RAILI VESTERINEN

EMISSIONS FROM WOOD AND PEAT -FIRED HEATING PLANTS

PUUTA JA TURVETTA KÄYTTÄVIEN LÄMPÖLAITOSTEN PÄÄSTÖT

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The use of wood and peat in small scale boilers (10 kW—10 MW), has increased because the price of oil has advanced. Further the acidification of environment caused by emissions of sulphur oxides has increased. Wood and peat with their small sulphur content are good fuels in this respect.

Emissions of sulphur dioxide, hydrocarbons and nitrogen oxides are not too high during good combustion process. If wood and peat is burnt in plants (1—10 MW), emissions of hydrocarbon and polynuclear aromatic hydrocarbons (PAH) are low. High emissions of tar, total hydrocarbon and PAH have been measured from combustion of wood and peat in small furnaces. The development of boilers to correspond better the properties of the fuels used may decrease significantly these emissions. Also the complete control of the whole combustion process helps to the emissions.

The dust emissions of small plants can be decreased with flue gas collectors. The multicyclone has generally been used as the collector in this scale. Emissions of some metals depend on the fly ash separation efficiency.

Key words: emissions, air pollution, wood firing, peat firing, combustion process.

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INTRODUCTION

With the diminishing of world oil reserves and the increase in acidification, interest has been directed towards the increase in the use of alternative fuels. In the Nordic countries among other places the use of wood, peat, and straw as fuels has increased in small-scale combustion (size of installation 10 kW—10 MW). The principal reason for the replacement of oil by these fuels has been the ready availability of the raw materials, but environmental questions are also weighing increasingly in the choice of fuels. The acidification of nature in the industrial countries using fossil fuels is forcing people to consider methods of combustion and cleaning technique to prevent the destruction of nature. As lowsulphur fuels wood, peat, and straw are the object of considerable interest. Combustion emissions when the installation is operating inefficiently may become a limiting factor in the increase of the use of wood and peat fuels.

THE COMPOSITION AND PROPERTIES OF WOOD AND PEAT FUELS

From the environmental point of view the most important properties of fuels are their sulphur and ash content and mineral composition. Wood and peat are low-sulphur fuels. The sulphur content of wood varies from 0,01 to 0,1 of % dry matter. The sulphur content of peat is slightly higher with an average of 0,05—0,3 % of dry matter, but higher sulphur contents also appear (Seppälä et al., 1982).

The ash content of the dry matter of wood is 0,4—3 %. Saw waste, especially bark, which is widely used as a fuel in Finland, can contain such impurities as sand, earth, and other mineral substances, which increase the ash content of the fuel. The ash content of peat varies in Finnish peat fuel with an average of 2—10 % of dry matter (Table 1).

A very important factor influencing the emissions from the combustion of wood and peat is the variation in the properties of the

Table 1. Basic element and ash contents of fuels (Seppälä & Asplund 1980).

Taulukko 1. Polttoaineiden alkuaine- ja tuhkapitoisuuksia (Seppälä & Asplund 1980).

Fuel *Polttoaine*	C %	H %	0 %	N %	S %	Ash % *Tuhka*
Birch chips *Koivuhake*	48—50	6,0—6,5	38—42	0,5—2,3	0,05	0,4—0,6
Bark waste *Kuorijäte*	51—66	5,9—8,4	24,3—40,2	0,3—0,8	0,05	0,1—3
Milled peat *Jyrsinturve*	52—56	5,0—6,5	30—40	1,0—2,5	0,05—0,3	4—7
Sod peat *Palaturve*	52—56	5,0—6,5	30—40	1,0—2,5	0,1—0,3	4—7
Peat briquettes *Turvebriketti*	52—56	5,0—6,5	30—40	1,0—2,5	0,1—0,3	4—7
Brown coal *Ruskohiili*	65—76	4,5—5,5	20—30	1—2	1—3	5—10
Coal *Kivihiili*	76—87	3,5—5,0	2,8—11,3	0,8—1,2	0,5—3	8,5—10,9
Heavy fuel oil *Raskas polttoöljy*	83—86	11,0—12,5	0,5—1,5	0,2—0,3	2,0—3,5	0,1—0,3

Table 2. Average metal contents of fuels according to fuel-energy ($\mu g/MJ$) (Projekt KHM 1983).

