STUDY OF PEATLAND FIRES AS SOURCES OF PAH EMISSION

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Abstract
In the paper results study of peatland fires as sources of PAH emissions are discussed. The work included observation of real peatland fires for detection of specific features (conditions) of such fires, statistics collection for estimation of peat volumes burned at fires, peatland fires modelling with waste gases sampling and PAH in emission analytical determination, data processing and emission factors estimation. It is shown that peatland fires can be significant source of emission low-molecular PAH.

Introduction
Peatland fires are characterized by a long duration, inaccessibility to fire protection services which make they quenching difficult. Due to the fact that combustion during peatland fires has an underground nature, it is sometimes difficult to detect it. Smoke is laid over the ground during peatland fires (carbon monoxide is a gaseous product of incomplete peat combustion). A large amount of organic matter is burnt even on a small fire area. It is expedient to account this emission source category for regions with a high peatland content (boreal area).
Peatland fires can result both from human activity and from peat self-ignition. There are no estimates available for these processes ratio; the first factor is likely to prevail taking in consideration other fire categories. Peat self-ignition occurs as a rule on drained peat bogs (fields of peat production), and also in areas of peat storage.
Peatland fires emission issues are studied poorly; this is valid for PAH emission.

Purpose of the study - assessment of PAH emission from peatland fires

Methods
Work included:
- observation of real peatland fires for detection of specific features (conditions) of such fires;
- statistics collection for estimation of peat volumes burned at fires;
- peatland fires modelling with waste gases sampling and PAH in emission analytical determination;
- data processing and emission factors estimation.

Experiment description
In the course of experimental works on POPs emission study we took into account current methodologies of POPs sampling from the air and from off-gases devised in the USSR and in the CIS countries (1, 2). Besides, we used aerosol and gas content sampling methodologies devised and applied in the countries of Western Europe and in the USA (3).
During the experimental investigations main attention was paid to PAHs emission studies.
High bog peat from natural bog and transition peat from cut-off bog were combusted. Main features of combusted material and model experiment can be seen in Table 1.

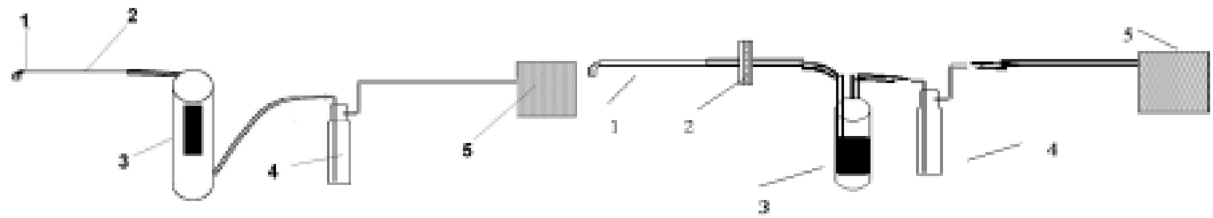
Table 1: Composition of biomass burnt for peatland fires modeling

№ of sample	Type of substratum (mass %)	Moisture content, %	Ash content, %
755, 783	Peat – 85; wood – 15	10.3	26.3
834	Peat – 78, twigs – 21, peatland plants – 1	9.0	28.2
836	Peat – 55, twigs –41, pine boughs – 3, dwart shrubs – 1	11.2	8.0
838	Wood – 62, peat – 36, needles+ dwart shrubs – 2	10.7	5.9

Sampling procedures and samples preparation were agreeable to the standards on the filter materials technical characteristics. Sampling unit leak-proofness, chemical vessels preparations for liquid samples storage and handling were done. The aerosol and vapour phases of PAHs were collected by ordinary sampling train with pumping of waste gases through the filter (first stage) and sorbent (second stage) (Figure 1). The sampling off-gas was done at temperature 40-150^{o}C. Filters were located 10-30 cm from the source of open burning; sampling time - 60 min, average sampling rate – 10 l/min.

Figure 1: PAH sampling train. A - using flat filter and solid sorbent: 1 - dust collection probe; 2 – filter holder, 3 – solid sorbent module; 4 – drop collector; 5 – electric aspirator. B - using volume filter and solid sorbent: 1 – nozzle with filter holder, 2– dust collection probe, 3 – solid sorbent module; 4 – drop collector; 5 – electric aspirator.

A B



The experimental works involved, apart from the flue gas sampling, the study of main fuels properties (moisture, ash content, composition) and their combustion conditions, evaluation of burnt organic matter and its composition, and also off-gas main parameters.

