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ASSESSMENT OF RURAL AREA RESIDENTS' AWARENESS OF MUNICIPAL WASTE INCINERATION*

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Abstract

Municipal solid waste (MSW) management is an element of environmental protection, environmental health, and sustainable development. The presence of MSW in the environment may be the cause of a variety of threats, including the pollution of the atmosphere, water, and soil, as well as those related to health. Due to improper management of MSW, an adverse interaction with the environment may occur in the form of volatile chemical substances released as a result of burning. The best way to reduce MSW impact on the environment is primarily to prevent production of waste and to promote its recycling, and later proper collection and disposal. The aim of the study was to carry out research related to social awareness (of rural area inhabitants) of MSW management via incineration, as well as the dangers of improper waste disposal. The research was conducted in the form of a direct interview. An inclusion criterion was the ownership of own heat source in the household in the form of a solid fuel furnace. The research was carried out using the diagnostic survey method and direct observation. 30% of the female and 70% of the male participants declared they burned MSW, while biodegradable waste burning was indicated by 88.9% of the female and 91.6% of the male participants. The main causes of this situation were the high prices of solid fuels, the costs of waste collection, as well as the

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low awareness of the effects of burning MSW among the rural area inhabitants. Official control of the ways of heating households in the scope of proper MSW management in rural areas is a chance for the amount of MSW burned in household furnaces to decrease. Educational measures should be undertaken systematically in local communities, with the aim of providing information about the toxic substances emitted into the atmosphere, especially regarding the related health hazards.

Keywords: rural areas, waste management, municipal waste, waste incineration, environment, health, environmental risk, health risk, education.

INTRODUCTION

The growing amount of municipal solid waste (MSW) and its improper management cause serious environmental issues with social, political, ecological, and health consequences.

According to the current legal regulations, MSW is understood to be the waste produced in households, excluding end-of-life vehicles, as well as the waste that does not contain harmful waste originating from other waste producers, which resemble household-produced waste due to their nature or composition (Ustawa 2012).

MSW composition is a mix of various waste and depends on many factors, such as the area it comes from, the wealth of the inhabitants, environmental awareness of the inhabitants, prices of solid fuel, and the fees for waste collection (Doaemo et al. 2021).

According to the data from the Statistics Poland (GUS), in Poland in 2020, 13.1 million tons of MSW were collected (which is a growth of 2.9% in comparison with 2019), with a simultaneous 25.1% growth of selectively collected MSW in comparison with the previous year. Household-produced waste, which constitutes 86.1% of all MSW produced, reached 11.3 million tons, with 342 kg collected MSW per capita, which signifies a growth of 10 kg in comparison with the previous year (GUS 2020), while in the EU, the average MSW per capita is 487 kg (Walosik et al. 2021). The World Bank estimates state that by 2025, 4.3 billion city inhabitants will generate 1.42 kg of waste daily per person (Rahman et al. 2021). However, there is a lack of complex data related to rural area inhabitants.

The morphology of the MSW composition shows different kinds of waste in it, such as food waste, plant waste, animal food product waste, paper and cardboard, plastics, textiles, glass, metals, as well as organic and mineral waste (Lewandowska et al. 2016, Jurczyk et al. 2018, Khair et al. 2019).

Improper MSW management not only causes economic loss (as it cannot be reused), but also has a negative impact on the condition of the environment and human health. The literature states that dangerous chemical substances are released into the environment as a result of municipal waste incineration (Chmielewski et al. 2020, Walosik et al. 2021).

