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Analysis of Firewater Samples from Simulated Fires in Illegal Waste Dumps †

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Abstract: The aim of the work was to simulate a fire in the illegal waste dumps and to find out whether the used firewater represents a potential danger to the environment after its runoff into the surrounding area. Laboratory analysis confirmed the presence of heavy metals and other chemical compounds (nitrates, sulphates and chlorides). Given the results of the above analysis, we can state that the used firewater contains hazardous substances, which confirms the release of these substances into the water during extinguishing of waste-dump material. This thesis does not aim to criticize the tactical procedures of firefighters in extinguishing such fires, as their main goal is to eliminate waste-dump fires and eliminate the further spread of fire.

Keywords: illegal waste dump; fire; extinguishing; environment; danger

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1. Introduction

There is no current legislation to address the issue of hazardous substances contained in firewater, specifically for water used for extinguishing illegal waste dumps. In real conditions (during an ongoing fire) it is unthinkable to measure the content of hazardous substances in the runoff firewater, but no work has been found that would deal with the issue, and therefore (at least to give you an idea) we have the opportunity to find out something more about what remains in the place of illegal waste dumps after their fire.

It is almost impossible to find a specific number of illegal waste dumps in the Czech Republic, because the Ministry of the Environment does not keep any agenda that would record the statistical number of illegal waste dumps [1]. At least approximate numbers can be obtained through various applications that allow citizens to report illegal waste dumps. Three of them are the applications ZmapujTo, TrashOut or ZlepšemeČesko. For example, in the ZmapujTo application, it is possible to find out that from October 2021 to October 2022, 2674 illegal waste dumps were reported throughout the Czech Republic.

The main feature of an illegal waste dump is the accumulation of waste by an unknown producer. Such waste is characterised by its diversity and collection outside the designed areas [2]. Because of its very existence, the illegal waste dump encourages people to pile up more waste in such places, which causes an increase in the volume of the waste dump and thus increases the risk of possible fire and contamination of the surroundings. The most common locations of illegal waste dumps are remote places of the suburban districts.

The risk of illegal waste dumps burning is relatively high, and fires occur across the country during all seasons. One of the possibilities of an illegal dump fire can undoubtedly be the spontaneous ignition of stored materials. The Fire Rescue Service of the Czech Republic does not distinguish between legal and waste dumps, so there are no statistics available to distinguish the number of fires.

2. Materials and Methods

According to the ZmapujTo.cz portal, ten localities across the Ústí and Labem Region were selected, where illegally stored waste was to be found. Field research revealed that waste is actually present at six of these sites. The structure of the waste was the same in several places, so samples were taken from only four illegal waste dumps. A sufficient amount of waste was collected from each site using the necessary tools.

Sample 1 consisted of PET bottles, a LED bulb, sheet metal packaging from synthetic paint, sheet metal packaging of wood glaze, plastic packaging of fertilizer, Tetrapak packaging and insulating polystyrene.

Sample 2 contained material from a car wreck (seat cover, foam seat filling, plastic bottle with coolant, textiles, printed circuit, plastic box with bulbs and fuses).

Sample 3 consisted of cut parts of the tyre. The composition of a tyre generally consists of rubber, steel reinforcement and a modified fabric.

Sample 4 consisted of dirty fabric, Christmas decorations (wood, plastic, polystyrene), tin food packaging, cigarette wrapper, polystyrene filling material, coffee cup (plastic lid, paper cup with polypropylene) and thermal insulation gold foil.

After treatment, the samples separated or deformed by the tools were placed in transportable sealable plastic boxes. All sample boxes were sealed with insulating tape and numbered (including the lid of the box) according to the location for better clarity in further processing. (Figure 1).

Figure 1. Samples.

All material was carefully dried, shaped into the desired, suitable shape (cut with scissors, cut with a knife or deformed) and prepared for the subsequent simulated fire.