PAHs Analytical Determination

For PAH evaluation gas chromatography and mass spectrometry were used (Selected Ion Monitoring method, SIM). The analyses methodology is based on PAH extraction from samples using methylene chloride and the subsequent extract analysis. This methodology makes possible to identify and to determine 16 PAH in samples (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo-(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)-perylene).

Results

Total PAH content in fly ash vary from 342.8 to 1145.9 mg/kg, total PAH content in off-gases vary from 364.4 to 556.9 µg/m^3. Mean content 16 PAH are shown in the Figures 2 and 3.

Figure 2: Mean PAH content in fly ash from open burning of peat , mg/kg

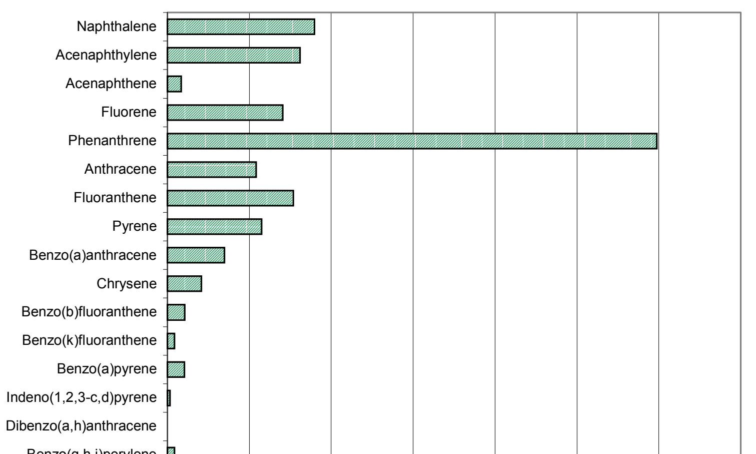
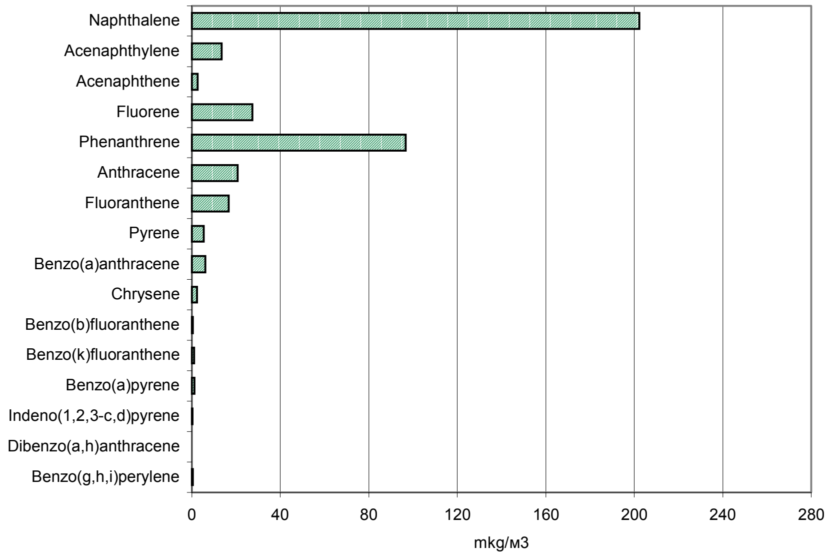


Figure 3: Mean PAH content in waste gases from open burning of peat, mkg/m^3



Low-molecular PAH species prevail (naphthalene, phenanthrene, fluorene, acenaphthylene, antracene, fluoranthene) – from 75 to 85% of PAH sum. Content of high-molecular PAH (benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)-anthracene and benzo(g,h,i)perylene) – from 2.5 to 5% of sum.

Meanwhile in spite of low share of such species in PAH emission sum, fly ash is significantly enriched by these dangerous compounds. Thus content of benzo(a)pyrene in fly ash hundred times higher MPL value for soils (0.02 mg/kg). Content of benzo(a)pyrene in waste gases (up to 2.6 mkg/m^3) exceed MPL for ambient air (0.001 mkg/m^3) also in hundred times.

The results obtained show, that indicator PAH species are detected practically at all combustion regimes (Table 2). The content of indicator compounds in fly ash and other PAH (and total sum respectively) is similar to the data obtained for ground litter combustion.

