrictions) are presented in Table 2.

A comparison of the total amounts of waste generated from 2017 to 2020 is summarized in Figure 2. It was noted that by 2019, the total amount of waste succinctly increased (ranging from 2.8% to 5.3% depending on the year). The highest amount of waste generated was recorded in 2019 (1148.65 Mg), while the lowest in 2020 was 959.8 Mg. In general, the amount of waste generated at that time was at the markedly lowest level (in relation to previous years) (Fig. 2). The phenomenon observed suggests that in the year in which the SARS-CoV-2 virus pandemic was announced, there was a clear reduction in the amount of waste generated (16.44% decrease from the 2019 level). Moreover, a rather unusual phenomenon was also found, i.e. on the one hand, a decreasing population in the municipality was observed from year to year (2017-2019) (although this was not a statistically significant trend by ANOVA KW, $p > \alpha$) (Fig. 2b), and on the other hand, the amount of waste generated increased correspondingly at the same time (Fig. 2a). At first glance, this was a rather incomprehensible phenomenon, as causal reasoning suggests that as the population grows/decreases, the stream of waste generated by them should correspondingly grow/decrease. We therefore hypothesised that the observed phenomenon might indicate that to a greater extent behavioral factors (reflecting the improving quality and lifestyle of the population) determined the stream of waste generated.

Table 2. Calendar of COVID-19 restrictions in Poland in 2020 and their rating (rank)

Month	Rating (rank)	Description
January	1	No significant restrictions. During this time, among other things, special procedures were put in place for passengers arriving from the People's Republic of China. In addition, laboratory testing of patients with suspected SARS-CoV-2 infection was initiated.
February	2	Recommendations to take special precautions and avoid large concentrations of people in areas where infection has occurred. Warnings against travel to countries with many centers of the disease. A ban on hospital visits.
March	5	Official announcement of COVID-19 epidemic in Poland. Introduction of a forced quarantine (the so-called "lockdown"). Temporary closure of the country's borders, air traffic, communication and public transport. Temporary closure of educational institutions, commercial and service facilities. Prohibition of movement in public places, use of places of rest and recreation, etc.
April	4	First stage of relaxation of restrictions: possibility to use rest and recreation places, increase of limits on people in shops.
May	3	Successive stages of abolition of the introduced restrictions. Restored the work of shopping centers, libraries, museums, art galleries, hotels and medical rehabilitation facilities (with sanitary regime). The activity of hairdressing and beauty salons, restaurants and cafes were restored (with sanitary regime). Cinemas, theatres, opera houses, swimming pools, fitness clubs, amusement and play parks have resumed their activities.
June	2	Opening of Poland's borders to European Union countries. Resumption of international flights. Possibility of organising gatherings of up to 150 participants.
July	2	Continued efforts to loosen restrictions. Lifting the person limit for open air entertainment events.
August	1	Introduction of zones with different levels of restrictions (regionalization of restrictions): red, yellow and green zones. The Sieniawa commune was located in the green zone (the zone with the mildest restrictions).
September	2	Continuation of regionalization of restrictions. At that time the municipality of Sieniawa was located between the yellow and the green zones.
October	3	Remote teaching in schools from grade 4 onwards and in colleges. Suspension of the operation of swimming pools and gyms. In addition, the possibility to participate in cultural events has been restricted, sports events have been allowed without an audience, the stationary operation of catering establishments has been temporarily closed, the operation of retail establishments has been restricted.
November	4	Remote learning has been introduced in grades 1-3, Cultural facilities and shopping malls have been temporarily closed. Assemblies and meetings were allowed: up to a maximum of 5 people. Limits on public transport introduced.
December	4	Introduction of an approximately two-week national quarantine. Temporary closure of hotels, shopping malls (except drugstores, pharmacies and grocery shops). Introduction of a compulsory quarantine for persons crossing the country's borders for a period of 10 days..

