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THE BULK DENSITY OF PEAT AND ITS DETERMINATION

JUHANI PÄIVÄNEN

SELOSTE:
TURPEEN TILAVUUSPAINO JA SEN MÄÄRITTÄMINEN

Saapunut toimitukselle 6. 9. 1968

The correlation between the bulk density, humification degree, and laboratory volume weight of the surface peat of virgin and drained peatlands has been studied.

The difference between bulk density and laboratory volume weight was the greatest for *Sphagnum* and the smallest for woody peats. The *Carex* peats were intermediate. The correlation was also close between bulk density and the degree of humification. The bulk density is required for e.g. water regime studies to convert the water contents of peat measured in weight units into volume percentages.

1. INTRODUCTION

This study is a part in a series of studies concerning the basic hydrologic characteristics of peat, its water retention capacity, the relationship between the water content of the surface layer of peat and the depth of the ground water table, the ratio of ground-water level change and the volume of water responsible for the change (ground water coefficient), and the water permeability of peat. In order to convert the water contents of peat measured in weight units in these studies into volume percentages, the volume weight of peat, based on the volume of a fresh peat sample, must be known. In the text, this will be called *bulk density*. The lack of data on the bulk densities of peats of different types and at different stages of humification has necessitated the use of peat water contents purely on a relative basis (e.g. HEIKURAINEN *et al.* 1964).

Volume weight (bulk density) is the mass-volume ratio of an object. The volume weight of peat has generally been determined in Finland from dried, ground and sifted peat (KAILA 1956, VALMARI 1956, SARASTO 1960, PESSI 1961, and MÄKELÄ 1963). This method will be called the determination of the *laboratory volume weight*. The degree of peat humification is ocularly determined as v. POST's (1922) humification degrees, humification degree 1 referring to unhumified and 10 to entirely humified peat. Several methods have been developed for the determination of humification in a more reliable and objective way. PJAVTSHENKO's (1958) humification per cent is based on the laboratory volume weight of peat, but it also considers the water and ash contents of peat and the volume weights of the unhumified parts of peat designated constant for each peat type. To facilitate the determination of the humification per cent, nomograms have also been constructed (PJAVTSHENKO 1963). SEGEBERG's (1952 b) humification value is similar, but the difference between the volume weights of the humified and unhumified residues are compared to the volume weight of the humified portion. KEPPELER (1920) determines the »Vertorfungsgrad» value of peat by the residue insoluble in 72 % sulfuric acid. SEGEBERG (1956) has studied the relationships between the »Vertorfungsgrad» and v. Post's humification degree and found them relatively constant. Determinations of humification based on the mechanical sifting of wet peat in water have also been reported (CONWAY 1949, p. 199—201). In the Soviet Union, a microscopic method of determining humification has also been used.

Besides peat type, the humification degree of peat is also decisive in assessments of the suitability of peat for various purposes. To obtain a more thorough picture of the physical characteristics of peat, the relationship between the laboratory volume weight and v. Post's humification degree of peat has been studied (KAILA 1956). SARASTO (1960) has compared v. Post's humification degree and Pjavtshenko's humification per cent. The volume weight of soil must be known, when for instance the results of fertility analysis are expressed in amounts of nutrients per hectare. A considerable error may result from marked differences in the laboratory volume weight and bulk density (LUNDBLAD 1945, p. 3, VALMARI 1956, p. 35, MÄKELÄ 1963, p. 54).

The need of the volume weight of an undisturbed peat sample is especially pressing in studies concerning the water regime of peat on a volume basis. The most usual way of determining the soil water content is weighing the soil sample immediately after extraction and reweighing after a sufficient period of time at 105°C. The weight difference is considered to represent the evaporated amount of water, and the water content is computed as a percentage of the dry weight. It would, however, be much more important, from the point of view of the water supply to plants, to know the water content in per cent of the soil volume (KRAMER 1949, p. 74). Several research workers have emphasized that even after the determination of water contents in weight units, they should be converted into volume units, if possible, on the basis of the bulk density of undisturbed soil (FRECKMANN and BAUMANN 1937, p. 136, BADEN and EGGELSMANN 1952, p. 245). Especially in respect to peat, water content percentages computed for the dry weight are misleading, since the bulk densities of different peats vary considerably. The water content of peat should also be determined for the wet peat volume, since peat samples shrink considerably when drying (LØDDESØL 1934, p. 107, BOELTER 1962, p. 80, BOELTER and BLAKE 1964, p. 178). If the total pore space of peat is desired, the volume weight of peat must be determined. Total pore space is determined by subtracting the volume of solid matter from total sample volume (e.g. PAAVILAINEN 1967, p. 9). Sedimentation rates, porosity coefficients etc. can also be computed (cf. SEGEBERG 1952 a, p. 196, EGGELSMANN and MÄKELÄ 1963, p. 82). A close correlation has been found between pore volume and bulk density (HOLSTENER-JØRGENSEN 1958, p. 155). In some studies, pore volume has been compared to the volume of water in a saturated soil. In these cases, the volume between peat particles has not been distinguished from the pore volume within the organic particles (BOELTER 1964, p. 434).

