Physical Test Methods Sub-Group

Technical Report

3rd Collaborative Study on Air Permeability in Accordance with ISO 2965:2019

December 2023

Study Coordination Group:

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1. INTRODUCTION

1.1 Purpose and Scope

It is an objective of the Physical Test Methods (PTM) Sub-Group of CORESTA to carry out inter-laboratory studies on physical parameters of tobacco products and their components. As air permeability is an important parameter of wrapping papers for tobacco products, the PTM Sub-Group has decided to carry out a regular collaborative study related to this parameter. The method for measuring air permeability is specified in ISO 2965:2019. ISO 2965:2019 allows two measuring heads to be used for the measurement of air permeability on cigarette paper, the 10×20 mm² measuring head, which is the more common head, and the 2×15 mm² measuring head, which is mainly used for measurements of air permeability on the bands of lower ignition propensity cigarette papers. However, ISO 2965:2019 also allows the use of the 2×15 mm² measuring head for air permeability measurement on cigarette paper, whenever the available area on the paper sample is too small for the 10×20 mm² measuring head. This may be the case for measurements on paper samples taken from cigarettes or other finished tobacco products.

In the 1st Collaborative Study on Air Permeability 2019 (PTM-217) repeatability and reproducibility data for the 2×15 mm² measuring head used on conventional cigarette paper were determined and results have shown that air permeability values obtained with the 2×15 mm² measuring head are substantially higher, by about 9 CU for a 60 CU cigarette paper than those obtained with the 10×20 mm² measuring head. This has been confirmed in the 2nd Collaborative Study on Air Permeability (PTM-302) and one of the purposes of this study is to also monitor the consistency of this difference over time.

Furthermore, this study allows the participating laboratories to monitor their performance in comparison to other laboratories, to derive actions for improvement of their internal processes and to fulfil accreditation requirements.

For the determination of repeatability and reproducibility this study followed ISO 5725-2, the laboratory performance was assessed in accordance with ISO 13528. This study conforms to the principles described in ISO 17043 *Conformity assessment — General requirements for proficiency testing*; however, CORESTA is not an accredited proficiency testing provider and does not adhere to certain aspects of ISO 17043.

All results will be presented in anonymized form.

1.2 Study Protocol

The test protocol used for this collaborative study is given in Appendix A and will be briefly summarized below.

The protocol contained information on the products to be tested, the preparation of samples, set-up and calibration of instruments and the procedure for carrying out the measurements. The study participants were required to provide data to identify their laboratory, data on the instruments and calibration methods used, all measurement results obtained and any deviations from the protocol. The results were collected in an Excel-sheet and sent to the Study Coordination Group for further processing and evaluation.

Once received, the data set was inspected for obvious inconsistencies and for deviations from the protocol.

Most laboratories used either 23 °C, 50 % rH, as recommended in ISO 187, or 22 °C, 60 % rH, as recommended in ISO 3402 for conditioning and testing of the samples. Laboratory 3 measured and conditioned the samples at 27 °C and 65 % rH, which is likewise possible according to ISO 187 in tropical regions and thus complies with ISO 2965. Measurements under this range of conditions may also be indicative of the extent of potential deviations in air permeability values, when measurements are made in a production environment, which often does not allow for proper conditioning.

Not all laboratories were able to measure all samples due to the wide range of air permeability values and the requirement for using different measuring heads.

The distribution of sample materials, the protocol and the data collection sheet started in June 2023 and laboratories were asked to report the results until 11th of September 2023. Two data sets were received after the deadline but were included in the analysis.

1.3 Products and Measurements

For this collaborative study a conventional (non-LIP) cigarette paper, a highly porous plug wrap paper and two perforated tipping papers were used as sample materials. Their details are given in Table 1. The permeability data in Table 1 do not necessarily represent actual measured values but just serve as an indication of the permeability values to be expected. The paper samples were provided by Schweitzer-Mauduit Intl., Tannpapier GmbH and Papierfabrik Wattens GmbH & Co KG.

Table 1 – Characteristics of the paper samples

ID	Product Description	Permeability		Measuring Head
		Type	Typical Value CU	
A	Cigarette Paper	Natural	60	2 mm × 15 mm
B	Cigarette Paper	Natural	60	10 mm × 20 mm
C	Plug Wrap Paper	Natural	10000	10 mm × 20 mm
D	Tipping Paper	Electro-perforated	300	10 mm × 20 mm
E	Tipping Paper	Laser-perforated	1400	10 mm × 20 mm

The cigarette papers A and B were identical, they only differed with respect to the measuring head that was to be used for the measurement.

For each paper sample A to E three replicate measurements had to be made on three consecutive days, with one replicate per day consisting of 20 individual measurements. Thus, a laboratory completing the full set of measurements had to make 3×5×20 = 300 individual determinations of air permeability.

For the measurements the laboratories had to follow ISO 2965:2019.

1.4 Study Participants

In total 12 laboratories participated in the study by submitting 21 data sets, with the list of participants in alphabetical order given in Table 2. A code was assigned to each laboratory, thus the order of laboratories in Table 2 does not agree with the order of the laboratories in other tables. Not all laboratories were able to measure all samples. Some laboratories did not have a 2×15 mm² measuring head available and some were not able to measure perforated paper or the high permeability of the plug wrap paper.