Based on the research, several chemical compounds released into the atmosphere were identified in the process of burning waste, accounting for the morphological composition of MSW, such as: persistent organic pollutants (POPs) carbon oxide (CO), nitrogen oxides (NO_x), primary organic aerosol molecules (POA), volatile organic compounds (VOC), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF). In the case where the burned MSW contains plastics, such as polyvinyl chloride (PVC), low and high-density polyethylene (LDPE and HDPE), polystyrene (PS), polypropylene (PP), and polyethylene terephthalate (PET), substances that are dangerous to the health are released, e.g., bisphenol A (BPA) or diethylhexyl phthalate (DEHP), hydrogen chloride, phosgene, and molecular chlorine. Moreover, a significant number of particulate matter molecules (PM), which contain toxic radicals, silicon, and aluminum, is released into the atmosphere during burning. The solid residue remaining after MSW incineration contains heavy metals, such as lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni), mercury (Hg) and cadmium (Cd), as well as polycyclic aromatic hydrocarbons – PAH (Lundin et al. 2013, Jouhara et al. 2017, Horák et al. 2019, Wang et al. 2019, Chmielewski et al. 2020, Li et al. 2021, Walosik et al. 2021).

The source of release of the above-mentioned compounds into the atmosphere is primarily the low emission from the combustion of MSW in home furnaces. Hence, the awareness of the inhabitants of those places where the incineration of this waste takes place, primarily the rural communities, plays such an important role.

Table 1 shows the emissions of pollutants released into the atmosphere during municipal waste landfill fires.

Exposure to smoke that contains toxic gases and chemical substances, particulate matter (PM) and heavy metals as a result of MSW incineration causes long-lasting health consequences, such as lung disorders, cancers, mental disabilities, genetic disorders, and reproductive disorders (Suades-

Table 1

Emissions of pollutants from landfill fire, ng m⁻³ (modified)
(Chmielewski et al. 2020)

Pollutant	Controlled landfill burning	Uncontrolled landfill burning
Phenanthrene	520	30
Anthracene	160	85
Fluorene	120	180
Pyrene	120	170
Fluoranthene	100	50
Benzo[a]pyrene	20	15
Total PAH	1480	810
Total PCB	15.5	590

-González et al. 2015, Jouhara et al. 2017, Chmielewski et al. 2019, Kicińska 2019, Oliveira et al. 2019, Chmielewski et al. 2020, 2020*a-h*, Di Maria et al. 2021, Velis, Cook 2021, Walosik et al. 2021).

The insufficient awareness of the risks originating from improper MSW management, related to their uncontrolled burning, and the improper manner of landfilling and disposal, not only lead to the atmosphere being polluted with the substances outlined above, but also, and more importantly, it has long-lasting, detrimental effects on human health (Brown 2015, Wang et al. 2019, Doaemo et al. 2021, Rahman et al. 2021).

The research carried out by Robert Oleniacz from AGH University of Science and Technology in Kraków in Krościenko Wyżne (situated in the south-eastern region of Poland in the Podkarpacie province) showed that approximately 50% of the community burn MSW in the home furnaces. On the other hand, the research presented in this article concerned the knowledge about the harmfulness of burning waste among only those residents who burn MSW in their home furnaces, and not randomly selected people. The scope of the research covered their state of knowledge about the harmfulness of MSW combustion, the frequency and reasons for MSW combustion, and the results supplement the poor state of knowledge in this field (Oleniacz, Tomkowicz 2009).

MATERIALS AND METHOD

The research included 150 rural area households from Guzowatka, Kuligów, Małopole, the Dąbrówka municipality, and villages across the Wołomin district and the Mazowieckie voivodship. The selection of the respondents was purposive. The inhabitants of these villages willingly took part in the study, unlike the inhabitants of other localities within a 100 km radius of Warsaw.

The research was carried out in accordance with the rules outlined by the Declaration of Helsinki (World Medical Association Declaration of Helsinki 2013). Participation was anonymous and voluntary. Participants were informed of its aims and their right to withdraw at any moment. The study was carried out between June and September of 2020, under sanitary conditions. The interview questionnaire was left in an envelope for the household inhabitants with a written request for it to be filled out by any one household member of age and a date for its collection was arranged. In an attached participant information sheet, the participants of the study were informed that the research is anonymous, and the collected data will only be used for educational purposes. Three exclusion criteria were applied: 1. The respondent unambiguously answering that they do not burn municipal waste in a furnace, 2. The respondent answering that the household

