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HYGIENIC INVESTIGATION OF SOIL POLLUTION WITH VOLATILE ORGANIC COMPOUNDS IN A MUNICIPAL LANDFILL AREA

M. SIDJIMOV*, AL. SPASSOV

National Center of Hygiene, Medical Ecology and Nutrition, 15 D. Nestorov Blvd., 1431 Sofia, Bulgaria
E-mail: soil@nchmen.government.bg; al.spasov@nchmen.government.bg

Abstract. Volatile organic compounds (VOCs) are substances with well expressed toxic and carcinogenic effects. Their sorption and release from soils is highly dependent upon organic matter content, temperature, saturation and salinity. The main route of human exposure to VOCs is through the respiratory tract and skin with intake via the gastrointestinal tract being less common. The investigation is executed in the region of a municipal landfill near the Suhodol village in Sofia, Bulgaria. The intensively used private agricultural land between the landfill and the village is at high risk for potential VOC pollution. Possible horizontal substance migration is studied through technical estimation of VOC presence in soil subsurface and in 1 m depth. Soil matrix and soil gas samples were taken from selected bore holes and investigated for presence of typical for municipal landfills volatile organic pollutants-vinyl chloride, 1,2-dichloroethane, benzene, toluene, ethylbenzene, xylenes and methane. The results obtained are compared qualitatively with the landfill monitoring data for the landfill gas drainage systems. Evaluated is the health hazard risk for the population from the nearby village and future prophylactic measures for residents and land use are discussed.

Keywords: VOCs, municipal landfill, health risk, soil, sample collection.

AIMS AND BACKGROUND

The investigation is executed in the region of a municipal landfill near the Suhodol district in Sofia, Bulgaria. The facility is situated at 1000 m from Suhodol, operates since 1984 and treats approximately 1000 t waste/day. Its second part built in 1997 functions as a 'sanitary landfill' with the introduction of synthetic lining materials, gas evacuation systems and monitoring equipment.

Like any other municipal landfill, the Suhodol one also releases big quantities of leachate and landfill gas. The average component content of the landfill gas from the site for the last 3 years is shown in Table 1.

* For correspondence.

Table 1. Landfill gas composition (expressed as % by volume)

Component	Typical value (mature refuse)
Methane	55-65
Carbon dioxide	33-40
Oxygen	0.2-2
Nitrogen	2-5
Hydrogen sulphide	<0.1
VOCs	<0.5
Others	0.5

Methane and carbon dioxide are the major gases produced by the bacterial decay of landfill wastes. Other gases released from municipal waste landfills have the potential to cause odours in neighbourhoods surrounding the landfill, such as reduced sulfur gases or sulphides (e.g., hydrogen sulphide, dimethyl sulphide, mercaptans). These odourous gases give the landfill gas mixture its characteristic 'rotting' smell[1].

In the municipal landfill leachate composition volatile organic compounds (VOCs) present in small volume part – less than 0.5%. Although their levels are typically minor compared to the levels of methane, carbon dioxide and sulphides, they are the basic contaminants of concern and have the greatest importance for the human health in the region of the landfill[2].

The aim of the present study is to investigate the presence of VOCs in soils around the Suhodol landfill, to evaluate the obtained results with comparison to international standards and previous experience, to give hygienic recommendations for ensuring future health well-being in the region.

Many different VOCs have been found in leachates and landfill gases. VOCs can have direct adverse effects on human health. Most VOCs have been classified as toxic and carcinogenic substances. These chemicals can represent a health concern when people are exposed to even relatively small amounts over long periods of time. Some health effects from overexposure to VOCs are dizzines, headaches, and nausea. Long-term exposure to certain VOCs has also been shown to cause chromosome aberrations, cancer and physiologic disturbances in the function of liver, kidney, and CNS. The main route of human exposure to VOCs in regions around landfill sites is through the respiratory tract. Bioaccumulation of most VOCs in plant cultures and animals is not observed[3].

Previous health-ecological investigations have shown that the typical for municipal landfills and most often met in soils in such regions volatile organic pollutants are vinyl chloride, 1,2-dichloroethane, benzene, toluene, ethylbenzene, xylenes and methane.