The simulation itself was carried out by burning individual samples in the galvanized containers, which were numerically marked according to the individual samples. Pieces of wood were first set on fire in the containers using paper and a gas lighter (the use of alcohol firelighters was not intended to eliminate the substances contained in these firelighters). After sufficient burning of the wood, the samples were gradually placed in the individual containers to burn them (Figure 2). Each sample was left to burn for 10 min, and then extinguishing was carried out. Using one "D flash", the individual simulated fires were extinguished relatively quickly (the diameter of hose D is 25 mm, it is used for extinguishing forest fires, but also for apartment fires). The firewater corresponded to the commonly used water that the fire protection unit takes from the municipal water mains.

Figure 2. Fire simulation.

After extinguishing successfully, the remnants of the individual burnt samples were allowed to cool in containers. Favourable climatic conditions at an outdoor temperature of 3 °C contributed to the fast cooling. The temperature of individual samples was continuously checked by a thermal camera, and after reaching a temperature of 15 °C, the used firewater was poured into prepared boxes to reduce the amount of burnt waste residues contained in the water (Figure 3).

Figure 3. Samples before filtration.

After pouring it into the boxes, the colouration of the firewater was clearly visible in some of the samples, and in the case of the burnt tyre sample, granular parts were clearly visible, which could not be separated by mere spillage, as they were carried away by water.

For the purposes of this experiment, an accredited laboratory was consulted in advance on how to store the firewater. The laboratory recommended taking a simple sample (single and randomly taken sample) in the PET bottles with a minimum capacity of 1 litre. These PET bottles (sample containers) and their bottle caps were rinsed with unused firewater three times before use. To pour the firewater into the prepared sample containers, it was recommended to use a filter fabric to prevent parts of the incinerated material from entering the samples intended for analysis. In our case, FITPOP I filter fabric was used (filter non-woven fabric with base fabric, 100% polypropylene, heat treated input side, grammage 500 g/m^2, thickness 2 mm, breathability 150 l/m^2/s at 200 Pa, heat resistance 90 °C). The sample container was filled to the brim with used firewater, with the total volume of each sample being 1.5 litres (Figure 4).

Figure 4. Samples after filtration.

The samples prepared in this way were transported to the laboratory for analysis. The time from sampling to submission did not exceed 15 h, with all samples stored at 2–4 °C.

In order to work with the results of the analysis, it was necessary to create "sample 0", i.e., unused firewater from the mains, which was transported to the laboratory together with other samples and subjected to analysis.

An accredited laboratory ALS Czech Republic with a branch in Lovosice was selected for the analysis of firewater samples.

3. Results

Table 1 lists all parameters (marked in red) for which higher values than those allowed were measured [3]. At first glance, it is clear that the limits have been exceeded for all the samples analysed. Out of a total of 116 parameters (4 samples × 29 parameters), the limits were exceeded in a total of 35 cases.

Table 1. Limits exceeded in samples.