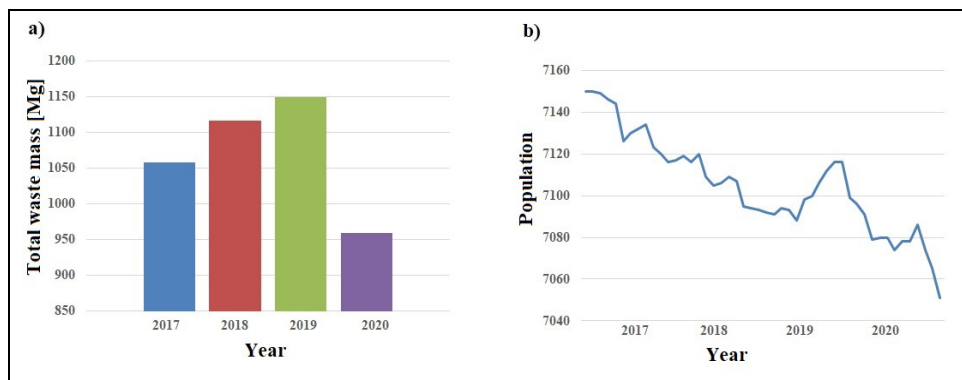


Fig. 2. a) Total amount of municipal waste produced in the commune of Sieniawa;
b) Population in the commune

Further comparing the 2019 and 2020 data, a clear variation in the amount of waste generated in each month was observed. In general, the highest mass of MMW) and SWC was recorded in the months of March and September/October (Fig. 3), which may be related the additional collection of bulky waste and electro-waste occurring in those months. March 2020 was an exception to this rule, as one of the smallest amount (mass) of waste was generated in that month.

While the comparison of data from January did not show any major differences (both in 2019 and 2020 the amount of waste generated at that time was at a similar level). Thus already in the months of February and March 2019 and 2020, clear differences were found in the amount of waste generated at that time (Figs. 3c and 3d). In March 2019, the total amount of waste generated was close to 120 Mg, while in the same month of 2020 a significant decrease was about 60 Mg. This represents a nearly 50% reduction in the amount of waste generated during this time (in relation to March 2019). This situation suggests that the drastic restrictions introduced at that time may have translated into the amount of waste generated at that time.

On the other hand, with the successive lifting of restrictions (the period from April to the end of May 2020), the situation in the amount of waste generated began to stabilise and reach comparable levels from the previous year. The culmination of this phenomenon was observed in August 2020, where the highest amount of waste generated (about 110 Mg) was recorded, and this amount was close to the level of the corresponding period of 2019 (Fig. 3). In turn, the effects of the partially reinstated autumn (September - December 2020) restrictions were reflected in the quantities of waste generated recorded during this period. After an upward phase (June - August), a clear downward trend was again observed between September and December (Fig. 3d). However, the decrease was not as pronounced as in spring.