Taulukko 2. Polttoaineiden keskimääräisiä metallipitoisuuksia polttoaineen energiaa kohti laskettuna ($\mu g/MJ$) (Projekt KHM 1983).

Metal *Metalli*	Coal *Kivihiili*	Wood *Puu*	Peat *Turve*	Oil *Polttoöljy*
As	150	5	100	2
Be	40	—	5	0,2
Cd	10	10	10	0,7
Co	150	7	100	11
Cr	400	50	250	1,2
Cu	400	100	500	8,5
Hg	4	1	5	0,06
Mn	2000	5000	4500	0,5
Ni	400	30	300	400
Pb	500	200	250	25
V	900	100	450	1300
Zn	1000	1200	900	20

fuel. Variations in the size of pieces, bulk density, and moisture content of the fuel hinder the operation of especially small installations. In the combustion of wood chips sticks among the pieces can cause arching and faults in the operation of the stoking equipment. Dross and foreign matter such as sand and stones cause disturbances in the combustion of sod peat. The fact that the dross can be considerably damper than the sods is a particular problem.

New fuels of more even quality, wood and peat pellets and briquettes, are manufactured either commercially or experimentally from wood and peat. Their moisture content is lower and their heat value higher than those of wood chips or milled and sod peat. The evenness of quality of the fuels has a great influence in improving relative efficiency and reducing emissions.

The metal contents of fuels for fuel-energy are shown in table 2 (Projekt KHM 1983). The metal contents of wood and peat in g/kg of dry matter are smaller than the corresponding contents of coal, the contents for fuelenergy ($\mu g/MJ$) can be of the same order of magnitude (Table 2). This is due to the fact that, apart from compressed fuels, the effective heat value of wood and peat fuels in their original state is considerably lower than that of coal.

EMISSIONS FROM THE COMBUSTION OF WOOD AND PEAT

Dust emissions

The amount of the dust emissions depends both on the ash content of the fuel and also very much on the combustion process and the completeness of combustion. Flue gas

Table 3. Dust emissions from wood and peat-fired heating plants (< 100 kW).

Taulukko 3. Puuta ja turvetta polttavien lämpölaitosten (< 100 kW) hiukkaspäästöjä.

Plant *Laitos*	Fuel *Polttoaine*	Dust content mg/m³ₙ *Hiukkaspit.*	Dust emissions mg/MJ *Hiukkaspäästö*	*)
Boiler equipped with a retort 20 kW *Retortilla varustettu 20 kW:n kattila*	wood pellets *puupelletit*	28—60	30—40	1
"	peat/bark	35	39	1
	pellets *turve/puupelletit*	50—60	40—55	1
Boiler 20 kW *Kattila 20 kW*	birch wood *koivupuu*	43	52	1
Stove *Uuni*	wood briquettes *puubriketit*	33-200	33—150	1
"	peat briquettes *turvebriketit*	100—300	250—750	1
Side-draught stove *Alapalokattila*	birch firewood *koivuklapi*	45—130		2
Up-draught stove *Yläpalokattila*	birch firewood *koivuklapi*	30—1660		2
Stoker burner *Stokeripoltin*	PDF wet carbonized peat pellets *PDF-märkähiilletyt turvepelletit*	40—140		2
Up-draught stove 35 kW *Yläpalokattila 35 kW*	birch firewood *koivuklapi*	80—120		2
Stoker furnace *Stokerikattila*	wood chips *puuhake*	110—490		2
Stove 6—7 kW *Uuni 6—7 kW*	wood *puu*	9,6—350	13—170	3
Stove 12—14 kW *Uuni 12—14 kW*	wood *puu*	34—140	16—78	3
Central heating furnace 35 kW *Keskuslämmitys-kattila 35 kW*	wood *puu*	120—360	67—190	3
Central heating furnace with prechamber fire-box 35 kW *Etupesällinen keskuslämmitys-kattila 35 kW*	wood chips *puuhake*	72—2300	45—1600	3