As is shown by the preceding review, we know practically nothing about the bulk densities of peats of different types and at different stages of humification. It has been necessary to determine the bulk densities for the needs of water regime studies. Since the volume weight of peat is determined for dried and ground peat in several laboratory methods, e.g. when the humification degree is checked against PJAVTSHENKO's (1958, 1963) humification per cent, one of the main objectives of this study has been to determine the accuracy of bulk density estimates based on laboratory volume weight determinations. No studies of this kind concerning the volume weights of virgin or drained peatlands have so far been published. Corresponding records are, however, available for peat from cultivated *Sphagnum* and mud peatlands (MÄKELÄ 1963). The data also provide a possibility to compare the determined volume weights to field determinations of v. POST's (1922) humification degree and to discuss possibilities to estimate the bulk density of peat within a peat type by the mere humification degree. This paper is also considered useful in converting laboratory volume weights to be found in the literature into bulk densities of undisturbed peat. In the following, g/cu.cm will be used as the dimension of the volume weights.

2. DATA AND METHODS USED

In connection with the water regime studies of peat carried out at the Department of Peatland Forestry at the University of Helsinki, a series of over 300 volume weight samples based on the volume of a fresh peat sample have been collected in the summers 1966 and 1967. Since the samples have been collected from virgin or drained peatlands where such water regime experiments have been carried out, the samples are not evenly distributed among peat types and humification degrees (table 1).

Table 1. Distribution of samples according to peat type and humification degree (v. POST 1922).
Taulukko 1. Näytteiden jakaantuminen turvelajin ja maatumisasteen (v. POST *1922) mukaan.*

Peat type *Turvelaji*	Humification degree *Maatumisaste*										Total *Yht.*
	1	2	3	4	5	6	7	8	9	10	
Sphagnum peat *Rahkaturpeet*	33	38	37	30	35	13	6	4	2	—	198
Carex peat *Saraturpeet*	—	—	25	13	25	9	3	7	—	—	82
Woody peat *Puuturpeet*	—	—	—	—	2	5	7	10	12	—	36
Total — *Yhteensä*	33	38	62	43	62	27	16	21	14	—	316

Most of the *Sphagnum* peats are poorly or moderately humified, the *Carex* peats are moderately humified, and the woody peats represented by only 36 samples, are highly humified. The heterogeneous distribution of the data is a source of uncertainty requiring new studies to be made.

TRNKA (1914, p. 364) classifies volume weight determinations of soil into two types of methods:

a) Soil structure is broken.

b) An attempt is made to retain the structure of undisturbed soil.

The first of these can be classified into two further methods. The ground soil is placed in a container with a fixed volume, or the soil is placed in a graduated cylinder enabling the reading of its volume. This study is based on the use of all these methods.

For the determination of bulk density and the extraction of an undisturbed sample for soil physical determinations, a number of different sampling devices have been developed (e.g. COILE 1936, LUTZ 1944, BADEN and SEGEBERG 1951, VALMARI 1956, HEINONEN 1960). Coating the soil sample with molten paraffin and determining the volume on the basis of Archimedes' law have also been tried (TRNKA 1914, p. 371). Determinations of soil volume are, however, difficult by all methods and it is probably impossible to measure soil volumes accurately.

Bulk density was determined in this study in the following way: A sample was taken from the desired peat layer by a cylinder with an inner diameter of 79.6 mm. The sample was cut with a knife to a length of 50 mm as accurately as possible; giving a sample volume of 250 cc. The samples were wrapped into airtight plastic and taken to the laboratory, where the fresh sample was weighed. The peat type and humification degree (v. POST 1922) were recorded on the basis of macroscopic observation. The samples were dried at 105°C for 24 h and weighed. The water content of the sample was computed in per cent of the volume at sampling, bulk density by dividing the dry weight by the constant volume used. The water content at sampling must be determined, since several research workers have found that it affects the bulk density results (MÄKELÄ 1963, p. 59, BOELTER and BLAKE 1964, p. 178). These determinations were made for all 316 samples.

Two methods were used to determine *laboratory volume weight*. Volume weight was determined for all samples by PJAVTSHENKO's (1958) method (see also SARASTO 1960, PESSI 1961). Laboratory-dry peat was ground in a mill and sifted with a 0.5 mm sieve. The ground peat was carefully mixed and gradually poured into a 10 cc graduated cylinder, simultaneously compacting it by tapping the bottom of the cylinder lightly on an elastic surface. The final compaction of the peat was done with a plunger at a pressure of 1 kg/sq.cm. Peat volume was read in the graduated cylinder to the closest 0.1 cc. This method was used for two samples for each dried, originally 250 cc sample, and the mean of the two determinations was used in computations. The peat volumes from the two determinations were compounded and used for determining the moisture of laboratory-dry peat and the ash contents of the samples. The volume weight and humification per cent of absolutely dry and ashless peat was computed according to PJAVTSHENKO's (1958, p. 4) method.