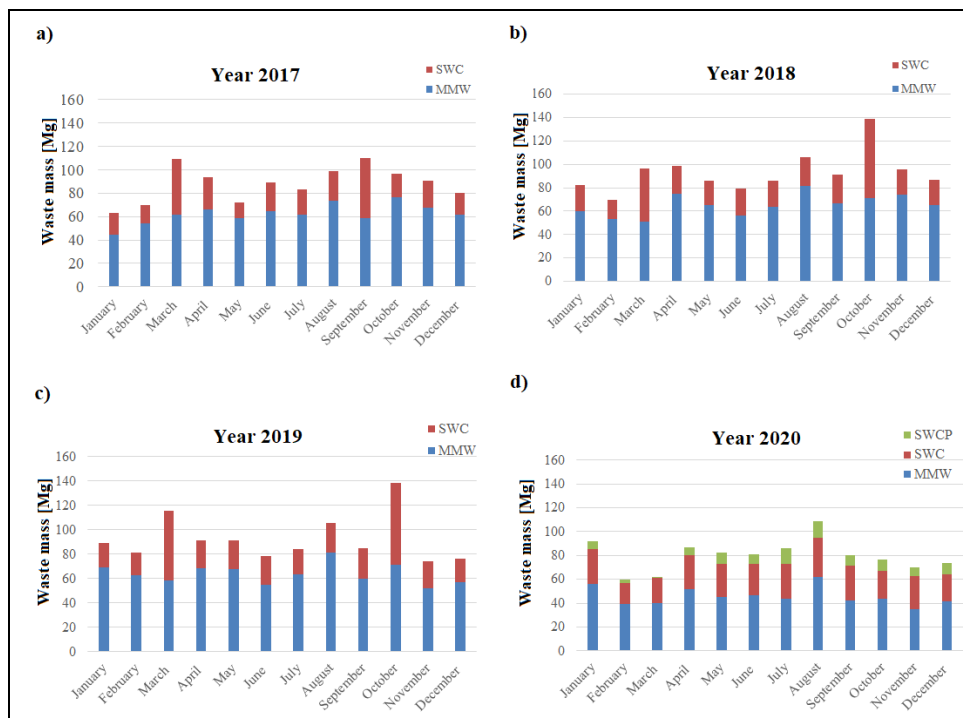


Fig. 3. The amount of waste generated in the area of Sieniawa commune, broken down into mixed waste (MMW), selectively collected waste (SWC) and waste coming from the selective waste collection point (SWCP)

In order to carry out a detailed analysis of the impact of the COVID-19 pandemic on the amount of waste generated (MSW), the data obtained in this respect and the ranks of the restrictions assigned to them were compared (Fig. 4). A statistically significant (negative) correlation was observed between the total amount of MSW generated and the introduced restrictions ($r=-0.61$, $p<0.05$). It was noted that the response to the restrictions introduced was a marked reduction in the stream of municipal waste generated.

Ultimately, such a strong association between these parameters indicates that COVID-19 had a significant impact on the amount of waste generated in the study area. Due to the fact, that generally assumed to the escalation of the COVID-19 pandemic have increased solid waste generation (including municipal solid waste) [3, 4]. Our study are in some opposition to the thesis so far put forward on this topic. Here, researchers point out that online purchases (including groceries) were very popular during the pandemic, thus indicating an increase in packaging waste feeding the municipal waste stream [20]. On the other hand, however, one of the positive changes in behaviour changes among the population in many countries has been a significant reduction in the (previously widespread) phenomenon of food waste [10, 21]. It follows that, in

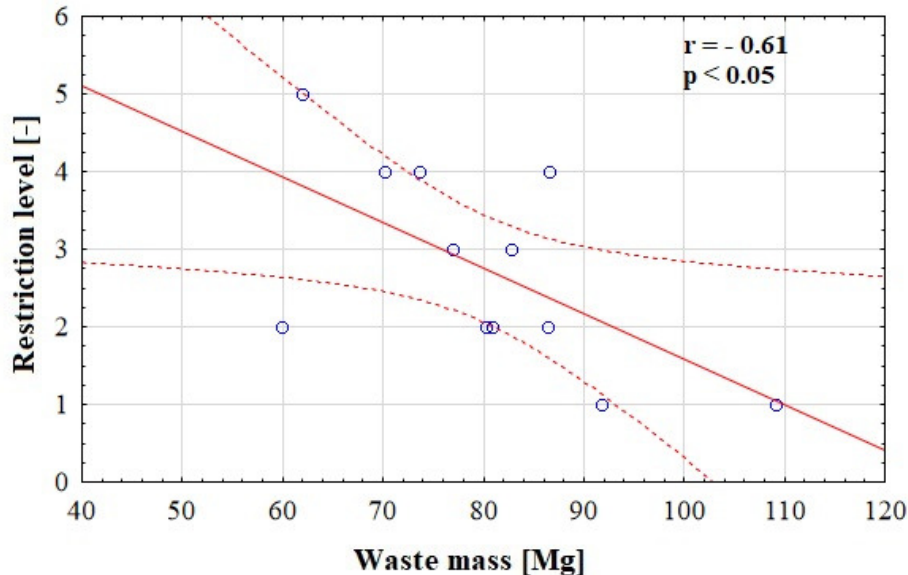


Fig. 4. Relationship between monthly amount of municipal waste generation in 2020 and COVID-19 restrictions implemented

the current state of knowledge, no clear patterns have been developed to predict the mechanisms of shaping the level (scale) of waste generated during an emergency.