*) 1. Rudling 1980   2. Hahkala et al. 1985   3. Rudling et al. 1983

separators are not used in the combustion of wood and peat in residential boilers (10—500 kW). For this reason the amount of dust emissions depends on the fuel and on the success of the combustion as well as on the relative proportions of fly and bottom ash. Flue gas cleaning is usually used in heating plants of more than 1 MW. The most usual separator is the multicyclone. The efficiency of collection is not always sufficient to achieve good cleaning. For this reason the use of electrostatic precipitators is increasing also in small heating plants. Electrostatic precipitators are now being used even in peat fired 7 MW plants.

Examples of dust emissions from wood and peat-fired heating plants (< 100 kW) are shown in table 3. The data on fuels indicate that if the dust emissions from the boilers (< 100 kW) are small, then the moisture content has been low (excluding the combustion of briquettes).

In addition to the fuel and the combustion

process the efficiency of the separator also has an effect on the dust emissions from heating (1—10 MW) boilers. Multicyclone separators were used in all the cases except gasification firing shown in table 4. Their efficiency is not adequate particularly for the finest particles. For example burning milled peat on a grate with a multicyclone separator seems to be very difficult. The moisture content of the peat has been rather high and the bulk density of the peat low.

Unburned material raises dust emissions. The proportion of unburned material can be as high as 40—60 % of fly ash determined on a dry basis. The development of combustion techniques, and the recruiting of a skilled operating crew help in reducing dust emissions. The better regulation of boilers and fuels than at present is of prime importance in attempts to reduce dust emissions.

Emissions of nitrogen and sulphur oxides

The nitrogen oxides released with flue gases originate from both the nitrogen in the fuel and the nitrogen in the combustion air. Only a part of the nitrogen in the fuel and the air is converted into nitrogen oxides during combustion. The nitrogen oxides are formed during combustion by two different mechanisms. The thermal formation of nitrogen oxides in the furnace is a reaction between the nitrogen and oxygen of the combustion air. The reaction is strongly dependent on temperature so that a high temperature causes a growth in the proportion of thermal nitrogen oxides. The formation of thermal NO_x is in practice insignificantly slow when the combustion temperature is under 1 700 K or c. 1 430 °C. Nitrogen oxide from the nitrogen of the fuel is formed by the oxidization of the chemically bound nitrogen of the fuel. This reaction is less dependent on the temperature of combustion. The nitrogen content of the fuel and the method of combustion have an important significance in the formation of nitrogen oxides derived from the fuel.

Table 4. Dust emissions from wood and peat-fired heating plants (< 10 MW) (Vesterinen et al. 1985).

Taulukko 4. Puuta ja turvetta polttavien (< 10 MW) lämpölaitosten hiukkaspäästöjä (Vesterinen ym. 1985).

