WATER CONTENT MEASUREMENTS IN HOUSEHOLD WASTE USING NEUTRON PROBE; EXPERIENCES FROM FIELD DIGESTION CELL AND LABORATORY

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ABSTRACT

Digestion is a treatment method in which organic waste is biodegraded under anaerobic conditions. The process generates methane gas which can be utilized for energy purpose. One of the most important factors for optimal methane gas production is the water content. However, at present method for measuring the water content in situ in waste material is failing. This paper focuses on water content measurements in a field digestion cell using neutron probe and calibration work in different household waste components.

1. INTRODUCTION

As a rather new member in the European union (EU), solid waste management strategies in Sweden are in a phase of adopting to the directives from the EU. Today the EU waste policy is based on a strategy document established in 1989. This document contains a hierarchy of waste management alternatives : reuse, recycle, energy utilization and landfill. First priority is given to the different recovery operations while landfill represents the ultimate storage of waste.

Disposal is a very common method for solid waste management in Sweden. There are 300 landfills presently in operation and about 4000 are closed. Approximately 50 % of the household waste is dumped at landfills and the rest is used in incineration plants.

Household waste has a high content of organic material that can be used for energy recovery. When compiled in small organized units they are called digestion cells. The objectives of these cells are quick degradation of the waste and an optimal control of methane gas production. The energy of the methane gas can be used in different ways and the digestion residual can be recycled into agricultural use. One of the most important factors for optimal gas production is an appropriate water content.

Technique for in situ water content measurements in waste material is failing. However, in soil science water content has been measured with neutron probe since decays back. The idea is to use the neutron probe for water content measurements in waste material.

2. WATER CONTENT MEASUREMENT WITH NEUTRON PROBE

The neutron probe equipment consists of two parts , a registering instrument and the measurement probe. Measurement is performed in pipes which are placed in situ in the material to be investigated.

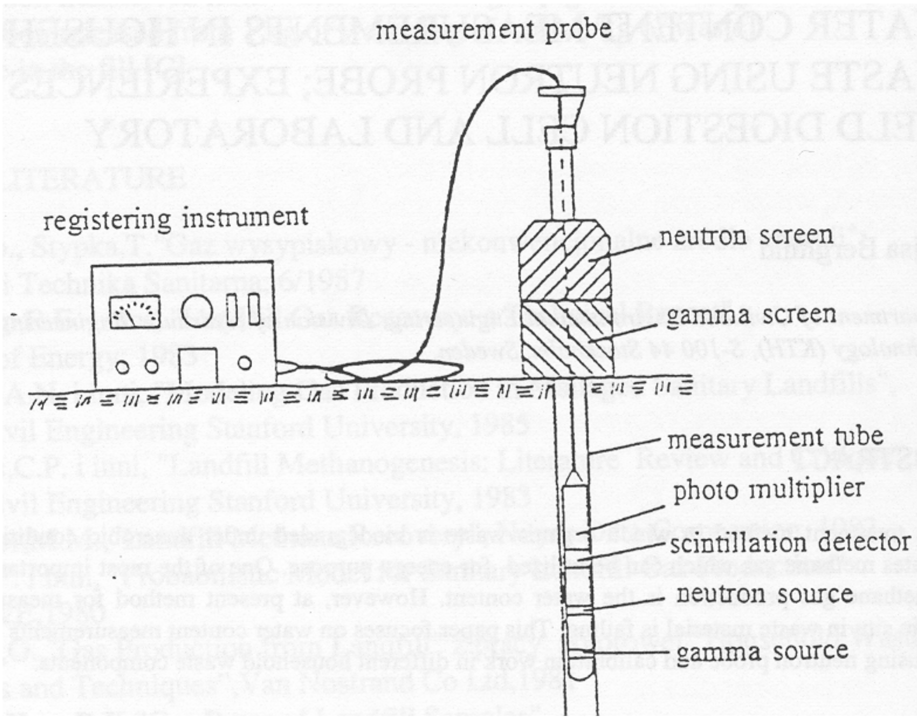

Figure 1. Illustration of a neutron probe (Nucletronics Aps, 1966).

Water content measurement is based on the fact that rapid neutrons emitted from a radium beryllium source are thrown back as slow neutrons when they strike a hydrogen nucleus. On the collision with a hydrogen atom the neutron loose energy and turn into slow thermal neutron. A photo multiplier in the probe detects the radiation from the thermal neutrons and sends a signal to the registering unit which gives a value in the unit count per minute(cpm) The method thus yields a measurement of the hydrogen atom concentration.