is heated with natural gas, heating oil, heat pump (due to the inability to burn waste), 3. The researcher deciding that the questionnaire was not filled out diligently and does not reflect reality (e.g., indicating higher education at the age of 20). The questionnaire was filled out by people interested in partaking in the research. The questionnaires were collected from 136 households. In 14 cases, people refused to participate in the research. Due to incomplete data in the answers or duplicate data in the demographic section, 16 questionnaires were excluded from the research, the researchers having decided that they were not filled out diligently and do not reflect reality. The analysis was carried out on 120 questionnaires. All participants answered in the affirmative when they were asked about burning MSW. The research tool used was a self-designed interview questionnaire, which covered 6 thematically blocked sections, consisting of questions on demographics (gender, age, education), means of heating the household (type of fuel), frequency of waste incineration in furnaces, the type of waste burned, reasons for waste incineration and general knowledge on the topic of health risks of burning waste. The questionnaire consisted of alternative choice questions (with answers which contradict each other, e.g., yes/no), single select multiple choice questions (where the respondent is supposed to pick one answer out of several options), multi select multiple choice questions (where more than one answer can be picked), control questions (questions asked once again but phrased differently to check if the respondent is truthful and exclude cases where they are not). Descriptive analysis of the obtained data was applied.

MSW produced in households in the Dąbrówka municipality is collected from each property by an economic entity appointed by the municipality. The municipality does not have limitations as to how much MSW can be collected from inhabited properties. The frequency and the dates of MSW collection were established in relevant Resolutions of the Dąbrówka Municipality Council. As of January 1st, 2020, the Dąbrówka municipality excluded properties with holiday homes, or others used for recreational and leisure purposes, from the municipal system of MSW management. The cost of MSW management in 2020 within the territory of the municipality for inhabited properties was 33.00 PLN/person/month in the case of selective MSW collection, and 132.00 PLN/person/month in case of non-selective MSW collection. The municipality wants to reduce the mass of MSW through inhabitants installing backyard composters, which will result in a lower cost of collection and management of the municipal waste that the inhabitants have to bear (UGD 2020).

RESULTS AND DISCUSSION

In Poland, until the entry-into-force of the regulations detailed in the Act of 29 July 2005 (Ustawa 2005), there were legal regulations (Rozporządzenie 2002) allowing for the thermal conversion of waste in household central heating installations and appliances, kitchens, and furnaces, with waste in the form of paper and cardboard, scrap paper, sawdust, wooden chips, chipboards, veneers, wooden packaging, tree bark waste, and wood or silviculture waste. The then regulations largely contributed to the fixed nature (through habituation) of the use of this waste in the economy through its burning in rural area households, especially amongst older people. This is confirmed by the obtained results, which indicate that approximately 80% of respondents (including 69.4% of women and 90.0% of men) burn mainly paper waste in home furnaces (Table 2).

Table 2

Material structure of the incinerated municipal waste*

Type of incinerated municipal waste	Total (<i>n</i> = 120)		Women (<i>n</i> = 36)		Men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Paper (e.g., newspapers, cardboard, magazines)	104	86.7	25	69.4	79	94.0
Plastic packaging (e.g., after beverages, food products, cleaning products, pharmaceutical drugs, disposable plastic bags)	86	71.7	23	36.9	63	75.0
Wooden materials (e.g., twigs, furniture, window frames)	76	63.3	23	63.8	53	63.1
Plastic products (e.g., plastic bowls, plates, cutlery, disposable cups)	24	20.0	4	11.1	20	23.8
Textiles (e.g., shoes, clothes, cloths)	18	15.0	2	5.5	16	19.0
Other (e.g., polystyrene, used fertilizer bags, drugs past expiry date)	14	16.7	6	16.7	8	9.5
Tires	8	6.7	0	0	8	9.5
Biodegradable waste (e.g., grass, leaves)	109	90.8	32	88.9	77	91.6

Source: developed by the authors

* number of people and answers do not total to 100% due to the possibility of multiple selection

The uncontrolled nature of MSW and incineration of plant remains contribute to the deterioration of the air quality as a result of the emission of many pollutants, including PAHs, PCDD/PCDF, or heavy metals (Chmielewski 2020, Chmielewski 2020*a,b*, Walosik 2021). The burning of MSW in households located in rural areas is one of the reasons behind the large share of this process in the total emission of chemical pollutants into the atmosphere (Olszowski et al. 2012).