Plant *Laitos*	Fuel *Polttoaine*	Separator *Pölyerotin*	Dust content mg/m^3_n *Hiukkaspit.*	Dust emission mg/MJ *Hiukkaspäästö*
Gasification firing 5 MV *Kaasupoltto 5 MW*	sod peat *palaturve*	— —	28—273	10—86
Grate burning 7 MW mechanical grate *Arinapoltto, mekaaninen arina 7 MW*	milled peat *jyrsinturve*	multi-cyclone *multi-sykloni*	576—1629	205—535
Grate firing mechanical grate 10 MW *Arinapoltto, mekaaninen arina 10 MW*	saw waste *sahanjäte*	,, ,,	170—343	67—108
Grate firing fixed grate 2MW *Arinapoltto, kiinteä arina 2 MW*	chips *hake*	,, ,,	136—350	41—115
Grate firing 2 MW prechamber + fixed step grate *Arinapoltto 2 MW etupesä + kiinteä arina*	sawdust *sahajauho*	,, ,,	470—618	155—224
Grate firing 5 MW *Arinapoltto 5 MW*	chips *hake*	,, ,,	103—307	39—116
Grate firing 6 MW *Arinapoltto 6 MW*	sod peat *palaturve*	,, ,,	50—233	27—90

In installations of less than 10 MW the combustion of wood and peat takes place principally as grate burning but fluidized boilers are increasing. In grate burning the temperature of the firebox is generally under 1 700 K, so that the formation of thermal nitrogen oxides is small.

The emissions of nitrogen oxides from installations of over 1 MW depend very much on the combustion technique. Wood chips are burnt in plants of this size in present tehcniques principally on a grate. The grate may be fixed or mechanical. Also in some installation designs a prechamber before the boiler is used. The nitrogen oxide content of the flue gases of the wood-chip or saw-waste combustion plants shown in table 5 varied from 28 to 195 mg/m^3. In other words the emission of nitrogen oxides has been less than 100 mg/MJ of input fuel-energy.

The NO_x emissions from peat combustion from plants of over 1 MW are, in the case of peat burnt in a grate or fluid bed boiler, somewhat higher than for wood-chip combustion. The NO_x emissions are, however, clearly higher, 250 mg/MJ expressed as NO from gasification combustion in installation of 5 MW operating on the up draft principle. The emissions of nitrogen oxides from wood and peat burning are generally smaller than from the burning of coal. According to the research of Pohjola et. al. (1983) the NO_x emissions from peat burning were on the average 160 mg/MJ, and from coal burning 300 mg/MJ expressed as NO.

Sulphur dioxide emissions arise when the sulphur in the fuel is burnt. Part of the sulphur remains in the bottom and fly ash. The sulphur content of wood fuels is low, less than 0,1 % of dry matter, so that the sulphur dioxide emissions formed are small, even though all of the sulphur in the fuel would be emitted. The sulphur dioxide emission from a wood chip-fired 5 MW district heating plant was 5 mg/MJ.

The sulphur dioxide emissions when burning peat are, depending on the method of combustion and amount of oil used as supporting fuel, higher than the sulphur dioxide emissions from wood burning. 0—20 % of the sulphur contained in peat is fixed in the ash. In fluid bed combustion, in which lime is used in the bed material the fixing of sulphur can be even more effective. The sulphur dioxide emissions from two sod peat-fired district heating plants were 147—268 mg/MJ. Sod peat was combusted on a grate. The sulphur dioxide emissions from coal-fired power plants are 500—670 mg/MJ.

Table 5. Emissions of nitrogen oxides from heating plants (< 10 MW) (Vesterinen et al. 1985).

Taulukko 5. Lämpölaitosten (< 10 MW) typen oksidien päästöjä (Vesterinen ym. 1985).

Plant / *Laitos*	Fuel / *Polttoaine*	NO_x[1] mg/m^3_n	NO_x[2] mg/MJ
Grate firing 7 MW *Arinapoltto 7 MW*	milled peat *jyrsinturve*	202—327	79—116
Grate firing 5 MW *Arinapoltto 5 MW*	chips *hake*	97—195	52—74
Cyclone firing 4,5 MW *Syklonipoltto 4,5 MW*	milled peat *jyrsinturve*	768—788	214—220
Grate firing 10 MW *Arinapoltto 10 MW*	saw-waste *sahanjäte*	108—145	42—56
Prechamber boiler combination 2 MW *Etupesä-kattila-yhdistelmä 2MW*	sawdust *sahanjäte*	28—180	10—44
Grate firing 2 MW *Arinapoltto 2 MW*	chips, bark *hake, kuori*	130	43
Grate firing 6 MW *Arinapoltto 6 MW*	sod peat *palaturve*	211—406	116—167
Grate firing 9 MW *Arinapoltto 9 MW*	sod peat *palaturve*	327—545	113—223
Gasification firing 5 MW *Kaasutuspoltto 5 MW*	sod peat *palaturve*	612—1108	207—349

