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THERMAL ACTIVITY ON LANDFILLS

Decay processes occurring in waste on landfills are connected with temperature rise and lead to stabilisation of organic phase. Those sources of thermal emission detectable using a thermovision camera in monitoring the bioactivity in organic mass on legally located landfills and also in detection of illegally located landfills are discussed. The thermovision method can be useful in detection of gas emission and emission leakage percolating through an unsealed lining system. There is a remote sensing short-term detection of leaks also in the insulating barrier of landfill.

1. 1NTRODUCTION

The investigation presented below was conducted in field conditions and confirmed that an infrared camera could be useful to monitor location of solid organic wastes, allowing short-term detection of leaks in the insulating barrier of the landfill by remote sensing method. Predominantly, detection of leaks by traditional method is costly and requires specialized instruments [1], [7].

There are many problems with the method using thermal infrared camera because there are many combinations that lead to relative temperature differences. Some of these are the presence or absence of vegetation, the nature and uniformity of the cover soils. But sometimes, when detection of gas emission location on landfill area is necessary, then remote sensing method can be useful. The problem is especially important when uncontrolled extraction of landfill gas is discussed [14].

The mechanism of fermentation is the result of microorganic activity – in the first stage – oxic, and in the second stage – anaerobic transformation. Organic substances in the first stage undergo hydrolysis, and then the intensive processes with aerobic and anaerobic microorganisms take place [4], [9]. Thus the term "giant bioreactor" referring to the landfill site is a reasonable description. The necessary conditions providing biochemical transformation are temperature, moisture, redox potential, and others [5], [13]. The processes are described by mathematical models given in [15].

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In practice, the main target when making the decision concerning biogas exploitation is to assess the potential of gas emission [2], [6], [11], [12].

2. INVESTIGATIVE METHODS USED AT LANDFILL SITES

Several research works confirmed the aptitude of the thermal method. EXLER [3] asserted in his work that both the resistance method and the thermal method are useful. The subject of his investigation was water leakage from a municipal landfill close to Munich. Temperature sensors and an electroresistance sounder detected temperature differentials at the site. Groundwater flow in the area investigated was directing the leakage in the same directions beyond the landfill boundary. The leakage extended to about 3 km over the area.

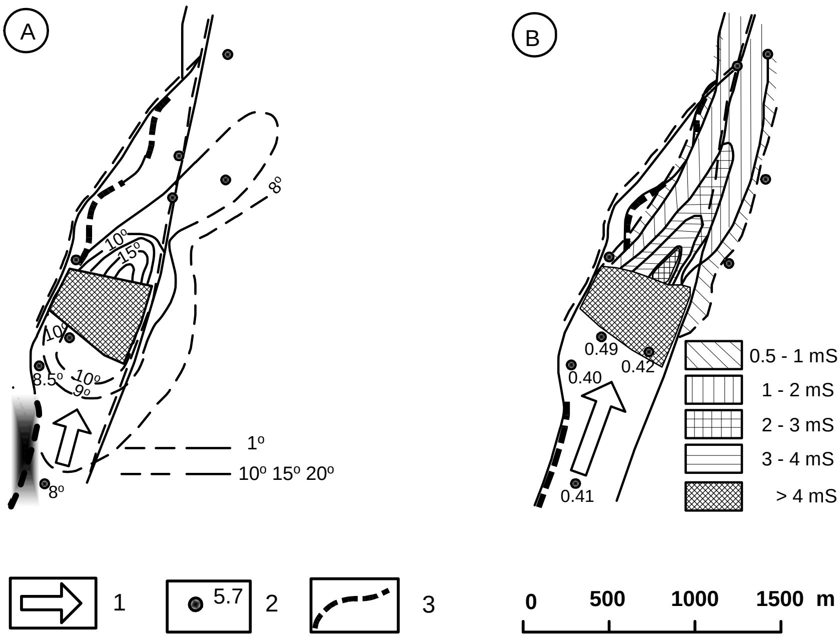

Fig. 1.Varying temperature and resistance of underground water influenced by municipal landfill: A – temperature distribution, B – conductivity; 1. water flow direction, 2. test point, 3. scarp's profile

It has been proved that variables of resistance are in line with variables of leakage temperature [3]. In figure 1, the configuration of isolines representing temperature distribution (in °C) is compatible with isolines representing electroresistance (in mS). This proves that the landfill was the source of migrating leakage and organic substance decay during fermentation processes which caused the temperature increase.