In general, the public's first reaction to the restrictions introduced in 2020 was to comply with them [22]. However, with time, some disturbing effects of the adopted strategy of fighting the virus began to be noticed. The consequences of the introduced restrictions were observed not only in the economic or environmental aspect, but also in the area of social life (especially in terms of population mobility) [17, 18, 23, 24]. An increase in the time spent at home (place of residence) has been highlighted. In this difficult time, a significant part of the population has been obliged to switch to working and/or studying remotely. In addition, as a result of the closure of many retail and service facilities, leisure and cultural venues were visited less frequently and public transport was used less. No less drastic declines were recorded in grocery shops and pharmacies. While in this case there was a clear downward trend in the use of such facilities in the first phase of the restrictions, this situation did not last long and the popularity of these outlets began to increase again over time [17].

The results of our research indicate that while in the circumstances of a sudden emergency (COVID-19) the reaction of the population was relatively predictable, i.e. in the first phase of the pandemic, the fear of virus infection caused a kind of natural social reaction of withdrawal from the existing lifestyle. This was ultimately reflected in a markedly reduced amount of waste generated at that time. However, as the pandemic continued, the reactions of the population were not so obvious. During the autumn 'second wave' of the pandemic, a certain

social relaxation was noticeable. It is presumed that as time passed, the public became accustomed to the risks of the SARS-CoV-2 virus and the fear of contracting the disease diminished. Most likely for this reason (despite the re-introduction of severe restrictions), the amount of waste generated at that time was at a comparable level to 2019. This may represent a kind of community resistance to increasingly onerous restrictions and a desire to return to life before the outbreak of the pandemic.

4. Conclusions

As a result of the announcement of the COVID-19 pandemic, the year 2020 was a special year and definitely different from previous years. In a short period of time, a number of changes took place, mainly in the aspect of functioning of the society. Among other things, people's lifestyles as well as their habits and customs changed dramatically. In the case of the analysed committee of Sieniawa, the year 2020 was characterised by a clear decrease in the amount of municipal waste generated (in relation to 2017-2019). Moreover, it was shown that a statistically significant impact on the situation occurred due to various restrictions and orders limiting civil liberties introduced at that time. For some time, the population withdrew from their activities (or was obliged to do so). Generally, along with the "loosening" of the economy, an increase in waste generation was observed. A clear manifestation of this was the culmination of waste generation in August 2020. The increase observed at that time may have been related to some kind of social loosening and the least restrictions. In contrast, the severe restrictions reintroduced in the autumn highlighted a recurring downward trend in waste generation (although not as large a drop as at the start of the pandemic). Nevertheless, the above observations confirm the clear link between the declared COVID-19 pandemic (with its related restrictions) and the reduced amount of waste generated at that time in the studied area (Fig. 5). It can be argued that while the measures taken did not translate into effective (complete) eradication of the pandemic, they certainly contributed to minimising the negative human pressure on the environment.

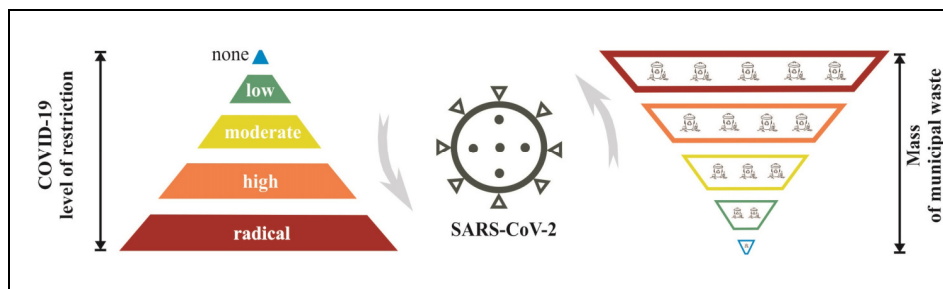


Fig. 5. Overall relationship between COVID-19 and amount of municipal waste generated

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