[1] calculated as NO, at a pressure of 101,3 kpa and temperature of 0°C.
[2] based on input fuel-energy

Emissions of organic compounds

Many organic compounds arise in incomplete combustion. The appearance of carbon monoxide in flue gases is a clear sign of incomplete combustion. When there is a measurable content of carbon monoxide in the flue gases, then there are also organic compounds such as light and heavy hydrocarbons.

The polycyclic aromatic hydrocarbons (PAH), which belong to the hydrocarbons have in recent years been the object of general interest, because many of the compounds belonging to this group have been proved to be carcinogens. The best known of these compounds appears to be benzo(a)pyrene, which appears in among other things, tobacco smoke.

When combustion succeeds well the carbon monoxide and hydrocarbon emissions are low. In power plants, in which process control is good and the operating personnel well skilled, the emissions of organic compounds are small. For example in a 321 MW coal combustion plant the total hydrocarbon emission expressed as equivalents of CH_4 is < 13 mg/MJ and PAH emission $11—13$ μg/MJ or $14—29$ g/h

and the PAH emission for a sod peat combustion plant of 35 MW is $5,8—7,6$ μg/MJ or $0,37—0,98$ g/h (Pohjola et al. 1983).

The size of the boiler installation has still at present a great significance in the success of combustion. Combustion in plants of more than one megawatt is clearly better than in residential boilers, which appears already in the carbon dioxide contents. In stoves and boilers of less than 100 kW contents of $4—16$ % CO_2 appear in wood and peat burning. In plants of more than one megawatt the flue gas CO_2 contents are $12,9—19,2$ %.

Table 6 shows the carbon monoxide, total hydrocarbon and polycyclic hydrocarbon contents in the flue gases of wood and peatfired district heating plants.

In the case of residential boilers incomplete combustion is often occasioned by the fact that in practice the boiler is not suitable for the fuel in question. The moisture content of the fuel and particularly its variation has a very great influence on the formation of emissions, the influence is greater the smaller the boiler installation in question and the less automation it has.

Table 6. Carbon monoxide, total hydrocarbon and polycyclic aromatic hydrocarbons (PAH) contents in the flue gases of district heating plants (Vesterinen et. al. 1985 and unpublished results).

Taulukko 6. Hiilimonoksidi-, kokonaishiilivety- ja polysyklisten aromaattisten hiilivetyjen (PAH) pitoisuuksia aluelämpölaitosten savukaasuissa (Vesterinen ym. 1985 ja julkaisemattomia tuloksia).

Plant and fuel *Laitos ja polttoaine*		CO mg/m^3	C_xH_y mg/m^3	PAH μg/m^3
Gasification firing 5 MW *Kaasutuspoltto 5 MW*	sod peat *palaturve*	0— 620	0.07— 5.7	34.1— 91.3
Grate firing 7 MW *Arinapoltto 7 MW*	milled peat *jyrsinturve*	0— 870		1.4— 2.8
Grate firing 5 MW *Arinapoltto 5 MW*	birch chips *koivuhake*	0— 3290	2.2— 48	1.8— 14.4
Cyclone firing 4,5 MW *Syklonipoltto 4,5 MW*	milled peat *jyrsinturve*	1610		
Grate firing 10 MW *Arinapoltto 10 MW*	saw-waste *sahausjäte*	124— 2480		10.0— 18.9
Grate firing 2 MW *Arinapoltto 2 MW*	chips *hake*	8300		
Grate firing 2 MW *Arinapoltto 2 MW*	saw-waste *sahanjäte*	7400		
Grate firing 2 MW *Arinapoltto 2 MW*	sawdust *sahajauho*	2100		
Fluidized bed 3 MW *Leijukerrospoltto 3 MW*	milled peat *jyrsinturve*	397— 4825	7— 309	5.5— 309.4
Grate firing 6 MW *Arinapoltto 6 MW*	sod peat *palaturve*	50.8— 272	10— 59	0.5— 13.9