The above data are confirmed by the research presented herein, which shows that over 70% of the surveyed inhabitants of rural areas burn such waste as plastic packaging of beverages, food products, cleaning agents, medicines and plastic bags (Table 2). As a result of the combustion process of wastes, PAHs, PCDD/PCDF and PCDD/F are released into the atmosphere.

Available data show that the main source of PCDD/F emission into the atmosphere in 2019 in Poland was the “other sectors” category (excluding the energy industry, manufacturing industry, construction industry, and transport), which produced 63% of the national emission, and was dominated by household furnace incineration emission. PAH emission into the atmosphere from household furnace incinerations was at the level of 3 800 kg Mg, hexachlorobenzene (HCB) at the level of 0.38 kg, and polychlorinated biphenyls (PCB) at the level of 0.39 kg. Meanwhile, the emission of heavy metals into the atmosphere as a result of incineration in household furnaces amounted to: 510 kg Pb, 320 kg Hg, 100 kg Cu, 5 290 kg Zn and 130 kg As (Kobize 2021).

The authors, having analyzed the state of knowledge, especially about the sources of emissions of the above-mentioned organic compounds, put forward a hypothesis that the main source is low emissions resulting from uncontrolled combustion in MSW home furnaces with a specific material structure. This hypothesis was verified by conducting a survey among the rural community burning MSW.

On the basis of the data collected for the research, it can be concluded that the means of heating the household allow rural area households to burn MSW (Table 3). The lack of sufficient knowledge in areas such as the scope of health risks related to the burning of municipal waste (Table 4), including biodegradable waste (Table 2), but also high costs of solid fuels, long waiting time for MSW collection and habituation (Table 5) result in burning the waste, mainly newspapers, cardboard, magazines, and plastic packaging, which are the most common type of incinerated municipal waste (Table 2).

Burning MSW in furnaces was declared by 30% of the women and 70% of the men participating in the research, while biodegradable waste incineration was indicated by 88.9% of the female and 91.6% of the male participants (Tables 6 and 2).

47.6% of the general participant pool admitted to systematically burning municipal waste in furnaces, 44.4% of the women and 48.8% of the men (Table 7).

Table 3

Heating system of the household divided into the type of solid fuel used

Means of heating the household Criterium of division	Total (<i>n</i> = 120)	
	<i>n</i>	(%)
Coal + wood	69	57.5
Ecopeas	18	15.0
Pellets	9	7.5
Wood or sawdust	17	14.2
Natural gas	4	3.3
Heating oil	3	2.5
Heat pump	0	0

Source: developed by the authors

Table 4

Harmfulness of municipal waste incineration*

Level of knowledge of the harmfulness of municipal waste incineration						
Criterium of division	total (<i>n</i> = 120)		women (<i>n</i> = 36)		men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Waste incineration is not dangerous for the environment	82	68.3	23	63.8	59	70.2
Waste incineration is not dangerous for the health	79	65.8	19	52.7	60	71.4
I am aware that waste incineration may create smoke that contains substances which are harmful to the health	68	56.7	21	58.3	47	55.9
I am aware that waste incineration may have adverse health effects in the long run	59	49.2	15	41.7	44	52.3
I have heard of dioxins and know what they are	49	40.8	11	30.5	38	45.3
I have heard of particulate matter and know what it is	53	44.2	15	41.7	38	45.2

Source: developed by the authors

* number of people and answers do not total to 100% due to the possibility of multiple selection

Table 5

Reasoning behind municipal waste incineration*

Reasons for municipal waste incineration	Total (<i>n</i> = 120)		Women (<i>n</i> = 36)		Men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
High prices of solid fuel	108	90.0	31	86.1	77	91.7
Long wait for the collection of municipal waste	82	68.3	18	50.0	64	76.1
Inability to deposit waste on landfills	53	44.2	16	44.4	37	30.8
Lacking the habit of segregating waste	34	28.3	8	22.2	26	30.9
Habit	57	47.6	16	44.4	41	48.8