Since another method of determining an estimate for the bulk density of peat in the laboratory has been used in other studies, e.g. fertility studies in Finland, it was considered necessary to carry out comparative measurements by this method also. From the previously described data, 72 samples were selected at random, representing quite evenly samples with different volume weights. The bulk densities of the samples were determined by a device developed by Kivekäs and described by KAILA (1956, p. 29—30). The device is composed of a cylinder in two parts, one of which is detachable, has a fixed bottom, and has a volume of 33 cc. The cylinder is filled with air-dry ground peat and dropped three times from a level of 20 cm against a flexible surface. The top part of the cylinder is »cut» off to the exact peat volume of the bottom part, which is weighed. VUORINEN and MÄKITIE (1955, p. 7—8) have described essentially the same method but the ground peat is compacted by tapping to a volume of 25 cc.

The macroscopic determination of the peat type was checked for two samples per sample plot and sampling layer. In microscopic checks, the same results were generally obtained as from this procedure. The final results are only presented by main peat types, since the data do not allow very fine classification.

3. RESULTS

31. COMPARING LABORATORY VOLUME WEIGHTS

Laboratory volume weight determinations were, as reported, carried out by two methods for greater accuracy and to determine any differences between the two methods. In one (Kivekäs') method, the peat volume is constant, in the other (Pjavtshenko's), the peat volume is read in a graduated cylinder. Two replicate determinations were made by either method. The significance of the differences between the duplicate determinations was tested for both methods separately by variance analysis. The differences were not significant for either method, as is shown by the following summarization:

Method	Computed F value	Tabulated F value	LSD 5%, g/cc
Pjavtshenko	0⁻	$F_{0.1\%}$ 11.87	0.003
Kivekäs	2.55⁻	»	0.003

MÄKITIE (1958, p. 74) found somewhat greater differences between duplicate determinations by the same person by a tapping method similar to the latter.

The correlation between the volume weights of peat obtained by Kivekäs' and Pjavtshenko's method were quite close (figure 1). The correlation was linear; the addition of the quadratic term did not significantly increase the 96.8 % coefficient of determination obtained for the function. A common function was computed for *Sphagnum* and *Carex* peats, since graphical examination indicated no clear differences between these types. Figure 1 shows that at lower volume

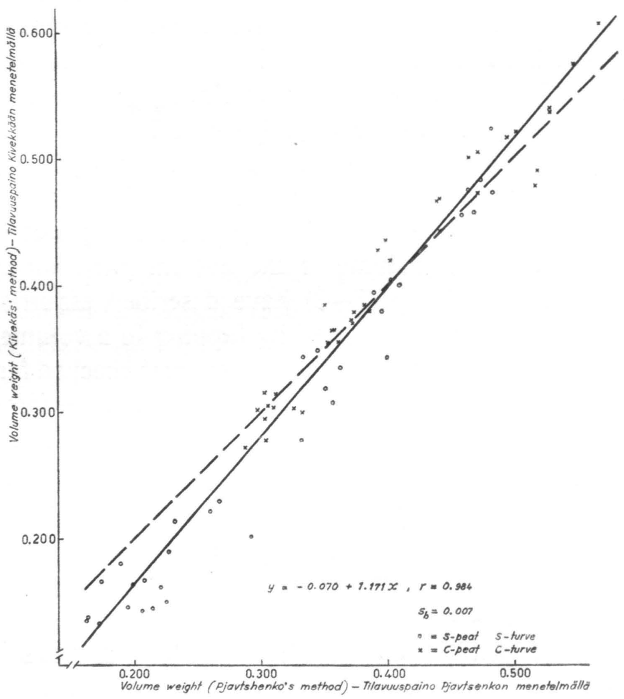

Figure 1. The correlation between volume weights determined in the laboratory by Kivekäs' (KAILA 1956) and Pjavtshenko's (SARASTO 1960) methods.

Kuva 1. Kivekkään (KAILA 1956) ja Pjavtshenkon (SARASTO 1960) menetelmillä laboratoriossa määritettyjen tilavuuspainojen välinen riippuvuussuhde.

weights of peat than 0.400, Kivekäs' method has given lower values than Pjavtshenko's method. The converse situation was true for higher volume weights. The gradient corresponding to a slope of 1.0 is indicated in the figure by a broken line. It is evident that the 1 kg/sq.cm pressure used in Pjavtshenko's method compacts raw *Sphagnum* peat much more efficiently than the dropping technique used in Kivekäs' method. The correlation between the methods is, however, close and can be used for the conversion of the results by either method. The importance of reporting the determination method for laboratory volume weights is obvious.

Kivekäs' method leads to a higher mean representativity of the volume weight, since a volume of 33 cc is used. The volume of peat used in Pjavtshenko's method is, after final compaction, only 4—8 cc varying by peat type and humification degree. The choice of the latter method for comparison with the volume weight based on the volume of a fresh peat sample is due to the desire to check v. Post's humification degree against Pjavtshenko's humification per cent for all peats in the water regime studies. When the humification per cent is determined, Pjavtshenko's volume weight determination is also required.