The conversion of the number of registered reversed slow neutrons into water content is handled by means of a calibration curve. The water content can be determined by taking samples in actual environment weighted before and after drying. Calibration curves have been drawn for our most common types of soils but fails for waste material probably because in soils it is mainly water which contains hydrogen and therefore the registered slow neutrons reflect the water content while in waste material hydrogen can be bounded in different chemical compositions.

If we wish to determine the local water content in a waste material a calibration is required for the different waste components. If on the other hand we wish to study how the water content changes with time - a relative measurement - it is fully acceptable to apply a calibration curve for a soil. The change in the hydrogen atom concentration which is then obtain is mainly a change in water content. This is largely due the fact that water molecules move very slowly compare with other molecules containing hydrogen, e.g. methane gas and the probability of encountering water molecules in particular is therefore high. Relative water content measurements were applied in a field digestion cell while calibration work in different household waste components has been carried out in the laboratory.

3. EXPERIENCES FROM A FIELD DIGESTION CELL

3.1 Description and conditions for the digestion cell

Field studies were carried out in a digestion cell at Hagby landfill site located 20 km north of Stockholm (Berglund, 1995). The digestion cell with a height between 6 m and 8 m is filled with 12 000 tons of household waste in the form of plastic sacks and bags.

When organic material is degraded methane gas is formed and collected and used for energy purposes. In order to reduce the loss of gas to the atmosphere the cell is supplied with a top cover consisting of 0.5 m soil and below that 0.5 wooden chips.

In order that the methane gas production may start on a large scale there must be access of water. Household waste normally has a water content slightly more than 40 %. Optimal gas production demands a water content approximately 70 % (Christensen et al,1996). This means that additional water must be supplied if optimal conditions are to be attained. At Hagby site the digestion cell is supplied with water by an internal horizontal watering system. The methane gas is sucked out from the waste body in a horizontal collecting system. The horizontal irrigation system and gas collecting system are located 2 m and 1m respectively below the surface of the cell.

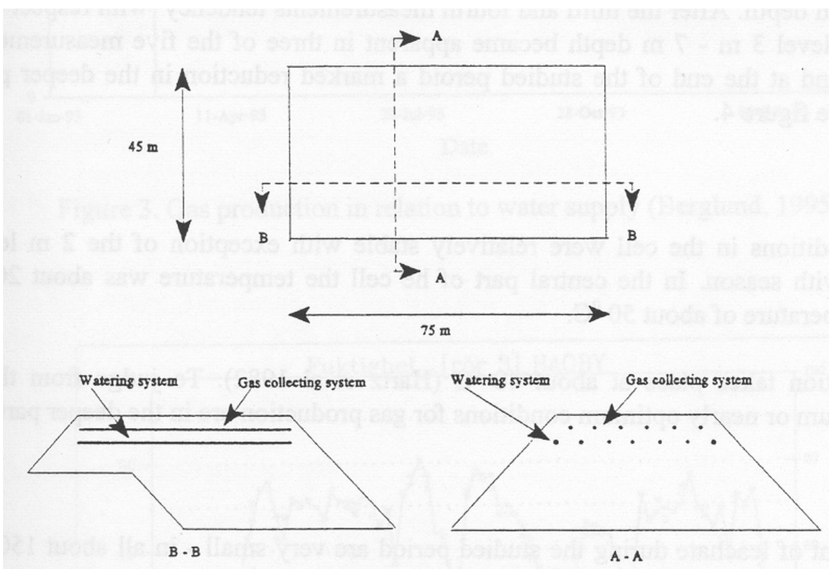

Figure 2. Plan and section of the digestion cell with watering and gas collecting system (Berglund,1998).

During the studied period March 1993 - March 1994 as much as 13 285 m^3 of water was added artificially to the cell. The precipitation on the cell was 629 mm.

3.2 Measuring equipment

The following measuring equipments were used in the field digestion cell :

Neutron probe : For measuring the relative water content in five prearranged vertical pipes fully penetrating the cell

Lysimeters: For measuring the amount of leachate. 20 lysimeters are placed in the waste body.
18 lysimeters take the form of halved oil drums filled with gravel where two are placed in the top cover and the rest are placed on 1.5 m - 2,0 m waste and with 5.0 m - 6.0 m waste and top cover above. 2 lysimeters are rectangular plastic liners placed on the cell bottom. The lysimeters are connected to a measuring station where the leachate drained out and measured manually. Together the lysimeters cover a horizontal area amounting to 0.6 % of the cell area or about 20 m^2.