Source: developed by the authors

* number of people and answers do not total to 100% due to the possibility of multiple selection

Table 6

Demographics (gender, age, education) of people burning municipal waste

Gender	Total (<i>n</i> = 120)		Women (<i>n</i> = 36)		Men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Man	36	30.0				
Woman	84	70.0	36	100	84	100
Age						
Criterium of division	total (<i>n</i> = 120)		women (<i>n</i> = 36)		men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
<20	2	1.7	0	0	2	2.3
20-30	11	9.2	2	5,5	9	10.8
30-40	18	15.0	5	13.8	13	15.5
40-50	24	20.0	7	19.4	17	20.1
50-60	28	23.3	9	25.0	18	21.4
>60	37	30.8	12	33.3	25	29,7
Level of education						
Criterium of division	total (<i>n</i> = 120)		women (<i>n</i> = 36)		men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Basic	23	19.2	8	22.2	15	17,8
Vocational	54	45.5	13	36.1	41	48.8
Secondary	28	23.3	10	27.8	18	21.5
Higher	15	12.5	5	13.9	10	11.9

Source: Own work

Periodicity of municipal waste incineration

Frequency of municipal waste incineration	Total (<i>n</i> = 120)		Women (<i>n</i> = 36)		Men (<i>n</i> = 84)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
I have done so systematically (for a few years)	57	47.6	16	44.4	41	48.8
I do it often (a couple of times a week)	19	15.8	6	16.7	13	15.5
I do it sometimes (a couple of times a month)	15	12.5	4	11.1	11	13.1
I do it rarely (a couple of times a quarter)	13	10.8	5	13.9	8	9.5
I do it sporadically (a couple of times a year)	16	13.3	5	13.9	11	13.1

Source: developed by the authors

The research indicates that the main reason that prompted participants to burn MSW was the high prices of solid fuels – as stated by 90% of the participants, but also the long waiting time for waste collection – 68.3% of the participants, meanwhile 28.3% of the participants admitted lacking the habit of segregating their waste, and 47.6% indicated a habit of burning waste (Table 5).

Amongst people who burn MSW in households, the dominating social groups were men – 70% of the participants, older people (above the age of 50) – 54.1% of the participants, as well as people with lower levels of education (primary or vocational) – 64.7% of the participants (Table 6).

The Latin maxim „*Consuetudo altera natura est*” (Habit is one’s second nature) was reflected in the results of the research, as the force of habit was indicated as a reason for MSW incineration by 47.5% of the participants, including 44.4% of the women and 48.8% of the men participating in the study (Table 5).

Among the most frequently mentioned MSW incinerated in households, participants pointed to: newspapers, cardboard and color magazines (86.7% of participants), plastic packaging that has contained drinks, food products, cleaning products or drugs (71.7% of participants), and wooden materials such as twigs, furniture or window frames (63.3% of participants), meanwhile 90.8% of the participants admitted to burning biodegradable waste (e.g., grass and leaves) – Table 2.

People participating in this study did not relate the process of burning MSW in the household with harming the environment (68.3% of the participant pool) or the health (65.8% of the pool). Participants of the study had a similarly low awareness of the detrimental effects of particulate matter (44.2%) and dioxins (40.8%) on health (Table 4).

As shown in the study, its participants decided to burn municipal waste within their households. It can be related to costs of purchasing solid fuel, low level of education, desire to get rid of residual municipal waste from their property, habituation, and low awareness of the harmful nature of such practices.

The available literature on the means of municipal waste management by inhabitants fails to report on rural areas. Carrying out research in this area is difficult and costly.