32. CORRELATION BETWEEN BULK DENSITY AND LABORATORY VOLUME WEIGHT

Bulk density for the fresh sample volume was determined for all 316 samples. Later, the samples were ground, and the volume weight was determined by Pjavtshenko's method. In this connection, the moisture and ash contents of the laboratory-dry peat samples were also determined. These mean contents were the following for the different peat types:

	Ash content % of dry weight	Moisture content % of laboratory-dry peat weight
Sphagnum peats	3.1	6.9
Carex peats	5.2	6.8
Woody peats	10.3	8.2

Slightly higher values have usually been reported for the moisture content of laboratory-dry peat, e.g. SARASTO (1960, p. 7), 9 %, VALMARI (1956. p. 34), 10 %, and PJAVTSHENKO (1958, p. 4), 12 %. Somewhat higher ash contents have also been reported for *Carex* peats than were found in this study (cf. KIVINEN 1948, p. 119, VAHTERA 1955, p. 34—35, PJAVTSHENKO 1958, p. 5, SARASTO 1960, p. 8).

The following symbols will be used in discussing the results of correlation computing concerning the volume weights determined by different methods, bulk density and the humification degree:

Dependent variable: y = bulk density
Independent variables: x_1 = laboratory volume weight (PJAVTSHENKO 1958)
x_2 = laboratory volume weight of absolutely dry and ashless peat
x_3 = water content of sample (vol. %) at sampling
x_4 = field determination value for humification degree (v. POST 1922).

A linear correlation was found between bulk density and laboratory volume weight for *Carex* and woody peats, but adding the quadratic term resulted in a significantly improved correlation for *Sphagnum* peats. There was a clear correlation for all types, as can be seen in the following summary:

S—p	$y = 0.005 + 0.292\,x_1 - 0.165\,x_1^2$	$r = 0.821$	
C—p	$y = 0.007 + 0.256\,x_1$	$r = 0.808$	$s_b = 0.021$
W—p	$y = 0.050 + 0.222\,x_1$	$r = 0.763$	$s_b = 0.032$
All data	$y = 0.008 + 0.242\,x_1$	$r = 0.808$	$s_b = 0.010$

The level differences in the regression lines for the different peat types are shown in figures 2—4. The dot clusters are partly intermingled. This is probably due to the classification of the peats according to principal peat factor only, despite that they are far from pure *Sphagnum*, *Carex*, or woody peats.

The following volume weight means were computed for all data for each peat type:

	Bulk density $\bar{y}$	Lab. vol. weight $\bar{x}_1$	Ratio $\bar{x}_1:\bar{y}$
S—p	0.083	0.339	4.1
C—p	0.113	0.412	3.7
W—p	0.156	0.480	3.1

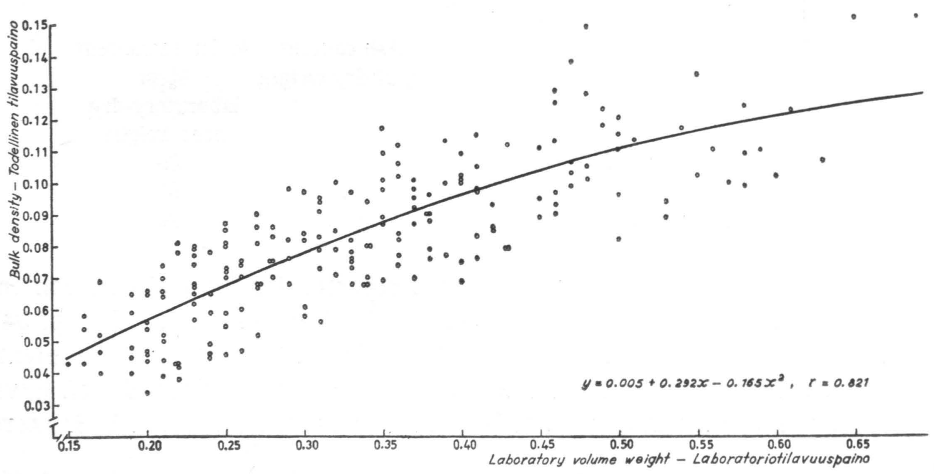

Figure 2. Correlation between bulk density and laboratory volume weight in *Sphagnum* peats.
Kuva 2. Todellisen ja laboratoriossa määritetyn tilavuuspainon välinen riippuvuussuhde rahkaturpeissa.

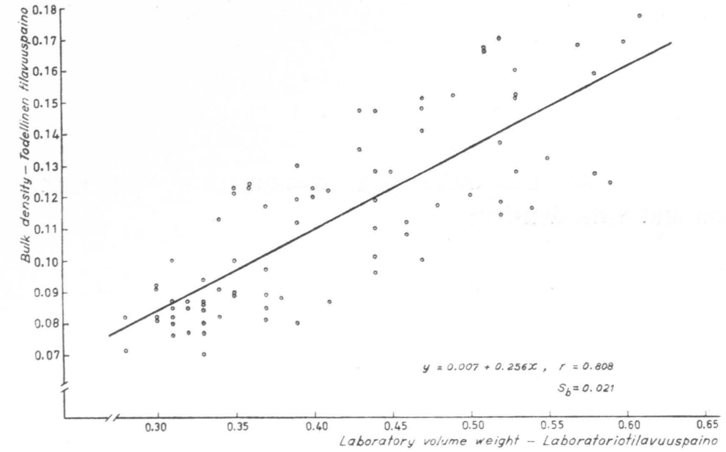

Figure 3. Correlation between bulk density and laboratory volume weight in *Carex* peats.
Kuva 3. Todellisen ja laboratoriossa määritetyn tilavuuspainon välinen riippuvuussuhde saraturpeissa.