Thermoelement: For measuring the temperature using installed pipes.The temperature was measured in three pipes at four levels, 2 m, 4 m, 6 m and 8 m at which thermoelement were placed.

Rain - gauge : For measuring the precipitation

Water level pipes : For measuring the ground water level in vertical pipes in the cell.

3.3 Field observations

<u>3.31 Water content</u>

During the year of observation there was no obvious tendency with respect to change in water content at levels between 0 - 3 m depth. After the third and fourth measurements tendency with respect to reduction of water content at the level 3 m - 7 m depth became apparent in three of the five measurement pipes. This reduction increases and at the end of the studied peroid a marked reduction in the deeper part of the cell could be observed, see figure 4.

<u>3.32 Temperature</u>

The temperature conditions in the cell were relatively stable with exception of the 2 m level where the temperature varied with season. In the central part of he cell the temperature was about 20 ^{0}C while the deeper parts had temperature of about 50 ^{0}C.

Optimal gas production takes place at about 40 ^{0}C (Hartz et al 1982). To judge from the temperature measurements optimum or nearly optimum conditions for gas production are in the deeper part of the cell.

<u>3.33 Leachate</u>

The measured amount of leachate during the studied period are very small - in all about 150 litres - which should be compared with the total amount of water supplied - 13 285 m^3.

<u>3.34 The development of gas production in relation to water supply, water content and leachate</u>

If we analyse the gas production we find three occasions when the gas production increases or increases remarkably. Simular we find three times when the gas production undergoes a negative development.

Situations when the gas production increases have been preceded by periods of watering. However, there are watering periods which do not get any clear increase of gas production but relatively large amount of leachate. Moments when the gas production decreases are connected with times when the water content decreases remarkably at level 4 m - 6 m, see figure 5. The registered amounts of leachate are at the same time relatively small.