Table 2 – List of participants

Participant Name	Number of sample sets	Country
British American Tobacco Brazil	1	Brazil
British American Tobacco UK	1	United Kingdom
British American Tobacco Venezuela	1	Venezuela
CNTQSTC, ZTRI	1	China
Godfrey Phillips India Ltd.	1	India
Indian Tobacco Company	2	India
Japan Tobacco International	1	Germany
KT International	1	Bulgaria
Labstat	1	Canada
Papierfabrik Wattens	5	Austria
PT Bentoel Prima	1	Indonesia
SWM International	5	France

2. STATISTICAL EVALUATION

2.1 Raw Data Treatment

In total 21 data sets were received and after an initial screening for inconsistencies the data were prepared for statistical analysis. Mean values (MV) over all laboratories, the average within-laboratory standard deviation (SDw), that is, the standard deviation of a single replicate averaged over all laboratories and the between-laboratory standard deviation (SDb), that is the standard deviation of the single replicate values obtained by each laboratory on the respective day of measurement, are provided in Table 3. The number (N) of data sets is also given.

Table 3 – Summary data for air permeability per day over all labs, outliers included

	Day 1				Day 2				Day 3			
ID	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	SDw	N
	CU	CU	CU		CU	CU	CU		CU	CU	CU	
A	65,82	3,95	4,27	16	65,40	3,71	4,39	16	64,91	3,66	4,19	16
B	60,46	2,01	3,46	21	60,22	1,61	3,14	21	60,07	1,73	3,07	21
C	9783,71	187,91	609,78	10	9865,07	262,10	646,76	10	9874,01	202,10	552,15	10
D	305,70	27,15	7,46	11	304,70	27,29	7,15	11	305,86	27,61	8,07	11
E	1502,07	59,48	37,50	11	1505,03	69,42	35,64	11	1503,46	61,84	35,67	11

2.2 Outlier Analysis and Removal

Repeatability and reproducibility data were determined following ISO 5725-2, whereby outlier testing according to Cochran's test and Grubbs' test was used. In a first step each set of 20 individual measurements was tested by Grubbs' test with respect to the maximum, minimum and the two highest and lowest values. Any outliers that were found were excluded, but the reduced data set was kept in the analysis.

Second, the three replicates of each laboratory were tested for their internal consistency using Grubbs' test and then the mean values and standard deviations of each laboratory were checked in comparison to the mean values and standard deviations of other laboratories using Cochran's and Grubbs' test.

After elimination of outliers, global statistics, in particular mean values and standard deviations, were calculated and the repeatability and reproducibility statistics were determined.

In order to evaluate laboratory proficiency in the form of z-scores, as described in ISO 13528:2015, a 'true' value and standard deviation need to be assigned to each paper sample, which form the basis for the calculation of z-scores. In contrast to other studies, where the 'true' value is known or can be easily assigned, such values are not available in this study. Consequently, the 'true' mean value and standard deviation were determined as the global average and standard deviation obtained by the above outlier elimination procedure used for the determination of repeatability and reproducibility. The z-scores were then calculated for all laboratories, which reported data, irrespective of whether their results were excluded in the calculation of the global mean value and standard deviation. The z-scores are based on the originally reported data set but after elimination of individual values by Grubbs' test.

The laboratories or data points which were excluded are listed for each sample in Table 4. The outliers are coded in the following manner. LxDy means that results from laboratory x on day y were detected as outlier. The addition of "Max1", "Min1" and "Max2" for Grubbs' test indicates that the maximum, minimum or the two highest individual values were excluded from further analysis.

Outliers were found for laboratories 1, 2, 3, 4, 5, 8, 9, 15, 16, 17, 18, 19, 20.

Table 4 – Laboratories that were excluded as outliers by Cochran's test or Grubb's test based on individual values, within laboratory replicates and between laboratory mean values.

Test	A	B	C	D	E
Grubbs' Test on Individual Values	None	L17D1Max1 L19D1max1 L2D2Max1 L3D2Max1 L8D2Max1 L15D2Max1	L5D1Max1 L20D1Max1 L5D2Max1 L20D2Max1 L16D3Max1 L5D3Min1	L4D1Max1 L9D1Max1 L2D2Max1 L3D2Max1 L19D2Max1 L20D2Max1 L9D3Max1	L4D1Max1 L18D1Max1 L3D2Min1 L1D3Max1 L16D3Min1 L19D3Min1
Grubbs' Test on Replicates	None				
Grubbs' Test on Mean Values				L5Max	
Cochran's Test on Standard Deviation	None				

The remaining data sets were then used to calculate a global mean and standard deviation.

2.3 Robust Mean Values and Standard Deviations

After the removal of outliers, robust mean values and between-laboratory standard deviations were calculated using ISO 5725-2 sections 7.4.4 and 7.4.5, respectively. The results are given in Table 5. The number of laboratories is denoted by N.