The scientists from Freiburg (Germany) determined some qualities of abandoned landfill by remote sensing using multispectral scanner system [8]. The observations were made from a helicopter from the height of above 350 m. The results were very useful to plan the next step of investigation, the purpose of which was to assess the location and impact of abandoned landfill.

3. THE FOCUS AND RESULTS OF INVESTIGATIONS

In order to assess bioactivity of two different kinds of municipal landfill, an experiment with thermovision camera was carried out. The landfills under investigation (figures 2–4) were located in the vicinity of Kielce (Poland).

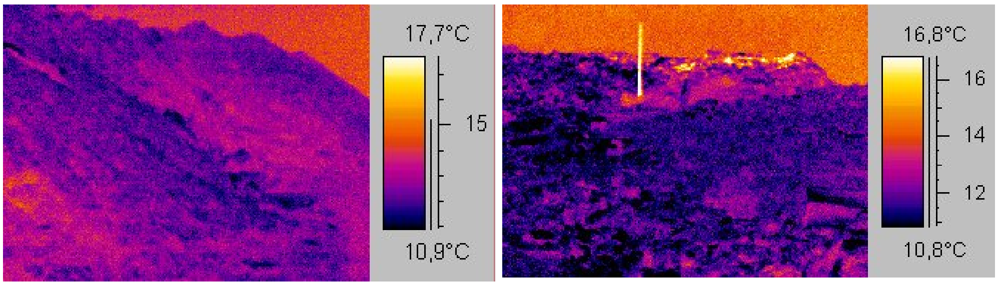

Fig. 2. Heaps on the landfill after long exploitation

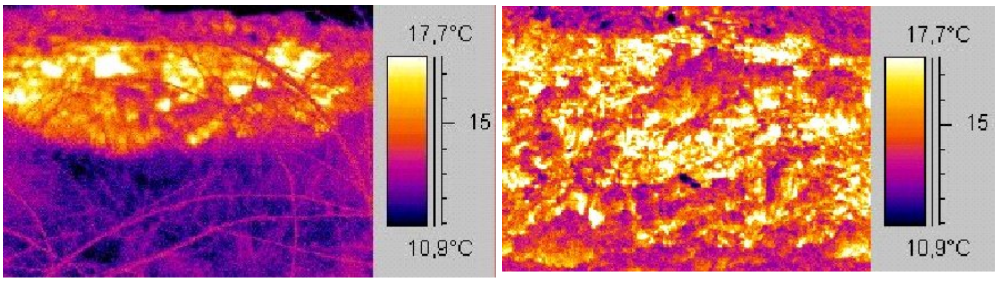

Fig. 3. Bioactive heaps of landfill

The landfill presented in figure 4 was investigated in the final stage of its exploitation (stage of covering the heap). Observation was made from a helicopter flying above the landfill. Thermal activity was monitored by the thermovision camera AGEMA THERMOVISION 550 operating in short wave spectral range and equipped with two standard lenses: 10° and 20°.