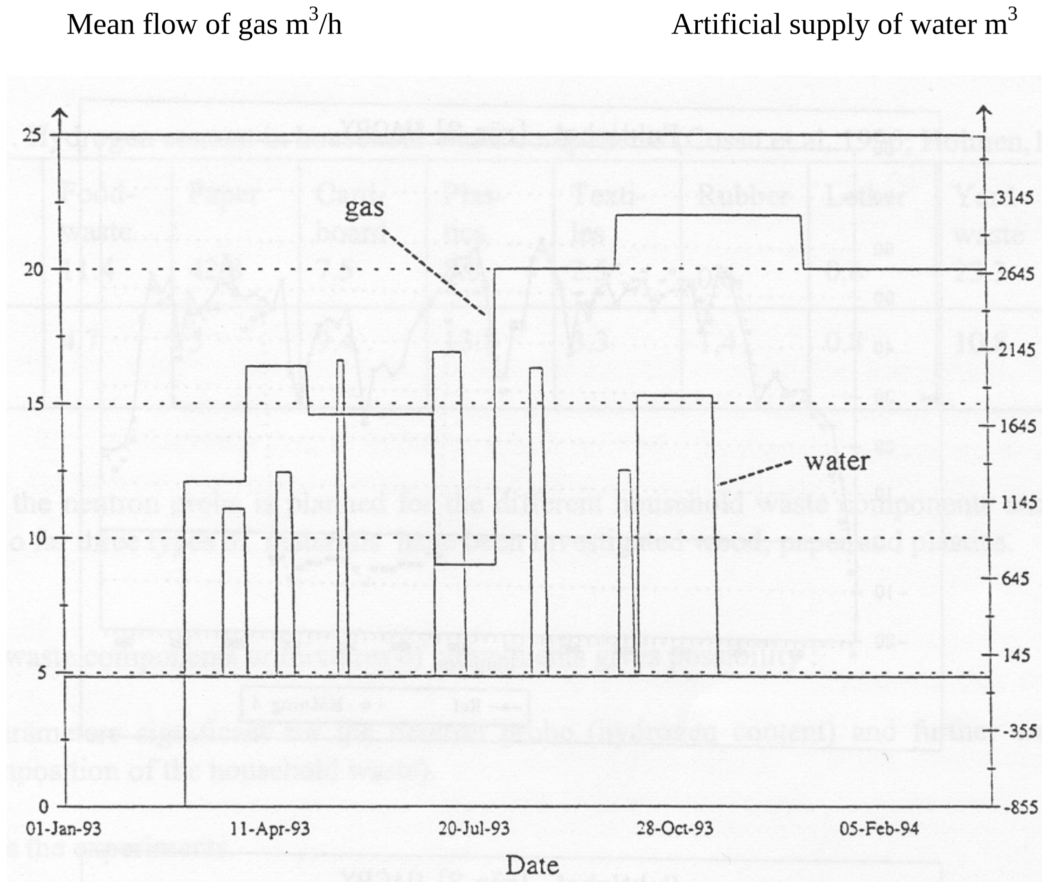

Figure 3. Gas production in relation to water supply (Berglund, 1995)

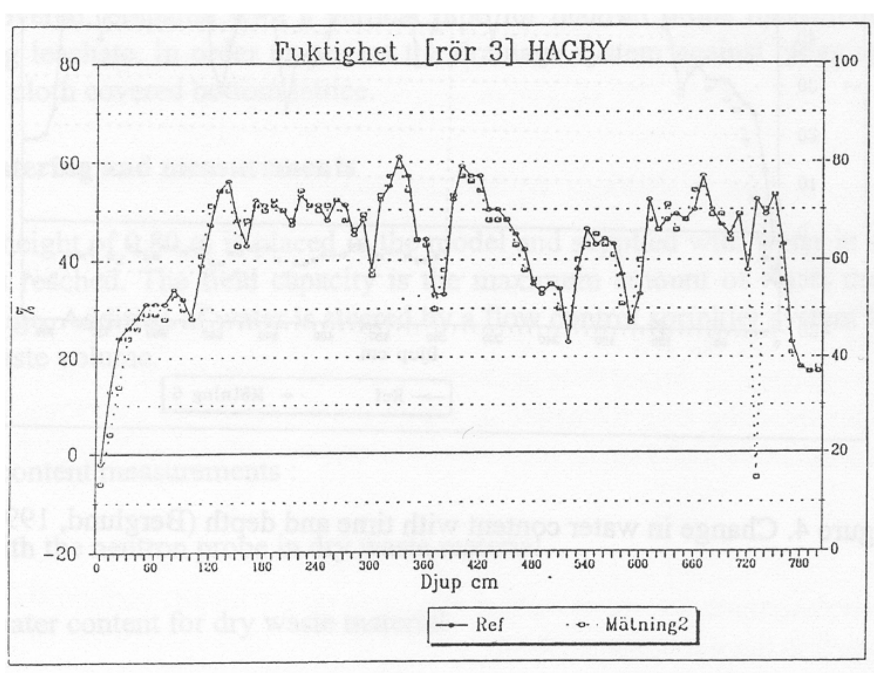

Figure 4. Change in water content with time and depth (Berglund, 1995)