Table 2: PAH content in emissions from peat combustion (model burning)

Compound	PAH content in fly ash and soot, mg/kg		PAH content in waste gases, μg/m^3	
	range	mean	range	mean
Benzo(b)fluoranthene	ND-16.6	8.5	ND-1.98	1.10
Benzo(k)fluoranthene	ND-6.8	3.4	ND-0.83	0.43
Benzo(a)pyrene	ND-19.9	8.4	ND-2.55	1.15
Indeno(1,2,3-c,d)pyrene	ND-4.9	1.2	ND-0.73	0.38

ND – not detected

PAH emission factors

The data on PAH content in emissions was used for the production of draft PAH emission factors. Additional data – volumes of waste gases and dust specific emissions – were obtained from literature. According to (4) specific emission factors for soot in peatland fire makes up to 11 kg/t, for smoke (ultradispersed particles SiO_2) – 55 kg/t.

Emission factors are as follows: benzo(b)fluoranthene - 0.56, benzo(k)fluoranthene - 0.22, benzo(a)pyrene - 0.55, indeno(1,2,3-c,d)pyrene - 0.10. It should be stressed that these figures are draft only and valid for limited conditions of firing – mainly for small fires.

Volume of organic matter burnt at peatland fires

In every case the ratio of material burnt (soil cover, wood, peat) will be different. During peatland fires a complete burning of soil cover, ground litter and a thick layer of peat takes place (5). The depth of peat burning ranges amounts 50 cm and more.

We conducted investigations of peatland fires to determine fire nature and organic matter burning conditions. Small bogs in the vicinity of Minsk (and also within city limits) were under study as well as natural high bog Yelnya (area about 20 000 ha). It was stated, that vast bog territories are caught by

ground fires where burning processes are rather active: as a result grass vegetation was burnt completely, bottom parts of brushwood and trees is considerably burnt. In such cases peat is either not burnt or only its top (insignificant part) is burnt.
In case of underground fire the area of burning places ranges a lot: from less than 1 to 10 m^2 and more. Peat burning is not homogeneous; most active smoldering is found in root area. Peat burning depth makes up often from 5 to 50 cm and averages up to 25 cm (Illustration 1).

Illustration 1: Low-intensity peatland fire

Taking into account this fact, and also soil cover burning conditions, we evaluate the mean material burnt as 75 t/ha.

Fires statistics
Partially fires are taken into account in the forest fires statistics, but it is only for territories owned by the State Forest Fund. A more detailed report can be found in the Ministry of Natural Resources and Environment Protection, however, these data are not included into the statistics database. The Ministry of Accidents has also an account of fires; the account is only of those fires the Ministry fights. These data are not published in statistical reviews and can be obtained only by a special inquiry.
The area of peatland fires can be comparable with forest fires area according to statistical data in Belarus. Thus, the Ministry of Nature Resources gives the following data: in 1999 peatland fires area made up to 2.2 thous. ha, in 2000 – 1.3 thous. ha; the Ministry of Accidents gives the figures – 2.6 thous. ha and 6.5 thous. ha respectively.

PAH emission estimation
For PAH emission PAH emission factors, area of peatland fires and volumes of combusted material are necessary.
Using PAH emission factors, volumes of combustible material and peatland fires statistics (for 2001) the following draft PAH emission figures were obtained (kg/year): benzo(b)fluoranthene - 7.0, benzo(k)fluoranthene – 3.0, benzo(a)pyrene – 7.0, indeno(1,2,3-c,d)pyrene –1.0.

Conclusion
Modelling and testing of emission from peatland fires allows to establish significant levels of low-molecular PAH in waste gases. Draft emission factors were obtained. Analysis of peatland fires statistics, peatland fires combustibles and using emission factors first estimates of PAH emission from peatland fires for the territory of Belarus were obtained.
In general efficiency of modelling for the estimation of open fires emissions was proved.

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References

(1) Methodology of benzo(a)pyrene concentration measurement in air and on sources of air pollution by VEGH method. Sanct-Peterburg, Russia, (1998) (In Russian)
(2) RD 52.04.186-89. Guidebook for monitoring of atmosphere pollution. Moscow, Russia, (1991) (In Russian)
(3) Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846). Vol. 2. Method 0010. Modified Method 5 Sampling Train. Method 0020. Source Assessment Sampling System (SASS), (September, 1986)
(4) Method of pollutions determination and emission estimation from forest fires. State Committee of Russian Federation on the Environmental, Order N 90, Moscow, Russia, (5 March1997) (In Russian)
(5) Kositsyn V.N., Dynamics of forests resources after peatlands fires // State and monitoring of forest in the XXI century. Minsk, Belarus, (7-9 April, 1998) (In Russian)

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