CONCLUSIONS

Dust emissions depend on the ash content of the fuel. In installations without flue gas

cleaning dust emissions depend on the relative proportions of fly and bottom ash. Poor combustion increases dust emissions through the formation of soot. When boiler installations

operate well it is possible to achieve dust emissions of less than 20 mg/MJ in domestic boilers. With good flue gas cleaning it is possible, in installations of 1—10 MW to achieve dust emissions of less than 100 mg/MJ also when burning wood and peat.

Emissions of sulphur oxides from the combustion of wood and peat are low compared to the emissions from the combustion of coal and oil. The emission of sulphur dioxide from the combustion of peat is a quarter of that from the combustion of coal and the sulphur dioxide emission from the combustion of wood is still considerably smaller. This is due to the low sulphur contents of wood and peat and to the partial binding of sulphur to ash.

The emissions of nitrogen oxides from the combustion of wood and peat are generally smaller than from the combustion of coal. In some installation design the emissions of nitrogen oxides from the combustion of peat can rise to the level of those from the combustion of coal. The matter is then one of the combustion of peat in a high temperature of over 1 700 K in a cyclone using the so-called melted ash solution. The combustion of peat in a gasification plant operating on the counter current principle gave a high nitrogen oxide emission of 200—350 mg/MJ. The amount of the nitrogen oxide emissions from the combustion of wood depending on the type of installation cannot be determined on the basis of these studies. Variations in the amount of nitrogen oxides in the flue gases of various installations from 97 to 180 mg/m³ NO_x depend more apparently on the varia-tions in the nitrogen content of the fuel and the process. When information on emissions is given there should be as accurate as possible an account of the quality and properties of the fuel and above all of the combustion process during the period of the measurements.

Emissions of organic compounds arise when combustion is incomplete. In plants in which process control is good continually operating metering equipment to monitor for example O_2 and CO contents, and those in which plant maintenance is good have low emissions of organic compounds.

The concentrations of organic compounds in flue gases of residential boilers are generally many times higher than those of district heating plants. There is work to be done in product development and the standardization of boilers to remove this problem. There should be type guide values for small boilers. Boiler development has indeed progressed, for among other things pellet burning apparatus has been developed in Finland, which gives good combustion results.

To reduce the emissions of organic compounds from the combustion of wood and peat and to achieve first rate combustion it is essential that boilers and fuels suit one another better than before.

ACKNOWLEDGEMENTS

REFERENCES

Hahkala, M., Puustinen, H., Jormanainen, P. & Pohjola, V. 1985: Pienkattiloiden päästöt (Summary: Emissions of small furnaces.) — Valtion teknillinen tutkimuskeskus, Tutkimuksia. In press.

Pohjola, V., Hahkala, M. & Häsänen, E. 1983: Kivihiiltä, turvetta ja öljyä käyttävien voimalaitosten päästöselvitys (Summary: Emission inventory of coal, peat and oil-fired power plants.) — Valtion teknillinen tutkimuskeskus. Tutkimuksia 231. 125 pp. + appendix 135 pp.

Projekt KHM 1983: Kolets hälso- och miljöeffekter. Underlagsdel 1. Teknik för kolanvändning. 432 pp.