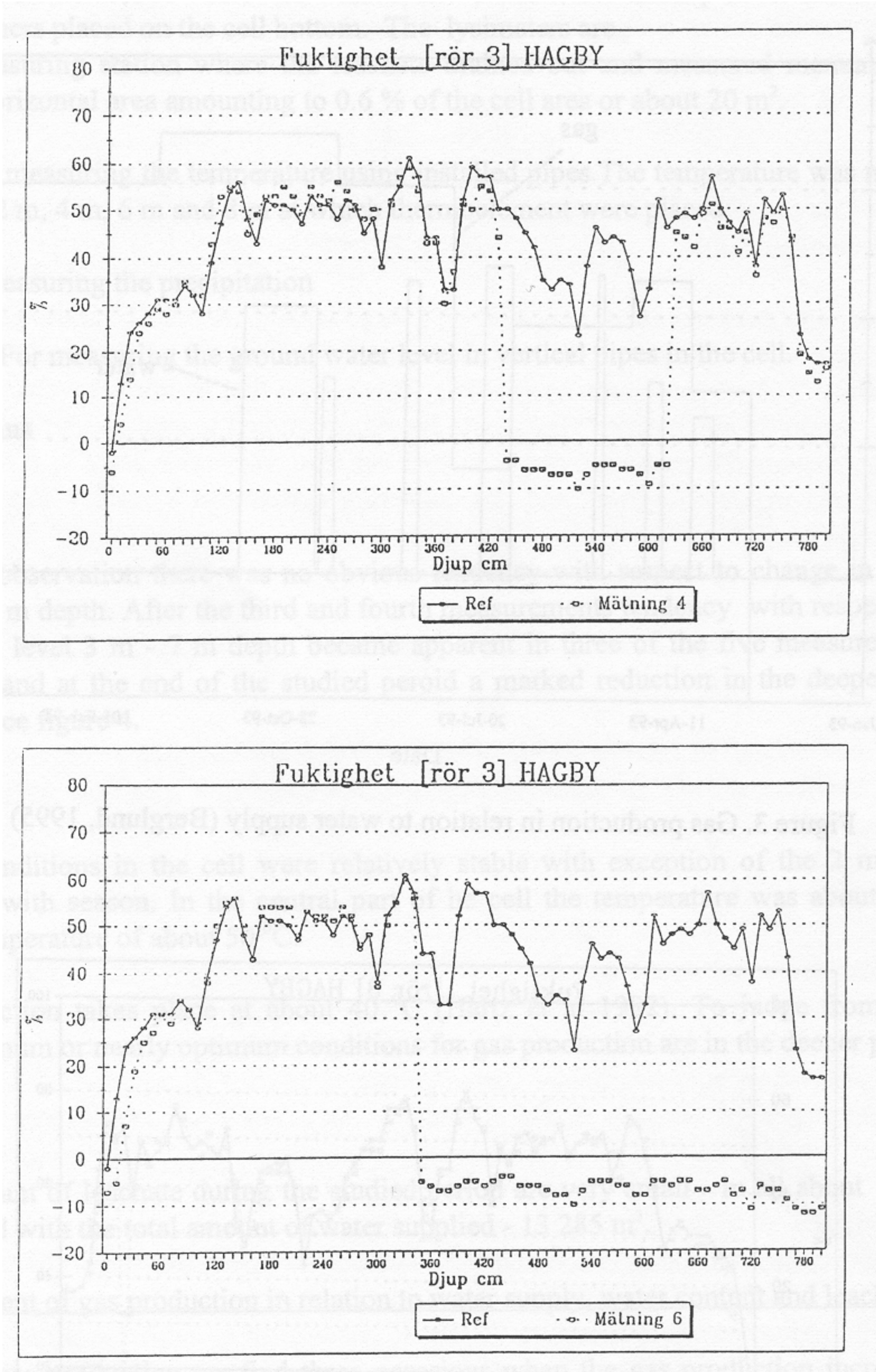

Figure 5. Change in water content with time and depth (Berglund, 1995).

4. CALIBRATION OF NEUTRON PROBE IN HOUSEHOLD WASTE COMPONENTS

Household waste is a mixture of different components with a variation in hydrogen content.

Table 1. Hydrogen content in household waste components (Cossu et al, 1996; Holmen,1999).

Component %	Food-waste 11.4	Paper 42.8	Card-board 7.5	Plas-tics 8.8	Texti-les 2.5	Rubber 0.6	Lether 0.6	Yard-waste 23.3	Wood 2.5
Hydrogen content %	4.7	5	9.4	13.8	3.3	1,4	0.8	10.8	5

Calibration of the neutron probe is planned for the different household waste components and mixtures of components. So far three types of materials have been investigated wood, paper and plastics.

To work with waste components or mixtures of components gives possibility :

- to vary parameters significant for the neutron probe (hydrogen content) and further waste handling strategies (composition of the household waste).
- to reproduce the experiments.

4.1 Description of a laboratory calibration model

A calibration model aimed for water content measurements in different household waste components is constructed in the laboratory. The model has the dimension of 1.2 m x 1.2 m x 1.2 m is made of wood with it´s inside plastic covered, prepared with a vertical pipe for neutron probe measurements and a drainage system for collecting leachate. In order to protect the drainage system against clogging the waste material was placed on a jute cloth covered bottom lattice.

4.2 Program for watering and measurements

Dry waste with the height of 0.80 m is placed in the model and supplied with water in steps by 2 litres until the field capacity is reached. The field capacity is the maximum amount of water the waste material can retain without drainage. Addition of water is steered by a flow control sprinkler system located 0.20 m above the surface of the waste volume.

Schedule for water content measurements :

1. Measurement with the neutron probe in dry waste material
2. Determine the water content for dry waste material
3. Supply of water

4. Measurement with neutron probe in water supplied waste material

5. Determine the water content for the waste material by taking samples on different levels for drying.

6. Supply of water.

And so on .....