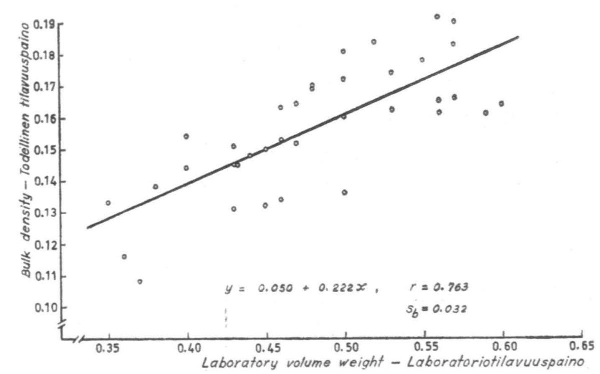

Figure 4. Correlation between bulk density and laboratory volume weight in woody peats.
Kuva 4. Todellisen ja laboratoriossa määritetyn tilavuuspainon välinen riippuvuussuhde puuturpeissa.

The values obtained by the laboratory method are thus three to four times the bulk densities (cf. HOLMEN 1964, p. 142). The ratio is smallest for woody and largest for *Sphagnum* peats. The ratios are not directly comparable, since the distribution among humification degrees has differed considerably for the peat types (cf. table 1), but it is evident that the difference between the laboratory volume weight and bulk density decreases, when the ash content increases (cf. MÄKELÄ 1963, p. 59). The difference between the results of the different volume weight determinations is partly due to the shrinking of peat at drying, and partly to the filling up of the pore cavities at grinding the samples. The relative significance of these two factors has not been studied during this project, but

BOELTER (1962, p. 60) and BOELTER and BLAKE (1964, p. 178) have found that oven-drying peat at saturation approximately doubles volume weight. Shrinkage has probably had a smaller role in this study, since the sample were not at saturation at sampling.

The following correlation coefficients were obtained between the volume weight of absolutely dry and ashless peat, computed by PJAVTSHENKO's (1958, p. 4) method and bulk density:

S—p	$r = 0.800$
C—p	$r = 0.809$
W—p	$r = 0.638$

When these are compared with the correlation coefficients shown earlier, it is clear that eliminating moisture and ash from laboratory-dry samples has not increased the correlation between bulk density and laboratory volume weight. A clear decrease is seen for woody peats. It should be repeated that ash and moisture were not eliminated in the sample used for determining bulk density

The average moisture content in volume per cent at sampling was 80.3 % for *Sphagnum* peats, 82.6 % for *Carex* peats, and 73.4 % for woody peats. BOELTER (1962, p. 50) determined bulk density for the volume of peat samples at saturation. At a soil water tension of 0.1 bar approximately corresponding to the water contents of the samples of this study at sampling, BOELTER (1962, p. 61) has found peat volumes from 87 to 94 per cent of the volumes of peat at saturation. PESSI (1961, p. 253) has also made some observations of the effect of water evaporation on the shrinking of peat samples (see also LUNDBLAD 1945, p. 7). The water contents of MÄKELÄ's (1963) volume weight samples were of the same magnitude as those in the data of this study, which exhibited some variation in the moisture content corresponding to the water regime of the undisturbed surface peat of drained peatlands (see also KIRKHAM 1964, p. 5—15).

The effect of the water content at sampling on the bulk density-laboratory volume weight ratios shown earlier was studied from computed correlations. The following equations and multiple correlation coefficients were obtained:

S—p	$y = 0.1559\ x_1 + 0.0004\ x_3$	$R = 0.824$
C—p	$y = 0.0952 + 0.2346\ x_1 - 0.0010\ x_3$	$R = 0.827$
W—p	$y = 0.0117 + 0.2411\ x_1 + 0.0004\ x_3$	$R = 0.784$
All data	$y = 0.0364 + 0.2454\ x_1 - 0.0004\ x_3$	$R = 0.813$

The significance of adding the moisture variable was tested by the t-test. Only for woody peats, the addition resulted in no significant increase in the amount of variation explained by the equation. For all data, the difference between bulk density and laboratory volume weight increases with an increase

in sample water content. For *Sphagnum* peat, the opposite effect was found. MÄKELÄ (1963, p. 58) has also found that the effect of the water content is not as distinct for *Sphagnum* peats than muddy peats. Very loose peat may easily be compacted, when the cylinder is driven into the soil, and water may simultaneously be removed from the wet peat. This may result in errors in determining bulk density and the water content of the sample.