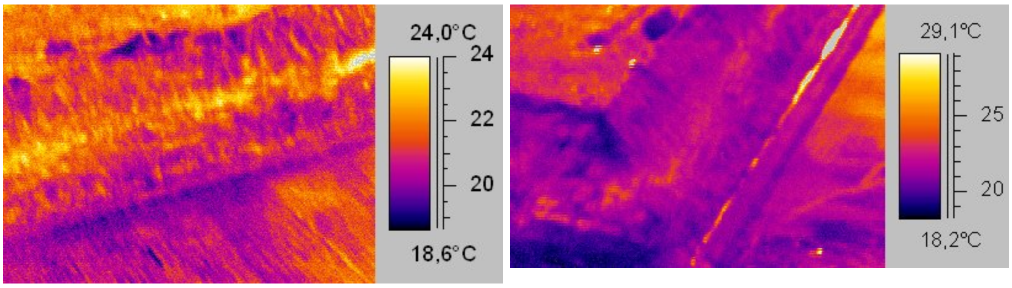

Fig. 4. The scarp of the heap on the landfill – bird 's eye view

3.1. MEASUREMENT LIMITATIONS OF RADIATION METHODS

The thermal field observation of the Earth's surface carries a lot of information. This results from the various physical and chemical processes taking place directly on the surface or under it. In the latter situation, the temperature signal is muffled depending on the depth at which the source of heat is located and on selected physical properties of the soil: conductivity, porosity, heat capacity, etc. A methodology of measurements depends on the purpose of the investigation, which should be very precise. A proper determination of this purpose enables other factors which influence the final result to be selected. These include: the time of the year and day, atmospheric conditions, observation parameters (a distance and inclination of the axis of the lens in relation to the object's surface), the possibility of conducting calibration measurements (of the coefficient of emission, the temperature of the reference point), the number and means of thermographs' analyses [10].

In the Central European climate, the season of the year is an important factor affecting observations and analysis of heat sources located under the surface. The exposure to the sun of an uncovered surface results in the ground temperature being much higher than that with vegetation cover. In the summer, when the soil is covered by vegetation of various kinds, limitations to temperature field analysis occur. These restrictions result from interferences which are connected with a degree of water saturation in the root zone. An additional effect of thermovision measurements at this period of time is a possibility of assessing the condition of crops in the fields. In the winter, the snow layer acts as an insulation, which weakens the measured signal beyond the detection point. Consequently, in this case the radiation technique cannot be applied. In areas where a mixture of water and ice or water and snow is present, thermovision measurements are even more difficult. In such conditions, the heat flux emitted from the surface is completely absorbed by the two-phase mixture whose temperature is close to 0 °C. Considering the above mentioned limitations, the spring and autumn are the most convenient periods of time for thermovision investigations, especially for areas where vegetation is an interfering factor.

Temperature changes throughout the day are another factor which needs to be considered during the planning stage of thermovision measurements. The slightest differences of the thermal field occur just before the dawn while the most significant ones around midday. If the measurements are focused on the detection of thermal anomalies which result from the presence of heat sources located below the surface, late night hours before the dawn are most appropriate, while midday hours are most convenient for analysis of surface features of the terrain and the greenery.

Water which is suspended or dissolved in the atmosphere, the wind blowing during the measurements and other parameters make it necessary to introduce special corrections. Correction parameters are required to be input into devices which detect infrared radiation to ensure that the temperature of an object under investigation is determined properly. These parameters comprise: emissivity, atmospheric transmissibility and relative air humidity.

In the case of surfaces of non-uniform sun exposure, selectively heated and corrugated, the choice of the observation direction and its angle is crucial. The non-uniformity of the ground temperature between the measuring device and an object is a source of deviation resulting from the lack of knowledge of the real value of the coefficient of transmission, which, among others, depends on the density of the atmosphere. The self radiation, which is usually difficult to determine, is also an additional component of the radiation beam reaching the detector. A similar deviation occurs when an improper observation angle of surfaces of non-uniform sun exposure is chosen. Reflected sun radiation might be the source of such a deviation.

The result of the temperature measurement of a surface is its thermal field, on the basis of which the temperature of particular points, areas or along lines could be determined, as well as isotherms, average values, etc. If need arises, their non-stationary distributions might also be determined. The interpretation of a thermal image is easier when a map and photographs of an area are available. It is a common practice to take photographs of an area under investigation at the same time as thermographic measurements.