Table 5 – Robust mean values (MV), between-laboratory standard deviations (SDb) and within-laboratory standard deviations (SDw)

	Air Permeability			
ID	MV	SDb	SDw	N
	CU	CU	CU	
A	65,38	3,70	1,01	16
B	60,21	1,67	0,78	21
C	9829,79	187,98	147,45	10
D	297,18	3,80	2,37	9
E	1503,48	63,54	10,19	11

2.4 Evaluation of Repeatability and Reproducibility

Based on the robust mean value and the between-laboratory and within-laboratory standard deviations, repeatability and reproducibility statistics were calculated according to ISO 5725-2. The results are given in Table 6. The table shows the standard deviation (SD), the limit and the coefficient of variation (CoV) relative to the global mean value for repeatability and reproducibility.

Table 6 – Repeatability and reproducibility statistics for air permeability

	Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV
	CU	CU	%	CU	CU	%
A	1,01	2,86	1,55	3,79	10,71	5,79
B	0,78	2,21	1,30	1,79	5,07	2,97
C	147,45	417,06	1,50	223,23	631,38	2,27
D	2,37	6,69	0,80	4,27	12,07	1,44
E	10,19	28,83	0,68	64,08	181,25	4,26

2.5 Evaluation of Laboratory Performance (z-Scores)

Based on the robust mean value and the between-laboratory standard deviation the z-scores were calculated as described in ISO 13528:2015 and are provided in Table 7. In the table the fields marked in orange are z-scores with $2<|z|<3$ and the fields marked in red are z-scores with $|z|\geq 3$. Missing z-scores indicate that the lab reported no values for this sample.

Table 7 – Z-Scores for all laboratories and samples

	Paper Sample				
Lab	**A**	**B**	**C**	**D**	**E**
1	-2,07	-0,84	-0,53	-0,50	-1,02
2	0,68	-1,17	-1,57	0,42	1,37
3	1,05	-0,54	-0,11	1,78	1,63
4	-0,08	1,04	2,20	-0,41	0,61
5		1,10	-0,67	23,62	-0,49
6		-2,02			
7	1,33	1,22	-0,63		
8	0,91	-0,13			
9		0,99		0,84	0,42
10	1,13	-0,17			
11	-1,08	-1,11			
12	-0,89	-0,94			
13	-0,81	-0,13			
14	-0,50	-0,21			
15	-0,83	-0,43			
16	-0,48	-0,14	0,40	-1,21	-0,70
17	1,03	1,09	0,55	-1,22	-0,71
18		0,11	0,29	-0,35	-1,54
19	0,66	1,02		-0,43	-0,07
20		-0,65	0,08	0,66	0,50
21	-0,05	1,93			

3. DATA INTERPRETATION

3.1 Repeatability and Reproducibility

For comparison the repeatability and reproducibility limits as a percentage relative to the mean values as obtained in the 1st Collaborative Study on Air Permeability (2019), in the 2nd Collaborative Study on Air Permeability (2021) and from this study are provided in Table 8.

Table 8 – Comparison of repeatability (r) and reproducibility (R) limits as percentage of the mean air permeability (AP) reported in the 1st Collaborative Study on Air Permeability (2019), the 2nd Collaborative Study on Air Permeability (2021) and this study.

1st Study (2019)				2nd Study (2021)			3rd Study (2023)		
ID	AP	r	R	AP	r	R	AP	r	R
	CU	%	%	CU	%	%	CU	%	%
A	70,25	4,11	8,50	65,20	4,20	12,36	65,38	4,37	16,38
B	61,16	3,11	12,55	58,80	3,79	8,59	60,21	3,68	8,41
C	9462,92	4,23	8,02	9729,67	5,11	10,47	9829,79	4,24	6,42
D	341,00	3,15	11,84	296,23	2,25	6,39	297,18	2,25	4,06
E	1399,03	1,79	9,76	1438,05	2,79	7,35	1503,48	1,92	12,06

It has to be noted that while the paper samples used in all three collaborative studies were identical with respect to the type of the paper (cigarette paper, plug wrap paper, perforated tipping paper), only the samples in the 2nd and the 3rd collaborative study were from the same production batch. Thus, a direct comparison of permeability values with the 1st collaborative study is not meaningful.

Furthermore, it has to be taken into account that the testing of air permeability as carried out in this study is considered as "destructive" so that each individual measurement has to be performed on a different area of the paper sample. Consequently, repeatability and reproducibility data include the product variability, which is likely to differ between the samples used in each study.

The repeatability and reproducibility statistics reported in ISO 2965 agree in general with the results found in the 1st, 2nd and 3rd collaborative study. Table 9 shows repeatability and reproducibility values relative to the mean value which are essentially similar to those observed in this and the previous studies, taking in account, that the samples and the participating laboratories were different.

Table 9 – Repeatability and reproducibility values as percentage of the mean air permeability (AP) as reported in Table 3 of ISO 2965:2019.

ISO 2965:2019				
Paper	Similar to ID	AP	r	R
		CU	%	%
Cigarette Paper	B	31,75	10,45	11,72
Plug Wrap Paper	C	11171,14	12,74	15,95
Tipping Paper	E	1013,90	4,38	7,20

As expected, the repeatability statistics of measurements with the 2×15 mm² measuring head (sample A) are slightly worse than those for the 10×20 mm² measuring head (sample B), which may be due to the smaller measured area. Other than in the 1st Collaborative Study on Air Permeability, the reproducibility statistics again follow the trend of the repeatability and are higher for sample A than for sample B.