33. CORRELATION BETWEEN BULK DENSITY AND THE HUMIFICATION DEGREE

A close correlation was also found between bulk density and the humification degree, as is shown by the following summary:

S—p	$y = 0.045 + 0.011\ x$	$r = 0.870$	$s_b = 0.0004$
C—p	$y = 0.031 + 0.018\ x$	$r = 0.937$	$s_b = 0.0007$
W—p	$y = 0.052 + 0.014\ x$	$r = 0.846$	$s_b = 0.0014$
All data	$y = 0.038 + 0.014\ x$	$r = 0.918$	$s_b = 0.0004$

The original dot clusters and computed regression lines are shown in figures 5—7. It seems that the bulk density of peat is quite accurately estimated on the basis of the peat type and the humification degree, enabling conclusions concerning its hydrological properties.

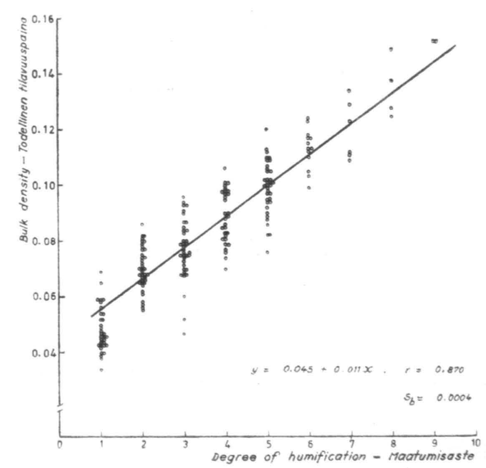

Figure 5. The correlation between bulk density and v. Post's humification degree in *Sphagnum* peats.
Kuva 5. Todellisen tilavuuspainon ja v. Postin maatumisasteen välinen riippuvuussuhde rahkaturpeissa.

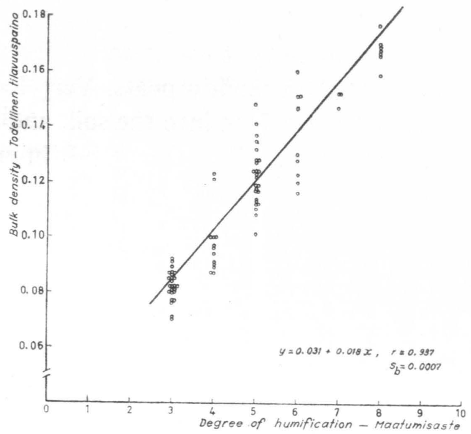

Figure 6. The correlation between bulk density and v. Post's humification degree in *Carex* peats.

Kuva 6. Todellisen tilavuuspainon ja v. Postin maatumisasteen välinen riippuvuussuhde saraturpeissa.

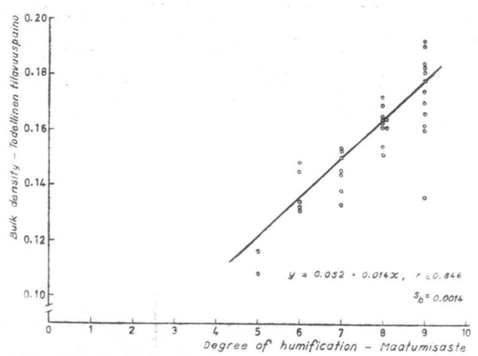

Figure 7. The correlation between bulk density and v. Post's humification degree in woody peats.

Kuva 7. Todellisen tilavuuspainon ja v. Postin maatumisasteen välinen riippuvuussuhde puuturpeissa.

34. DETERMINING BULK DENSITY AS A FUNCTION OF SEVERAL VARIABLES

Finally, the multiple correlation between bulk density and all independent variables can be examined. Since it was found unnecessary to eliminate ash and moisture from laboratory volume weights, bulk density will be discussed as a function of laboratory volume weight (x_1), the water content of the sample at sampling (x_3), and the humification degree determined in the field (x_4). The

following multiple correlation coefficients and variable significances were obtained:

	S—p	C—p	W—p	All samples
Multiple correlation coefficient ..	0.901	0.942	0.885	0.924
Determination %	81.1	88.7	78.3	85.4
Constant term	—[1]	—	—	***
Lab. vol. weight	***	*	**	***
Water cont., vol. %	***	—	—	—
Humification degree	***	***	***	***

[1]) Symbols: — term not significant
* term significant at 5 % level of probability
** term significant at 1 % » » »
*** term significant at 0.1 % » » »

When the not-significant terms are dropped, we arrive at the following multivariable equations:

$$\text{S—p} \quad y = 0.0611\, x_1 + 0.0003\, x_3 + 0.0075\, x_4$$
$$\text{C—p} \quad y = 0.0493\, x_1 + 0.0151\, x_4$$
$$\text{W—p} \quad y = 0.1130\, x_1 + 0.0095\, x_4$$
$$\text{All samples} \quad y = 0.0318 + 0.0552\, x_1 + 0.0121\, x_4$$

From the data available, 78 to 89 per cent of the bulk density variations in peat were determined by these multivariable correlations. The effect of the humification degree was the clearest, and of the water content at sampling the smallest, in determining bulk density.

4. DISCUSSION OF RESULTS AND COMPARISON WITH EARLIER STUDIES

As was stated previously, volume determinations for organic soils have not been adequately solved. In this study, also, small errors increasing the variance have been possible despite the utmost care taken in sampling.