EXPERIMENTAL, RESULTS

In the investigation were selected a number of VOCs sample collection points outside and, respectively, inside the landfill, corresponding to each refuse collection cell. The points were selected on several criteria:

1. Selection of spots outside the landfill covered with yellowish, died-back or dried grass while surrounding grass is green in spring and summer season. Possible landfill gas migration is suspected.

2. Monitoring of H_2S and CH_4 in the selected spots. In boreholes with higher concentration of these gases is more likely to meet presence also of VOCs.

3. The investigation was focused mainly on the area between the landfill and the Suhodol village and on the agricultural land in use.

4. Landfill gas contains H_2S, and sulphides can cause unpleasant odours even at very low concentrations. With the odours being a guidance indicator of whether other chemicals are present, the subjective impressions of some Suhodol residents for the spots with highest odour intensity and persistency are used. The direction of winds was also taken into account.

Analytical screening of the selected spots was executed through measurement of H_2S and CH_4 in soil gas in boreholes at 100 cm depth with the landfill's portable monitoring equipment. H_2S was measured through a Jerome Model 630X hydrogen sulphide meter, and CH4 with the help of a Landtec GEM 500 infrared gas analyser. For the following collection of soil samples for VOCs investigation, from 25 investigated spots around the landfill were selected 10 spots with the highest presence of H_2S and CH_4 in the soil gas. To each of them outside the landfill was selected a corresponding point inside the landfill near a respective landfill refuse collection cell. Thus, each landfill cell was evaluated as a separate, individual potential VOCs pollution source[4].

Some of the results of the H_2S and CH_4 screening in soil gas are presented in Table 2 and a map of the sample collection points is presented in the Scheme.

The collection of soil samples for investigation of VOCs content from the selected points was executed with sampling from 120 cm depth of 200 g intact soil block from each borehole, stored in sterile and hermetically sealed vessel. The samples were collected with automatic auger and sampler 'Solo Multimot, Type 01'. The laboratory analysis of the soil samples was executed through international standard ISO 15009 which include extraction of VOCs and performance of a 'purge and trap' GC analysis. The results are presented in Tables 3 and 4.

Table 2. Screening values of H_2S and CH_4 in soil gas at the points with their highest concentration (mg/m³)

Sample collection points No	H_2S (mg/m³) in soil gas	CH_4 (mg/m³) in soil gas	Corresponding point on the territory of the landfill No	H_2S (mg/m³) in soil gas	CH_4 (mg/m³) in soil gas
1	0.004	2.0	1*	0.004	2.2
2	0.003	2.0	2*	0.004	2.4
3	0.001	1.5	3*	0.002	2.0
4	0.004	1.8	4*	0.007	1.6
5	0.006	2.2	5*	0.005	1.7
6	0.006	1.9	6*	0.004	2.1
7	0.005	1.9	7*	0.006	2.0
8	0.007	2.2	8*	0.007	2.2
9	0.008	2.3	9*	0.009	1.9
10	0.006	1.9	10*	0.006	2.1

Table 3. VOCs in soil samples from points outside the landfill (mg/kg), analytical standard ISO 15009

VOC	Detection limit	Sample No							International MCLs		
		1	2	3	4	5	6	7	EPA* limit for clean soil	Dutch list, norm B	EEA** data-base
Benzene	0.002	nd	nd	nd	nd	0.007	0.005	nd	0.06	0.50	0.065
Ethylbenzene	0.005	nd	0.010	nd	nd	0.008	0.010	nd	10	5.00	10.14
o-, *m*-and *p*-xylenes	0.005	nd	nd	nd	nd	0.030	0.035	nd	7.00	5.00	4.41
Styrene	0.010	nd	nd	nd	nd	nd	nd	nd	–	–	9.95
Toluene	0.002	nd	nd	nd	nd	nd	nd	nd	5.40	30.00	4.21
1,2-Dichloroetane	0.050	nd	nd	nd	nd	nd	nd	nd	1.40	–	0.41
Trichloretylene	0.030	nd	nd	nd	nd	nd	nd	nd	2.00	–	3.54
Vinyl chloride	0.010	nd	0.010	nd	nd	0.020	0.020	nd	0.10	–	0.50

nd – not detected; MCLs- maximum concentration levels; *United States Environmental Protection Agency; **European Environment Agency.