4.3 Experimental waste components

4.31 Wood

Wood material represents a relatively small part of the household waste today only 5 %. Shavings mostly from spruce was used in the model as wood material. This type of wood material characterizes by screw shaped units with an average length of 0.010 m, width of 0.005 m and thickness of 0.001 m. Wood is mainly constructed by cellulose and lignin. The hydrogen content bounded in the material was 5 %.

4.32 Paper

Paper is a very common waste component in household waste today representing 42.8 %. Shred newspaper was used as the sort of paper in the model. The production of newspaper is based on mechanical process which means that the pulp wood reduces to paper pulp without any addition of chemicals. The bounded hydrogen content in newspaper is therefore the same as for wood or 5 %.

4.33 Plastics

Today household waste consists of 8.8 % plastic material of which 74 % is polyethylen largely used for package and waste sacks and bags. Polyethylen was used in the model as small hand made packets from cuted waste sacks. The packets have an average length of 0.030 m, width of 0.015 m, and thickness of 0.010 m. The hydrogen content bounded in the material was 13.8 %.

4.4 Results from calibration work

4.41 Drying procedure

To determine the water content in shavings dry-freezing technique is used based on out sucking of water during freezing down to 80 ^{0}C. The dry- freezing method demands relatively small samples with the magnitude of 0.025 kg. Drying time is 24 hours. Non watering shavings had a water content of 8 %.

The paper and plastic materials are dried in oven in a temperature of 75 degrees of Celsius until no water is left. Higher drying temperature is impossible because of the risk for melting of the plastics and ignition of the wood material in combination with formation of water. Drying time varies between 5 minutes to 8 hours. Non watering paper and plastics had a water content of 8 % respectively 0.025 %.

4.42 Sample points

Four sample points for determine the water content are taken on six levels; surface, 0.05 m 0.10 m, 0.20 m, 0.30 m and 0.40 m depth in the waste material.

4.43 Calibration curves

Every two centimetres of the waste materials is registered by the probe with a radius of action of 0.30 m and compared with the results from the water content determination at the sample points.

Wood : The determination of the water content varies from 56 % at the minimum water supply to 73. 5 at the maximum water supply. The registering by the probe varies from 2500 cpm at the minimum water supply to 17 000 cpm at the maximum water supply. The calibration curve is shown in figure 6.

Paper: The determination of the water content varies from 64.3 % at the minimum water supply to 83.2 % at the maximum water supply. The registering by the probe varies from 3809 cpm at the minimum water supply to 26 000 cpm at the maximum water supply. The calibration curve is shown in figure 7.

Plastics: The determination of the water content varies from 1.62 % at the minimum water supply to 5.33 % at the maximum water supply. The registering by the probe varies from 6500 at the minimum water supply to 8200 at the maximum water supply. The calibration curve is shown in figure 8.

Neutron probe measurements in non watering wood, plastics and paper show that the registering in the plastic material is 2.5 times greater than for wood and paper which can be compared with the content of hydrogen in these material showing simular relation, se table 2.

Table 2. Data concerning calibration work.

Type of material	Amount (kg)	Volume (m^3)	Density (kg/m^3)	Hydro-gen con-tent (%)	Water content (non watering) % by dry weight	Field capacity % by volume	Dry density g/cm^3
Wood	150.7	1.15	131.0	5	8	11.5	0.068
Plastics	91.5	1.15	79.6	13.8	0.025	0.52	0.0004
Paper	119.3	1.15	103.7	5	8	18.3	0.063

Changes in dry density affect the calibration curve. Higher densities give higher count rates at the same water content. However, investigation of the dry density shows no variation in the separate components.