The absolute difference between air permeability values obtained with the 2×15 mm² measuring head compared to the 10×20 mm² measuring head was found to be 5,27 CU for a nominal 60 CU

cigarette paper which is in good agreement with the 2nd Collaborative Study on Air Permeability where a difference of 6,40 CU was found. Even without a statistical test it is obvious that this difference of about 10 % to 15 % is not only statistically significant but also of practical relevance. Thus, laboratories should exercise great caution when comparing air permeability values obtained with different measuring heads.

For the next revision of ISO 2965, the PTM Sub-Group proposes to add repeatability and reproducibility data for the measurements with the 2×15 mm² measuring head on conventional cigarette paper and to include an appropriate note on the influence of the size of the measuring head.

3.2 Laboratory Performance

In the individual data sets 25 of 4140 (0,60 %) values have been identified as outliers, which is in good agreement with the 2nd collaborative study in which 0,65 % outliers were identified. As the number of outliers is less than 1 % and thus less than would be expected from statistical considerations there is no reason for concern. Outliers in individual data sets that were excluded were almost always high values (21 of 25 values), which may be due to larger pores that have been included in the measurement and may contribute to individual high values. This is not unusual and no particular reason for concern.

Grubbs' test between the laboratories only identified laboratory 5 as an outlier for sample D. Laboratory 5 measured a mean value of 387,02 CU while the global mean value was just 297,18 CU. Such a large deviation may be, for example, due to issues with calibration or measuring the wrong sample. It is recommended that laboratory 5 check the reason for this deviation.

No other outliers were found when comparing the laboratories to each other.

As described in ISO 13528:2015, in normal circumstances about 95 % of all z-scores will be in the range between -2 and 2. Occasionally, absolute z-scores equal to or greater than 2 may be expected at a rate of about 5 %, while absolute z-scores equal to or greater than 3 will occur only at a rate of about 0,3 %.

Thus, for absolute z-scores between 2 and 3 it is up to the laboratory to decide if these exceptional values are of importance and require any corrective action or review of the laboratory procedures. For absolute z-scores of 3 or higher it is strongly recommended that the laboratory investigates the reasons for the deviation and derives appropriate actions from these investigations.

In the present study, laboratories 1 and 6 had z-scores slightly below -2 for samples A and B, respectively, and laboratory 4 had a z-score of 2,20 for sample C.

An exceptionally high z-score of 23,62 was found for laboratory 5 for sample D. As described above there may be various reasons for this high deviation, which should be investigated. All other laboratories seemed to be able to reliably measure air permeability.

The values for lab 3 were measured at 27 °C and 65 % rH and the z-scores for all samples are not in any way unusual so that these more extreme conditions allowed in ISO 187 did not have a statistically noticeable effect on the permeability values. Even though permeability values seem to be stable over a comparably wide range of temperatures and relative humidities, these results shall not suggest that proper conditioning is not relevant. Conditioning is still important to obtain good repeatability and reproducibility.

4. REFERENCES

- ISO 2965:2019, Materials used as cigarette papers, filter plug wrap and filter joining paper, including materials having a discrete or oriented permeable zone and materials with bands of differing permeability. Determination of air permeability
- ISO 3402:2023, Tobacco and tobacco products – Atmosphere for conditioning and testing
- ISO 187:2022, Paper, board and pulps; standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples
- ISO 5725-2:2019, Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method
- ISO/IEC 17043:2023, Conformity assessment – General requirements for proficiency testing.
- ISO 13528:2022, Statistical methods for use in proficiency testing by interlaboratory comparison.
- CORESTA Technical Report PTM-065: Recommendation of Measurement Area for Air Permeability Determination of Super-Slim Cigarette Papers, CORESTA PTM Sub-Group, September 2016
- CORESTA Technical Report PTM-217: 1st Collaborative Study on Air Permeability in Accordance with ISO 2965:2019, October 2019
- CORESTA Technical Report PTM-302: 2nd Collaborative Study on Air Permeability in Accordance with ISO 2965:2019, December 2021

APPENDICES

APPENDIX A – Protocol

The protocol is reproduced in its original form. Minor typographical errors were corrected and e-mail addresses were removed.

Protocol for the 3rd Collaborative Study on Air Permeability (2021)

Note: The purpose of a Collaborative Study is to assess r&R data of a method and it can also be used by laboratories to evaluate their performance with respect to this method in comparison to other laboratories. Therefore it is important that you strictly follow ISO 2965:2019**.**

1. Preparation of Samples

1.1 Where possible, all measurements should take place in an environment according to ISO 187: testing atmosphere: (23 ± 1) °C and (50 ± 2) %rH. If this is impossible, make a note in the comments column.

1.2 You will find 5 separate samples labelled "Sample A" to "Sample E". Each sample consists of 1 sheet with 3 series of strips of paper for day 1, day 2 and day 3. Inspect prepared samples visually to avoid measurement of damaged samples.