3.2. DETECTION OF LANDFILLS

The thermographic measurements presented in figures 2–4 were conducted late in the evening in the spring, with no wind and rain throughout. A standard lens of 20° was used for ground observations while for surveying from the air a 10° lens was applied. Emissivity of 0.92 was taken for calculations of the real temperature from a radiation one. In order to compensate the phenomenon of the infrared radiation being muffled on the optical path to the camera, a distance to the object, the temperature and relative humidity of the atmosphere were input to the device. These parameters were measured additionally and independently to eliminate major deviations of the measurement results.

In figures 2 and 3, brighter places represent temperature difference (more than 6 degrees) recorded at landfill heap surfaces. Very bright areas on the thermograms show places in the mass of waste where the fermentation processes of organic substances included in the waste are very active. This was caused by recent waste deposition. The thermograms show that biogas emission can be observed by means of the method presented. In figure 2, a very bright perpendicular spar-shaped object can be seen. It is a biogas probe well drilled into the waste body. The only possible reason for the temperature increase of this site is biomass degradation. As evidenced in by figure 2, biogas escape could be detected on a landfill area due to its higher temperature.

The landfill presented in figure 4 has been exploited since 1985. It had just been covered as the final exploitation stage was attained, according to the project. In figure 4, a bird's eye view of the abutment of landfill and the corner of landfill can be seen as the thermograms were made from helicopter. In the figure, two elements can be distinguished. One is a bright line coming out of the ground and going along the abutment. It shows how leakage penetrates into the waste and is collected in a ditch surrounding the heap. The temperature of leakage, similarly to biogas, is higher than that of the surrounding area.

The second characteristic element is more visible in figure 4 as a bright line going along the abutment and reaching almost the middle of its height. An explanation of this phenomenon became apparent after talking to the manager of the landfill, who knew its "history". In the final stage of landfill exploitation, a compactor was used to intensify density on landfill site. The landfill was exploited for a longer time than planned. The second landfill, next to the first one, was built later than had been scheduled. Consequently, it was necessary to take some steps to prolong the exploitation of the old landfill up to the moment when a new one would be ready. Such a situation, that is lack of a new landfill, was the reason why heaps of landfill were dumped at an angle of about 45°, which was more than could be accepted from a technician's point of view.

The manager of the landfill made a decision to cut (using heavy equipment) the abutment of landfill in the middle of its height for the purpose of compacting the waste by means of a compactor, and then to put the "current" waste on top of it and compact it all over again with heavy equipment. Thus, in the middle of the heap's abutment height the waste was affected by intensive fermentation process while in the waste located in higher and lower layers the bio-processes were dormant (as nutritive substrates for micro-organisms had been exhausted).

5. CONCLUSIONS

Thermal-active processes taking place in waste on landfill can be monitored by an infrared camera, which can be treated as a remote sensing tool for assessing process stabilization of the landfill. It can also be used to localize illegal landfills, which constitute a potential threat to the environment.

The thermovision method can be used for detection of biogas and leakage escape from the landfill, which are often very difficult to carry out in field conditions.

The temperature of both biogas and leakage penetrating into the body of landfill is higher than that of the surrounding areas, and therefore, even a slight penetration by those media can be determined by means of a thermovision camera.

The advantages of the present method include environmental protection around the landfill and prevention of ground water contamination with leakage from landfills as well as explosion due to uncontrolled emission of biogas.

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AKTYWNOŚĆ TERMICZNA NA SKŁADOWISKACH

Proces rozkładu odpadów na składowiskach wiąże się z aktywnością termiczną i prowadzi do ustabilizowania substancji organicznej. Zjawiska te mogą być monitorowane za pomocą kamery termowizyjnej, która służy do oceny aktywności biologicznej legalnych składowisk lub do wykrywania nielegalnych składowisk. Jest to zdalna i szybka metoda wykrywania emisji biogazu i odcieków składowiskowych, także przez bariery zabezpieczające.