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Units	Limit
Physical parameter						
pH value	7.53	5.62	6.67	6.57	-	5–9
Inorganic parameters						
Ammoniacal nitrogen	0.38	4.51	0.831	3.56	mg/L	0.23
Chlorides	131	254	9.8	27.7	mg/L	150
$CHSK_{Cr}$	137	3050	201	1280	mg/L	26
Sulphates e.g., SO_4^{2-}	37	35.6	68.2	133	mg/L	200
Total nitrogen	4.04	19.3	6.79	15.8	mg/L	6
Total metals/major cations						
Ag	<0.0050	<0.0050	<0.0050	<0.0050	mg/L	0.0035
Al	0.739	0.382	0.152	1.98	mg/L	1
As	<0.010	<0.010	<0.010	<0.010	mg/L	0.011
B	0.016	0.035	0.013	0.101	mg/L	0.3
Ba	0.36	0.281	0.0667	0.129	mg/L	0.18
Be	<0.0002	<0.0002	<0.0002	0.00022	mg/L	0.00005
Ca	99.9	73.3	25.4	74.8	mg/L	190
Cd	<0.0020	0.0173	<0.0020	<0.0020	mg/L	0.00015
Co	<0.0020	0.0894	0.0027	0.0049	mg/L	0.003
Cr	<0.0020	0.0109	<0.0020	0.0138	mg/L	0.018
Cu	0.0316	0.0732	0.034	0.208	mg/L	0.014
Fe	0.368	6.53	0.45	3.58	mg/L	1
Hg	<0.010	<0.010	<0.010	<0.010	mg/L	0.07
Mg	3.97	4.07	4.04	17.5	mg/L	120
Mn	0.036	0.175	0.0344	0.424	mg/L	0.3
Mo	<0.0030	<0.0030	<0.0030	0.0053	mg/L	0.018
Ni	0.0086	0.0498	<0.0050	0.0158	mg/L	0.034
P	<0.050	0.74	<0.050	1.4	mg/L	0.15
Pb	<0.010	0.506	<0.010	<0.010	mg/L	0.014
Sb	0.334	1.14	<0.020	<0.020	mg/L	0.25
Se	<0.030	<0.030	<0.030	<0.030	mg/L	0.002
V	<0.0020	<0.0020	<0.0020	<0.0020	mg/L	0.018
Zn	1.67	92.6	4.38	5.12	mg/L	0.092

4. Discussion

Again, it is necessary to state that the composition of waste dumps (whether legal or illegal) is always diverse, but it is evident that the stated values of parameters increase after a fire in any waste dumps.

During the evaluation of the results of the analysis and the procedure of the experiment, a possible link between the amount of measured zinc values and the use of zinc containers in waste incineration was discovered. The containers used for the experiment were made of sheet steel to which a zinc layer ("galvanized") was applied to prevent corrosion of the material. It is therefore probable that due to the thermal reaction there was a significant release of this element into the resulting samples. For any further experiments, it will certainly be appropriate to use a laboratory environment with adequate equipment to eliminate this phenomenon.

A point for reflection may be the development of extinguishing agents that would "neutralise" hazardous substances typical for waste dumps (identified on the basis of analyses and other research). As already mentioned, cartridges containing wetting agents that reduce the surface tension of water have already been used. Thanks to this, the water effectively wets the surface and at the same time flows better into the depth of the burning material. Therefore, the development of a cartridge on a similar principle and the introduction into the standard equipment of firefighting brigades would be beneficial in the event of such fires to reduce the leakage of hazardous substances into the soil or surface water.

5. Conclusions

For this work, four samples were selected from illegal waste dumps from different locations and of a different composition. After comparing the measured values with the permitted limits, it was found that the greatest burden on the environment is represented by fires in car wrecks, particularly the materials of car interiors. Surprisingly, the least burdensome content was the content of substances after a tyre fire (which is not to say that the substances contained in the water after such a fire are not dangerous).

The analysis found that the main elements released in the fire were potassium, copper, sodium, calcium, iron and zinc. In terms of toxicity, concentrations of antimony, barium, aluminium, cobalt, phosphorus, nickel and lead were measured. Each of these elements, by its characteristics, poses a greater or lesser risk to the environment. Some elements occur naturally in the environment and are dangerous only at higher values. On the contrary, other elements have a negative effect on the environment even at lower concentrations. As far as physical parameters are concerned, all samples experienced a decrease in pH and an enormous increase in chemical oxygen demand (which was predictable due to the fact that the firewater was drinking water and after contamination with foreign material, the chemical consumption increases).

Finally, the recommendations for municipalities in whose territory illegal waste dumps occur could be to assume they may be burnt and be prepared for the subsequent need to decontaminate the environment, which should be treated as an area affected by a leak of a dangerous substance, or to prevent such fires by timely removal of these waste dumps or, in the best case, by frequent monitoring of the places of probable origin.

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