The research carried out by Olszowski et al. in typical Polish village areas were directed at establishing the level of emission and deposition of chosen pollutant gas compounds in the air (SO_2 , NO_2 , C_6H_6), as well as solid particles, while keeping their chemical composition in mind (Mn, Zn, Pb, Ni, Cd, Cu). The results of the study showed that the quality of the air in rural areas is determined mostly by the influence of local sources (agricultural emission and uncontrolled waste incineration), while the quantity of toxic substances entering the environment depends on the cyclic states of the weather. According to the researchers, the presence of heavy metals and the size of their deposition in the dust signify that the quality of air in the area under research is unsatisfactory. The deposition of solid particles in the atmosphere is dependent on the source of emission of the pollutant (agricultural emission and uncontrolled waste incineration). It has been established that the reason for the gaseous pollution of the environment is the emission resulting from the uncontrolled incineration of waste in households (Olszowski et al. 2012).

Bieniek et al. described the phenomenon of municipal waste incineration in households in their research, concluding that village inhabitants burn waste composed of biomass, paper, and plastic. The study showed 36% of the participants think that burning waste in incinerators is harmful (Bieniek et al. 2013).

As Ciesielczuk and Rosik-Dulewska explained in their research, incineration of municipal waste by village inhabitants is not just a result of the lack of elementary knowledge and reluctance towards rational waste management, but in many cases is motivated economically. In their opinion, negative patterns of behaviors consisting of burning municipal waste in fires are still being instilled in Poland (Ciesielczuk, Rosik-Dulewska 2014).

In his research, Sobczyk addresses the issue that a significant problem in rural areas is the low degree of hazardous waste management: agrochemical waste, waste from veterinary treatment, glass, metal items, contaminated solvents, used paint and varnish containers, tires, asbestos. Meanwhile, municipal waste taking the form of scrap paper, paper bags, and other general cardboard and paper waste is burned, and the ashes are used on site to spread on roads or level the ground (Sobczyk 2012).

Borkowska and Kruszyński point out that in a group of 50 agricultural producers, 26% of the participants declared that they burn plant protection

product containers in central heating boilers owned by households (Borkowska, Kruszyński 2019).

In the study carried out on a group of 500 people by Świątek-Prokop et al., 48% of the participants confirmed that they occasionally burn municipal waste. 52% of the people who admitted to burning waste in furnaces indicated that the waste they burn is paper (newspapers, ad leaflets from supermarkets, and cardboard containers). Burning food product containers (plastic bottles, disposable cups, foil bags, meat packaging, broken toys) was indicated by 34% of the people. 5% of the participants admitted to burning their old, worn-out clothes (Świątek-Prokop et al. 2016).

The results of this research point to the incineration of MSW taking the form of paper and plastic, as well as establish that the factors shaping these kinds of behaviors were the high cost of solid fuel and low social awareness of this process among rural area inhabitants, who were consequently prompted to burn MSW in their household furnaces.

The attitudes of the rural area inhabitants, as well as the picture of social awareness of the risks related to the uncontrolled incineration of MSW in households, were mirrored in other studies mentioned in this work (Oleniacz, Tomkowicz 2009, Ciesielczuk, Rosik-Dulewska 2014, Doaemo et al. 2021).

CONCLUSIONS

Improper management of MSW in rural areas is a genuine environmental and epidemiological threat to their inhabitants.

Environmental and health education in rural areas should be aimed at integrating environmental protection initiatives and encompass areas such as waste production prevention, elimination of dangerous components of household waste, avoiding excessive use of packaging, clean production, collective responsibility for the condition of the environment, and consequently, the health condition of rural area inhabitants.

Based on the literature data analysis and survey research, several conclusions can be drawn:

1. Proper management of MSW in rural areas is not just a testament to the level of environmental education, but also a guarantee of the life and health quality for the inhabitants.

2. The study showed that among the significant reasons for MSW incineration in rural areas, the dominating aspect is the economic one, as well as the type of solid fuel furnace owned. The ability to use own waste as a means of heating the household makes it a tempting alternative to fossil fuels.

4. The study showed that when rural area inhabitants burn MSW containing plastics, consequently causing the emission of pollutants, they contribute to the aggravation of the negative effects on the environment and health.

5. The specificity of the stream of MSW generated and burned in rural area households requires the implementation of broad measures of educating people in the area of environmental protection and human health.

6. It is valid and purposeful to continue research aiming at discovering the conditions of the phenomenon of improper MSW burning in rural area households and its related health risks.

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