No significant differences were found between duplicate determinations in the laboratory methods. The variance of the differences between bulk density and laboratory volume weight may be increased by the small size, 4—8 cc, of the compacted subsample taken in the latter method for the determination of the volume weight of a 250 cc sample. An attempt has been made to minimize this source of error by mixing the ground and sifted peat powder before taking the subsample. Since the ash content of e.g. raw *Sphagnum* peat can be very small, the ash content was determined from the compounded duplicate volume weight subsamples.

The model of the function used for simple correlation analysis was satisfactory, as can be seen even in the graphs. When bulk density was determined by a multivariable function, the model was tested by autocorrelation computations. These indicated that the empirically measured data were evenly distributed about the computed relative plane, supporting the validity of the choice of the model.

Similar studies have not been carried out previously; therefore, direct comparisons are not possible. In cultivated *Sphagnum* and muddy peatlands, VALMARI (1956, p. 35) and MÄKELÄ (1963, p. 59) have found somewhat smaller differences between bulk densities and laboratory volume weights. This sounds natural, since the surface peat of a dried and cultivated peatland will be compacted. The bulk densities of highly humified *Carex* and woody peats were ca. 0.16—0.19 in this study, while MÄKELÄ's values for the plow layer of muddy peatland were between 0.29 and 0.38. VALMARI (1956, p. 35) has also found that the bulk densities of the 0—10 cm surface layer of a cultivated peatland are higher than those of the 10—20 cm layer.

Figure 8 shows the correlation between bulk density and the degree of humification for all data. The mean laboratory volume weights of SARASTO (1960, p. 9) and TUORILA (1928, p. 60), converted into bulk densities, are also shown in

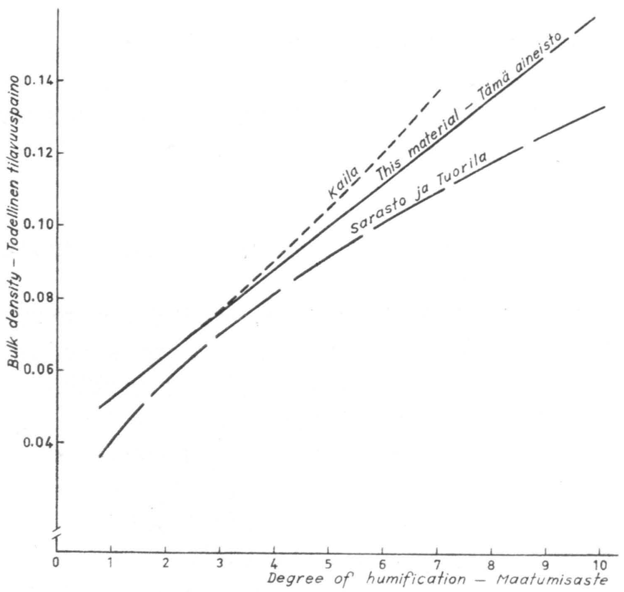

Figure 8. Average correlation between bulk density and v. Post's humification degree, and comparative bulk density curves computed on the basis of the laboratory volume weights reported by TUORILA (1928), KAILA (1956), and SARASTO (1960).

Kuva 8. Todellisen tilavuuspainon ja v. Postin maatumisasteen välinen keskimääräinen riippuvuussuhde sekä vertailu TUORILAN *(1928)* KAILAN *(1956) ja* SARASTON *(1960) laboratoriotilavuuspainojen perusteella laskettuihin todellisen tilavuuspainon arvoihin.*

the figure. Converting was carried out with the correlation equation found in this study for the data combined for all peat types. In slightly humified peat, the data led to rather similar results, but in highly humified peat, the correlations deviate by ca. 0.020 volume weight units from each other. In this work and that of SARASTO, the same method was used to determine laboratory volume weight; the exact method of determination is not described in TUORILA's paper. The somewhat greater volume weights found in this study may be due to the electric hammer mill (Culatti DFH 48) used to grind the peat, which probably has ground the peat more efficiently than the hand mortars used in the earlier studies.

The correlation computed on the basis of the equation published by KAILA (1956, p. 30) for the laboratory volume weight and v. Post's humification degree relationships is also shown in figure 8. The volume weights provided by the equation for each degree of humification are first converted into Pjavtshenko's volume weights by the equation shown in figure 1, and the corresponding bulk density values have then been computed by the equation computed for all peat types from this data (page 8). In slightly humified peat, the values are practically the same, but the difference in the volume weights increases rapidly, as the humification degree rises. However, KAILA's data consisted of few highly humified samples, e.g. only two samples with a humification degree over 8, and thus also the volume weights are rather uncertain at this level.

PAAVILAINEN (1966, p. 33 and 35) has reported much higher bulk densities for slightly or moderately humified *Sphagnum* peat samples than were found in this study. The relatively high portion of *Carex* and woody residues in the peat and extremely efficient drainage especially in peatlands with a small ditch spacing may have had a partial effect in increasing the bulk densities.