Table 4. VOCs in soil samples inside the landfill borders (mg/kg), analytical standard ISO 15009

VOC	Detection limit	Sample No							International MCLs		
		1	2	3	4	5	6	7	EPA* limit for clean soil	Dutch list, norm B	EEA** data-base
Benzene	0.002	nd	nd	nd	0.003	0.005	0.006	nd	0.06	0.50	0.065
Ethylbenzene	0.005	nd	0.014	nd	0.007	0.015	0.010	nd	10	5.00	10.14
m- and *p*-xylenes	0.005	nd	nd	0.008	nd	0.040	0.015	nd	7.00	5.00	4.41
Styrene	0.010	nd	nd	nd	nd	nd	nd	nd	–	–	9.95
Toluene	0.002	nd	nd	nd	nd	nd	nd	nd	5.40	30.00	4.21
1,2-Dichloroetane	0.050	nd	nd	nd	nd	nd	nd	nd	1.40	–	0.41
Trichloretylene	0.030	nd	nd	nd	nd	nd	nd	nd	2.00	–	3.54
Vinyl chloride	0.010	nd	0.020	nd	0.013	0.028	0.022	nd	0.10	–	0.50

nd – not detected; MCLs- maximum concentration levels; *United States Environmental Protection Agency; **European Environment Agency.

The presence of benzene, ethyl benzene, xylenes and vinyl chloride in the landfill refuse and, respectively, in the soil samples is explained with the impossibility for absolutely strict control over the materials to be deposited on the landfill. The concentrations of the investigated VOCs are far below internationally adopted MCLs (maximum concentration levels) and levels needed to produce toxicity.

From the sample collection points outside the landfill, highest VOCs concentrations are found in points 5 and 6 corresponding to the lowest part of the landfill near the leachate collection tank. This is also the nearest to the Suhodol part of the landfill, situated at 900-1000 m from the village.

Exists coincidence in the discovered types VOCs in the samples inside the landfill and in the corresponding to them points outside the landfill border. The concentrations outside the landfill are lower and, thus, prove existing gradualness in the subsoil VOCs migration.

Despite VOCs concentrations lower than MCLs, still minor quantities of VOCs are detected also in the soils from the other selected points. This fact should raise the public awareness, should serve as a warning indicator for potential hazard and proves the need of future monitoring studies.

The partial migration of landfill gas and leachate increases the mobility of various VOC components of the landfill gas into adjacent soils and subsequently permits the absorption of these VOCs by the soil pore water and the groundwater. Contamination of the groundwater aquifer may result.

In this connection is executed additional investigation of wells (used for irrigation needs) in private yards in the Suhodol village for presence of VOCs. Investigated are 5 wells in the nearest to the landfill part of the Suhodol. The

analyses are performed through sample collection and laboratory standards ISO 15680 and ISO 10301. In no one of the wells are detected VOCs and the water in them is evaluated as clean from these compounds and safe for use.

CONCLUSIONS

1. Hygienic investigation of VOCs in soils in the Suhodol landfill area is executed for the first time. The levels of the investigated VOCs that might reach surrounding environment and homes are far below these which are known to cause ill effects. The Suhodol landfill does not emit enough of these VOCs to increase substantially the health hazard risk for the community.

2. The amounts of the investigated VOCs could vary from one year to the next and depending upon what was deposited at the landfill. The strict acceptance control of only general municipal waste is a prerequisite for low population heath risk in the region and should not be violated with the deposition at the landfill of hazardous waste streams.

3. While it is impossible VOCs in landfill gases to be sensory ascertained from the residents of Suhodol, the odours may, at times, be unpleasant and produce discomfort and temporary symptoms. Measures to capture landfill gases and prevent their migration to the community will be hygienic warranty for protection from persistent nuisances.

4. The water in wells in private yards in the Suhodol district is practically clean from VOCs presence. From safety reasons for the population health in the region continuous well monitoring should be executed with additional attention on ensuring steady impermeable isolation of the centralised drinking water supply system.

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