1.3 Samples should be conditioned for 48 hours regarding to ISO 187 prior to the measurement

1.4 To avoid changes in sample moisture, samples should be transferred from the conditioning environment to the instrument in tightly closed plastic boxes.

2. Instrument Setup

2.1 Prior to a set of measurements, all instruments have to be checked and calibrated.

2.2 According to ISO 2965, calibration and instrument settings as used in your laboratory.

2.3 All specific instrument information should be recorded in the *Instrument configuration* sheet

3. Measurement Plan

3.1 Measurements on each sample (and each instrument, if applicable) should take place on 3 consecutive days (e.g. Monday to Wednesday).

3.2 On each day determine the air permeability of each of the samples from A to E by performing 20 individual measurements in your laboratory.

3.3 On each day a new series of sample strips shall be used. You have 3 series.

3.4 Never measure on the same area twice.

3.5 Visually check the samples before measurement.

3.6 Do not touch area to be measured with your bare fingers.

Example of sample A with 3 series of paper strips, 1 per day of measurement.

3.7 Samples should be as flat as possible.

3.8 Please use a new sample strip for each measurement series and realize 20 measurements per day (you have 20 strips of paper)

3.9 If you do not have a 2x15 mm head available, do not measure sample A. Measurements on sample A using a different head will be discarded.

4. Recording of Results

4.1 Please record the results using the yellow cells as defined in data collection sheets Day 1, Day 2 & Day 3.

It is not permitted to make any changes to the data recording sheets. Results, which are not reported correctly, may be disregarded in the collaborative study. For any additional information or remarks please use the comments column. You can also add additional spreadsheets.

E-Mail completed spreadsheets (as Excel file) to:

Bernhard Eitzinger

Philippe Le Men

Results must be submitted until September 11th, 2023.

APPENDIX B – Data Summary

Appendix B.1: Mean values of air permeability over all laboratories and days, outliers included. The mean value is given in CU.

	Day 1					Day 2					Day 3				
Lab	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	58,9	57,7	9633,7	297,5	1451,1	57,9	59,5	9710,6	293,0	1434,0	56,5	59,2	9848,7	295,4	1437,9
2	69,1	59,1	9525,3	300,8	1585,9	67,4	59,0	9513,5	297,1	1607,8	67,2	57,1	9562,7	299,5	1577,8
3	70,4	59,2	9766,8	306,5	1596,5	69,3	60,0	9698,7	303,5	1616,0	68,0	59,2	9961,8	303,0	1605,0
4	64,5	63,3	10217,6	296,5	1539,0	65,8	61,1	10509,5	295,6	1542,8	65,0	61,4	10003,3	296,0	1552,0
5		62,2	9654,3	386,1	1475,5		62,2	9865,7	386,3	1478,3		61,7	9732,0	388,7	1463,7
6		57,1					56,6					56,8			
7	70,8	62,2	9808,2			70,1	62,5	9747,3			70,0	62,0	9579,1		
8	67,2	61,4				70,2	59,5				68,8	59,5			
9		61,5		300,5	1534,5		62,2		300,9	1530,5		61,9		301,6	1526,0
10	70,1	59,5				69,6	59,4				69,0	60,9			
11	60,7	58,7				61,8	58,5				61,6	57,8			
12	63,0	59,7				61,4	58,1				61,9	58,2			
13	63,0	60,6				62,4	60,0				61,8	59,4			
14	63,7	60,0				63,4	59,5				63,5	60,0			
15	63,2	58,7				62,0	60,2				61,8	60,2			
16	62,1	59,6	9805,3	287,6	1445,4	64,8	60,1	9971,0	294,1	1463,5	63,9	60,2	9998,8	296,1	1462,0
17	70,6	61,3	9786,1	293,3	1465,7	69,0	61,9	9839,8	290,8	1440,9	68,0	63,3	10171,6	293,5	1468,2
18		60,3	9918,8	295,0	1409,8		60,4	9903,6	295,3	1402,7		60,5	9828,5	297,3	1407,0
19	69,8	63,3		295,8	1493,4	66,5	61,5		297,0	1500,4	67,0	61,4		294,9	1498,3
20		59,1	9721,1	303,1	1526,2		59,3	9891,1	298,3	1538,8		58,8	10053,7	298,6	1540,3
21	65,8	65,2				65,0	63,1				64,7	62,0			

Appendix B.2: Standard deviations of air permeability over all laboratories and days, outliers included. The standard deviation is given in CU.