Rudling, L., Ahling, B. & Löfroth, G. 1980: Kemisk och biologisk karakterisering av rökgaser från småskalig eldning med flis och ved (Summary: Chemical and biological characterization of emissions from combustion of wood and woodchips in small furnaces and stoves.) — Statens naturvårdverk PM 1331. 79 pp.

Rudling, L. 1983: Rökgasemissioner vid användning av olika fasta bränslen i småskaliga system (Summary: Emissions from residential combustion of different solid fuels.) — Statens naturvårdsverk PM 1666. 76 pp.

Seppälä, R. & Asplung, D. 1980: Jyrsintäturpeen käsittely ja polttotekniikka Suomessa, Irlannissa ja Neuvostoliitossa — Valtion teknillinen tutkimuskeskus, Technical Research Centre of Finland. Tiedotteita 63. 379 pp. + appendix 91 pp.

Vesterinen, O., Paakkinen, K., Pyykkönen, M. & Virkki, J. 1985: Kotimaista polttoainetta käyttävien aluelämpölaitosten päästöt. (Abstract: Emissions from wood- and peatfired district heating plants.) — Valtion teknillinen tutkimuskeskus. Tutkimuksia 371. 85 pp. + appendix 54 pp.

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TIIVISTELMÄ:

PUUTA JA TURVETTA KÄYTTÄVIEN LÄMPÖLAITOSTEN PÄÄSTÖT

Tutkimuksessa mitattiin kymmenen kotimaista polttoainetta käyttävän aluelämpölaitoksen ja 0,5 MW:n koepolttolaitoksen päästöjä. Kuudessa laitoksessa käytettiin polttoaineena puuta, joko haketta tai puuteollisuuden jätettä. Kahdessa laitoksessa polttoaineena oli jyrsinturve ja kahdessa palaturve. Koepolttolaitoksessa poltettiin sekä haketta että palaturvetta arinalla. Puupolttoainetta käyttävissä laitoksissa oli polttolaitteena arina. Jyrsinturvetta poltettiin sekä arinalla että syklonissa. Palaturvetta käyttävillä aluelämpölaitoksilla polttotapana oli kaasutuspoltto ja arinapoltto. Savukaasun puhdistimena oli multisykloni paitsi kaasutuspolttolaitoksella ja 400 kW:n hakelämpökeskuksessa, joissa ei ollut puhdistinta lainkaan.

Laitosten savukaasuista mitattiin hiukkas-, hiilimonoksidi-, hiilidioksidi-, kokonaishiilivety-, typen oksidien sekä polysyklisten aromaattisten hiilivetyjen päästöjä. Laitoksista kerättiin samanaikaisesti prosessitietoja jatkuvatoimisesti automaattisella tiedonkeruulaitteella. Lisäksi kerättiin polttoaine- ja tuhkanäytteitä.

Savukaasujen hiukkaspitoisuus oli lähes kaikissa laitoksissa alle 500 mg/m^3_n (Taul. 3). Jyrsinturpeen poltto arinalla antoi suurimman hiukkaspäästön (Taul. 4). Haketta käyttävän laitoksen hiukkaspäästö oli hieman pienempi kuin sahanjätettä käyttävän laitoksen hiukkaspäästö. Palaturpeen polton hiukkaspäästö oli pienempi kuin jyrsinturpeen hiukkaspäästö. Puupolttoaineiden polton typen oksidien (NO$_x$) päästö laskettuna NO:ksi oli alle 100 mg/MJ eli asettui kaasun ja öljyn polton päästöjen välille. Typen oksidien päästö turvetta poltettaessa arinalla oli hieman korkeampi kuin puun polton NO$_x$-päästö. Turpeen sykloni- tai kaasutuspolton NO$_x$-päästö oli kaksin- tai kolminkertainen arinapolton päästöihin verrattuna (Taul. 5). Hiilivetyjen ja polysyklisten aromaattisten hiilivetyjen päästöt aluelämpölaitoksissa olivat pienet (Taul. 6).