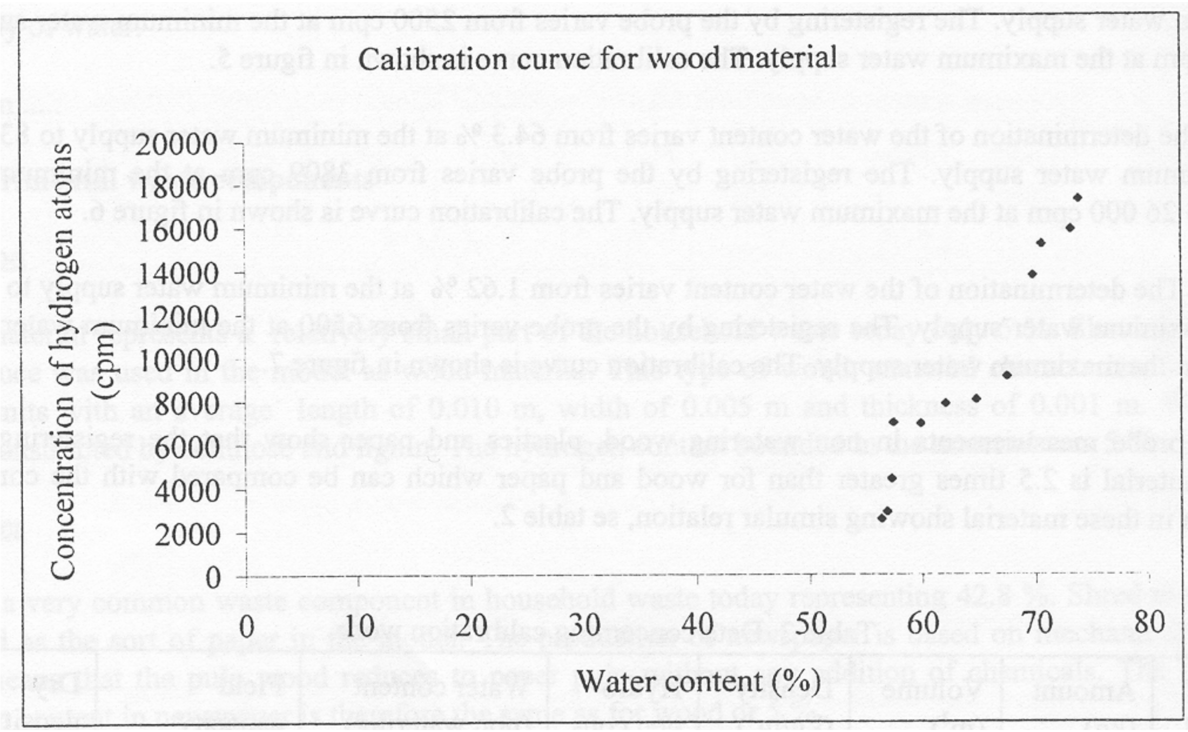

Figure 6. Calibration curve for wood material

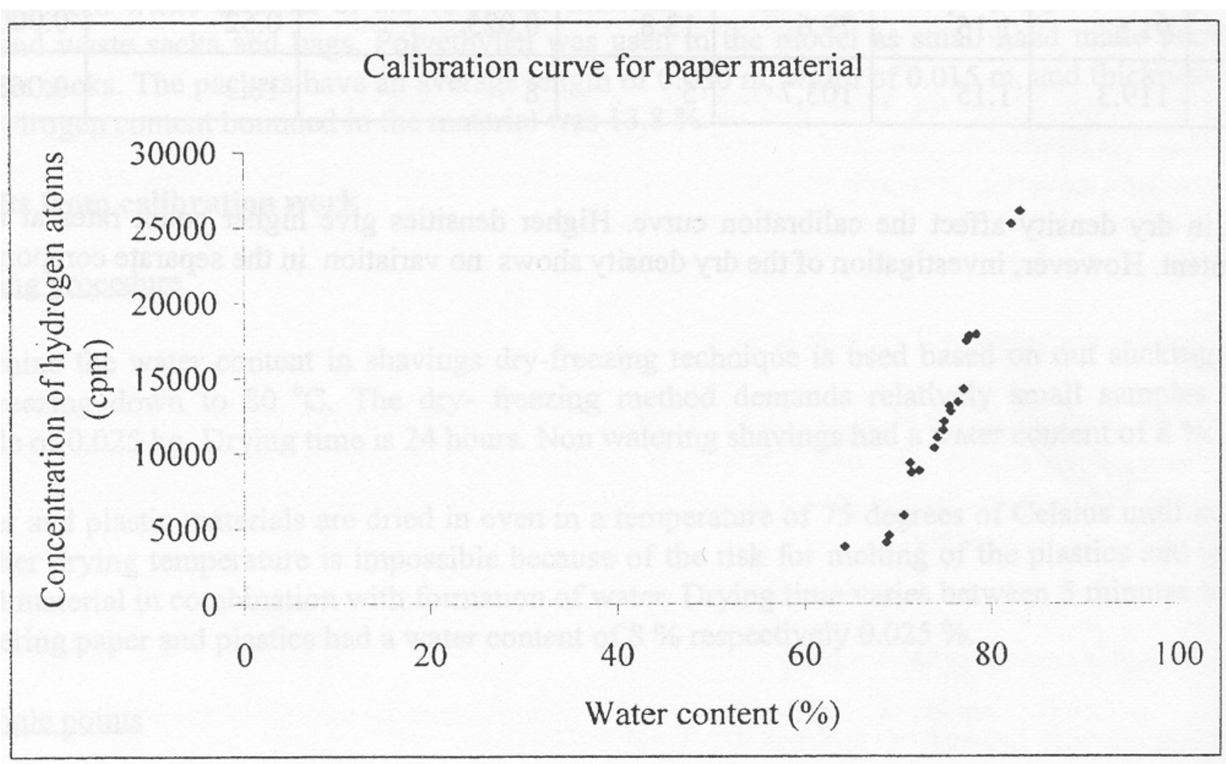

Figure 7. Calibration curve for paper material

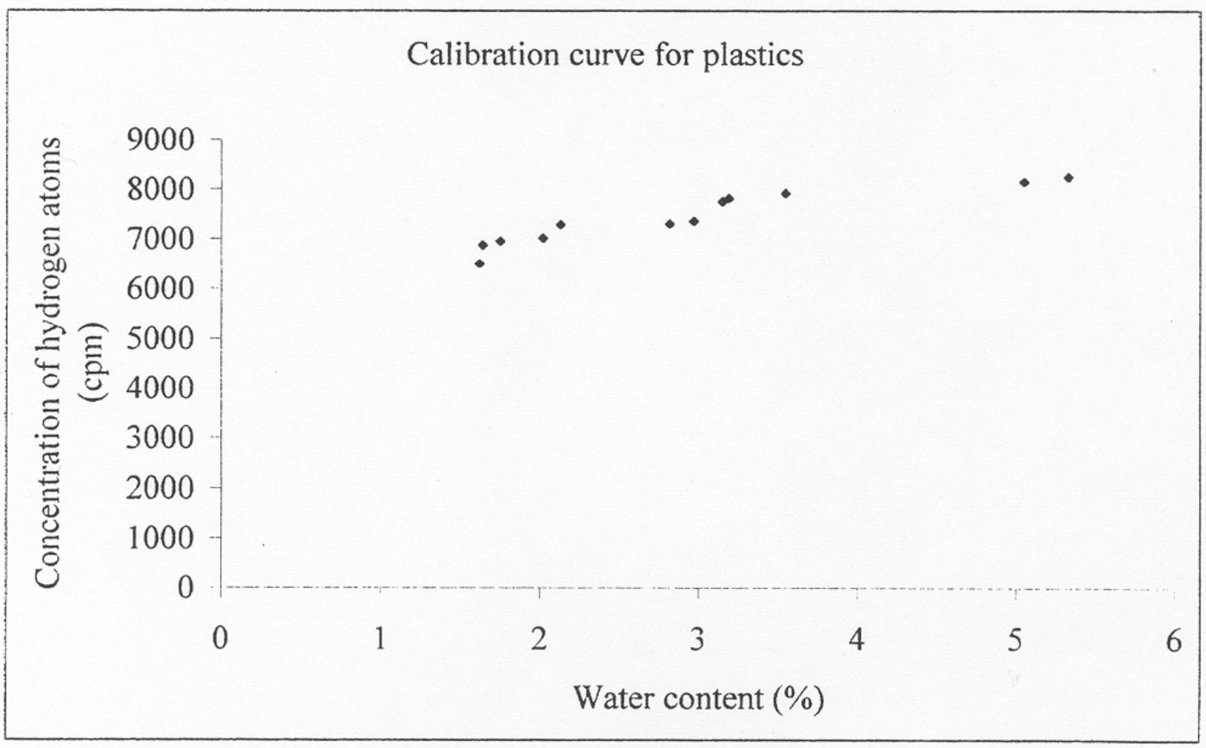

Figure 8. Calibration curve for plastics

5. CONCLUSIONS CONCERNING THE FIELD AND LABORATORY WORK

Results from water content measurements with neutron probe in the digestion cell show clearly coupling between water content, gas production and leachate. The neutron probe technique applied for measuring the water content could perhaps also be used for measuring the gas production. Interesting results from the calibration work are the relation between hydrogen content for non watering material and registering by the probe as well as findings of stable dry density in the separate waste components.

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