	Day 1					Day 2					Day 3				
Lab	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	3,31	3,00	613,36	5,87	42,25	3,27	3,66	610,82	5,61	49,89	3,11	3,61	498,05	6,41	45,41
2	4,16	3,52	568,88	6,76	41,18	4,16	3,26	609,03	7,29	44,57	3,12	2,88	540,47	7,52	36,60
3	4,78	3,47	739,70	7,81	41,44	5,28	3,31	675,77	8,34	25,67	5,39	3,72	506,71	7,57	32,60
4	6,30	4,11	791,45	8,96	45,87	6,30	3,43	886,24	5,98	25,11	6,00	2,61	442,96	6,70	42,01
5		4,87	598,63	7,01	41,57		4,59	802,78	6,77	36,21		4,01	387,43	8,06	26,86
6		1,47					1,57					1,55			
7	4,32	2,83	463,67			4,49	3,79	608,52			5,11	3,24	664,09		
8	5,68	4,33				4,82	3,05				4,76	2,86			
9		3,03		6,97	15,18		1,74		6,35	14,12		2,91		10,13	16,91
10	5,08	3,28				4,66	2,90				4,44	1,42			
11	2,99	2,99				2,98	2,84				3,62	3,65			
12	4,44	4,49				2,94	2,94				4,33	4,25			
13	3,98	3,98				2,91	2,91				3,50	3,50			
14	3,31	3,20				4,21	3,83				3,47	2,50			
15	3,07	3,11				4,27	3,68				3,11	2,96			
16	3,33	2,70	705,37	7,64	36,21	3,34	2,41	545,39	6,75	42,05	3,17	2,18	446,07	9,51	48,57
17	4,04	3,05	691,77	6,03	34,42	7,55	2,85	805,00	7,84	41,67	4,33	3,33	706,99	7,26	41,59
18		2,72	200,98	9,03	23,65		3,00	203,81	9,67	30,86		2,19	629,91	9,10	17,04
19	4,74	2,99		8,93	35,24	3,48	3,15		7,10	23,58	4,85	3,36		7,46	33,76
20		3,83	505,07	6,07	43,68		2,90	441,72	5,87	40,99		3,08	607,29	8,23	35,18
21	3,06	3,95				2,37	2,65				3,09	2,94			

Appendix B.3: Mean values of air permeability over all laboratories and days, outliers according to Grubbs' test on individual values excluded. The mean value is given in CU. Highlighted values have changed due to outlier elimination.

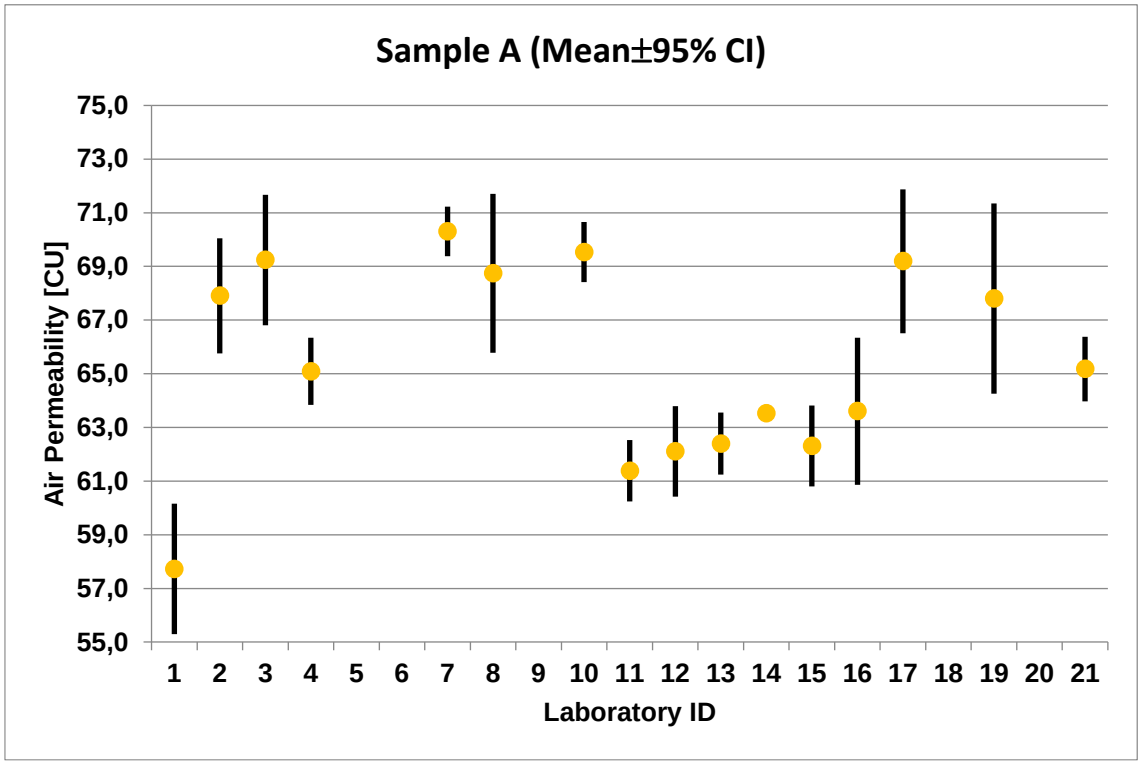
	Day 1					Day 2					Day 3				
Lab	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	58,9	57,8	9633,7	297,5	1451,1	57,9	59,5	9710,6	293,0	1434,0	56,5	59,2	9848,7	295,4	1430,5
2	69,1	59,1	9525,3	300,8	1585,9	67,4	58,5	9513,5	296,1	1607,8	67,2	57,1	9562,7	299,5	1577,8
3	70,4	59,2	9766,8	306,5	1596,5	69,3	59,5	9698,7	302,3	1619,5	68,0	59,2	9961,8	303,0	1605,0
4	64,5	63,3	10217,6	295,3	1532,6	65,8	61,1	10509,5	295,6	1542,8	65,0	61,4	10003,3	296,0	1552,0
5		62,2	9570,1	386,1	1475,5		62,2	9754,3	386,3	1478,3		61,7	9786,7	388,7	1463,7
6		57,1					56,6					56,8			
7	70,8	62,2	9808,2			70,1	62,5	9747,3			70,0	62,0	9579,1		
8	67,2	61,4				70,2	59,1				68,8	59,5			
9		61,5		299,5	1534,5		62,2		300,0	1530,5		61,9		301,6	1526,0
10	70,1	59,5				69,6	59,4				69,0	60,9			
11	60,7	58,7				61,8	58,5				61,6	57,8			
12	63,0	59,7				61,4	58,1				61,9	58,2			
13	63,0	60,6				62,4	60,0				61,8	59,4			
14	63,7	60,0				63,4	59,5				63,5	60,0			
15	63,2	58,7				62,0	59,6				61,8	60,2			
16	62,1	59,6	9805,3	287,6	1445,4	64,8	60,1	9971,0	294,1	1463,5	63,9	60,2	9937,8	296,1	1469,0
17	70,6	60,9	9786,1	293,3	1465,7	69,0	61,9	9839,8	290,8	1440,9	68,0	63,3	10171,6	293,5	1468,2
18		60,3	9918,8	295,0	1406,5		60,4	9903,6	295,3	1402,7		60,5	9828,5	297,3	1407,0
19	69,8	62,8		295,8	1493,4	66,5	61,5		296,0	1500,4	67,0	61,4		294,9	1502,7
20		59,2	9653,2	303,1	1526,2		59,3	9826,4	297,4	1538,8		58,8	10053,7	298,6	1541,1
21	65,8	65,2				65,0	63,1				64,7	62,0			