In the study of PAAVILAINEN and VIRRANKOSKI (1967, p. 5) concerning the capillary rise of water in peat, bulk densities between 0.065 and 0.104 are reported for *Sphagnum* peat. The corresponding humification degrees are not reported, but on the basis of this study, the humification degrees can be estimated to have varied from 1 to 4, which means that the peat profiles were slightly to relatively little humified.

The volume weights reported by EGGELSMANN and MÄKELÄ (1964, p. 82) also agree with the average correlation found in this study (figure 8). To enable comparisons, KEPPELER's (1920) »Vertorfungsgrad» values must be converted by the method described by SEGEBERG (1956, p. 77) into v. Post's humification degrees. The bulk densities reported by TACKE (1929, p. 28) for the moderately and highly humified peats of raised bogs agree with the results of this study (cf. figure 5).

By comparing the bulk density values reported in American peat studies with the ones reported in this study, estimates of the corresponding v. Post's humification degrees can be obtained. In these studies, the humification of the peats has not been classified, but described verbally instead (cf. BOELTER 1962, p. 63, 1964, p. 435).

5. SUMMARY

The material consists of 316 peat samples 250 cc in volume, for which the bulk density, the laboratory volume weight (PJAVTSHENKO 1958), the water content at sampling, and the humification degree (c. POST 1922) have been determined. For a part of the material, comparative laboratory volume weight determinations have been made by Kivekäs' method (KAILA 1956).

The correlation between bulk density and the laboratory volume weight was found to be close. Eliminating the ash and moisture content of air-dry samples did not improve the correlation. There were distinct level differences among peat types; the difference between bulk density and laboratory volume weight was the greatest for *Sphagnum* and the smallest for woody peats. The *Carex* peats were intermediate. The water contents at sampling may partly determine these differences. When the data were treated as a whole, the difference between bulk density and laboratory volume weight seemed to increase, as the water content increased.

The correlation was also close between bulk density and the degree of humification. For all data, multivariable correlation analysis revealed that bulk density was determined for the largest part by the degree of humification, least by the water content at sampling, laboratory volume weight being intermediate.

Thus already the determination of the degree of humification provides a clear picture of the magnitude of the bulk density for each peat type. On the basis of the laboratory volume weight, the bulk density of the peat can also be determined by fair accuracy.

The bulk density is required for e.g. water regime studies, to convert the water contents of peat measured in weight units into volume percentages. The results of this study will be used for this purpose in the other partial studies carried out to obtain better knowledge of the basic hydrological properties of peat.

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SELOSTE:
TURPEEN TILAVUUSPAINO JA SEN MÄÄRITTÄMINEN

Aineisto käsittää yhteensä 316 kappaletta 250 cm³:n suuruista turvenäytettä, joista on määritetty todellinen tilavuuspaino, laboratoriotilavuuspaino (PJAVTSHENKO 1958), näytteenottohetken kosteuspitoisuus sekä maatumisaste (v. POST 1922). Osasta näyteaineistoa suoritettiin laboratoriotilavuuspainon vertailumäärityksiä KIVEKKÄÄN menetelmällä (KAILA 1956).

Todellisen ja laboratoriossa määritetyn tilavuuspainon välinen korrelaatio osoittautui varsin selväksi. Tuhkan ja ilmakuivassa näytteessä olevan kosteuden eliminoiminen laboratoriotilavuuspainonäytteistä ei parantanut edellä mainittua riippuvuussuhdetta. Turvelajien välillä oli selviä tasoeroja; todellisen ja laboratoriossa määritetyn tilavuuspainon välinen ero oli suurin rahka- ja pienin puuturpeilla. Saraturpeet asettuivat edellisten väliin. Näytteenottohetken vesipitoisuudella saattaa olla merkitystä mainittuihin eroihin. Aineistoa yhtenä

kokonaisuutena tarkasteltaessa todellisen ja laboratoriossa määritetyn tilavuuspainon ero näytti suurenevan vesipitoisuuden kasvaessa.

Tarkasteltaessa koko aineistoa usean muuttujan korrelaatioanalyysillä todettiin, että todellista tilavuuspainoa selitettäessä maatumisasteen vaikutus oli selvin, näytteenottohetken vesipitoisuuden merkitys heikoin sekä laboratoriotilavuuspainon selitysvoimakkuus edellisten välillä.

Jo siis pelkän maatumisasteen määrittäminen antaa turpeen todellisen tilavuuspainon suuruusluokasta melko hyvän kuvan kunkin turvelajin puitteissa. Laboratoriossa määritetyn tilavuuspainon perusteella voidaan myös varsin tarkoin päätellä turpeen todellinen tilavuuspaino.

Todellisen tilavuuspainon tietäminen on välttämätöntä esim. vesitaloustutkimuksissa, jotta painoyksiköissä mitatut turpeen kosteuspitoisuudet voitaisiin muuntaa tilavuusprosenteiksi. Tähän tarkoitukseen käytetäänkin nyt käsillä olevan työn tuloksia tutkittavana olevan kokonaisongelman — turpeen vesitaloudellisten perusominaisuuksien — muissa osaselvityksissä.