Appendix B.4: Standard deviation of air permeability over all laboratories and days, outliers according to Grubbs' test on individual values excluded. The standard deviation is given in CU. Highlighted values have changed due to outlier elimination.

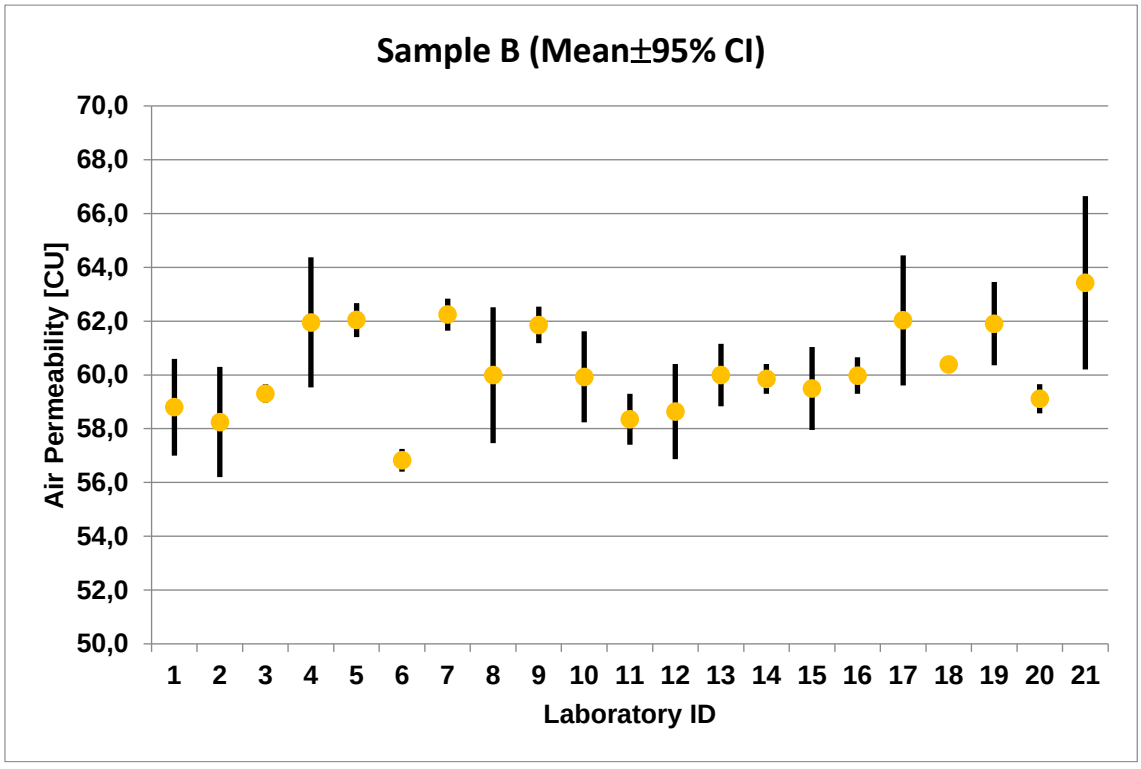
	Day 1					Day 2					Day 3				
Lab	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	3,31	3,06	613,36	5,87	42,25	3,27	3,66	610,82	5,61	49,89	3,11	3,61	498,05	6,41	31,85
2	4,16	3,52	568,88	6,76	41,18	4,16	2,35	609,03	5,90	44,57	3,12	2,88	540,47	7,52	36,60
3	4,78	3,47	739,70	7,81	41,44	5,28	2,68	675,77	6,57	20,89	5,39	3,72	506,71	7,57	32,60
4	6,30	4,11	791,45	7,47	36,95	6,30	3,43	886,24	5,98	25,11	6,00	2,61	442,96	6,70	42,01
5		4,87	478,13	7,01	41,57		4,59	646,80	6,77	36,21		4,01	308,52	8,06	26,86
6		1,47					1,57					1,55			
7	4,32	2,83	463,67			4,49	3,79	608,52			5,11	3,24	664,09		
8	5,68	4,33				4,82	2,45				4,76	2,86			
9		3,03		5,34	15,18		1,74		5,03	14,12		2,91		10,13	16,91
10	5,08	3,28				4,66	2,90				4,44	1,42			
11	2,99	2,99				2,98	2,84				3,62	3,65			
12	4,44	4,49				2,94	2,94				4,33	4,25			
13	3,98	3,98				2,91	2,91				3,50	3,50			
14	3,31	3,20				4,21	3,83				3,47	2,50			
15	3,07	3,11				4,27	2,92				3,11	2,96			
16	3,33	2,70	705,37	7,64	36,21	3,34	2,41	545,39	6,75	42,05	3,17	2,18	362,56	9,51	37,96
17	4,04	2,46	691,77	6,03	34,42	7,55	2,85	805,00	7,84	41,67	4,33	3,33	706,99	7,26	41,59
18		2,72	200,98	9,03	19,09		3,00	203,81	9,67	30,86		2,19	629,91	9,10	17,04
19	4,74	2,21		8,93	35,24	3,48	3,15		5,69	23,58	4,85	3,36		7,46	28,06
20		3,89	414,87	6,07	43,68		2,90	343,07	4,68	40,99		3,08	607,29	8,23	35,98
21	3,06	3,95				2,37	2,65				3,09	2,94			

APPENDIX C – Diagrams

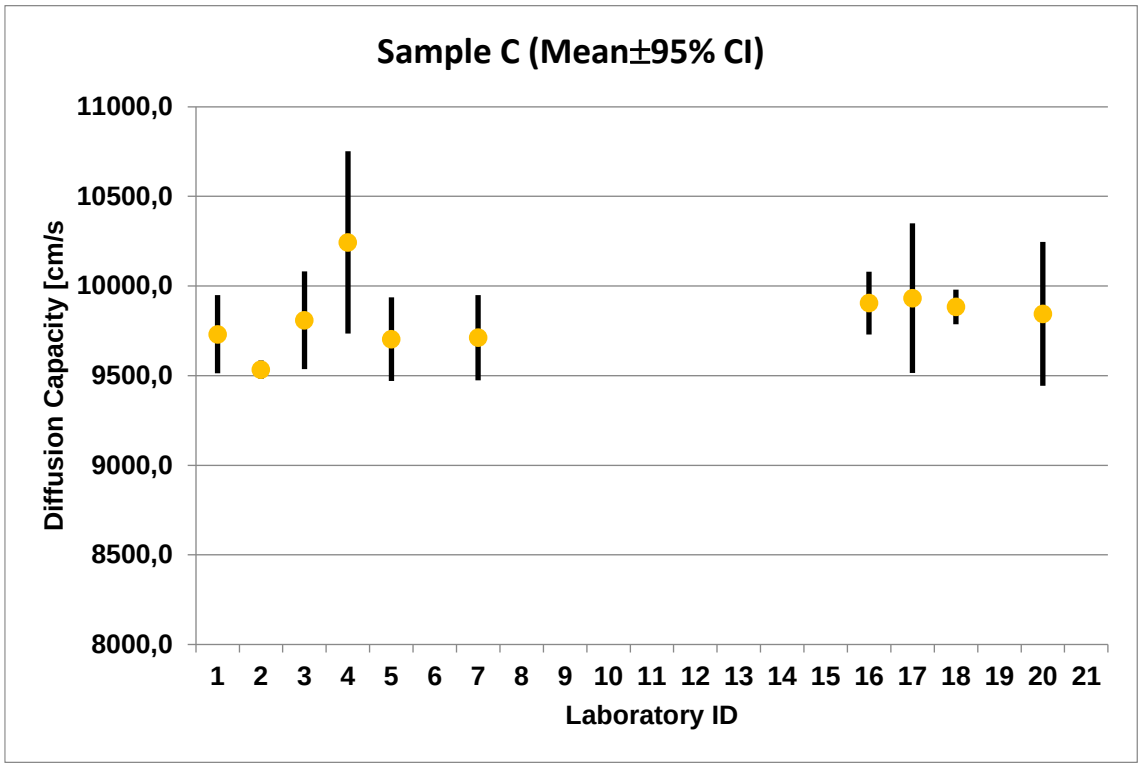
Appendix C.1: Mean value and confidence interval for air permeability over all laboratories for Sample A (cigarette paper).



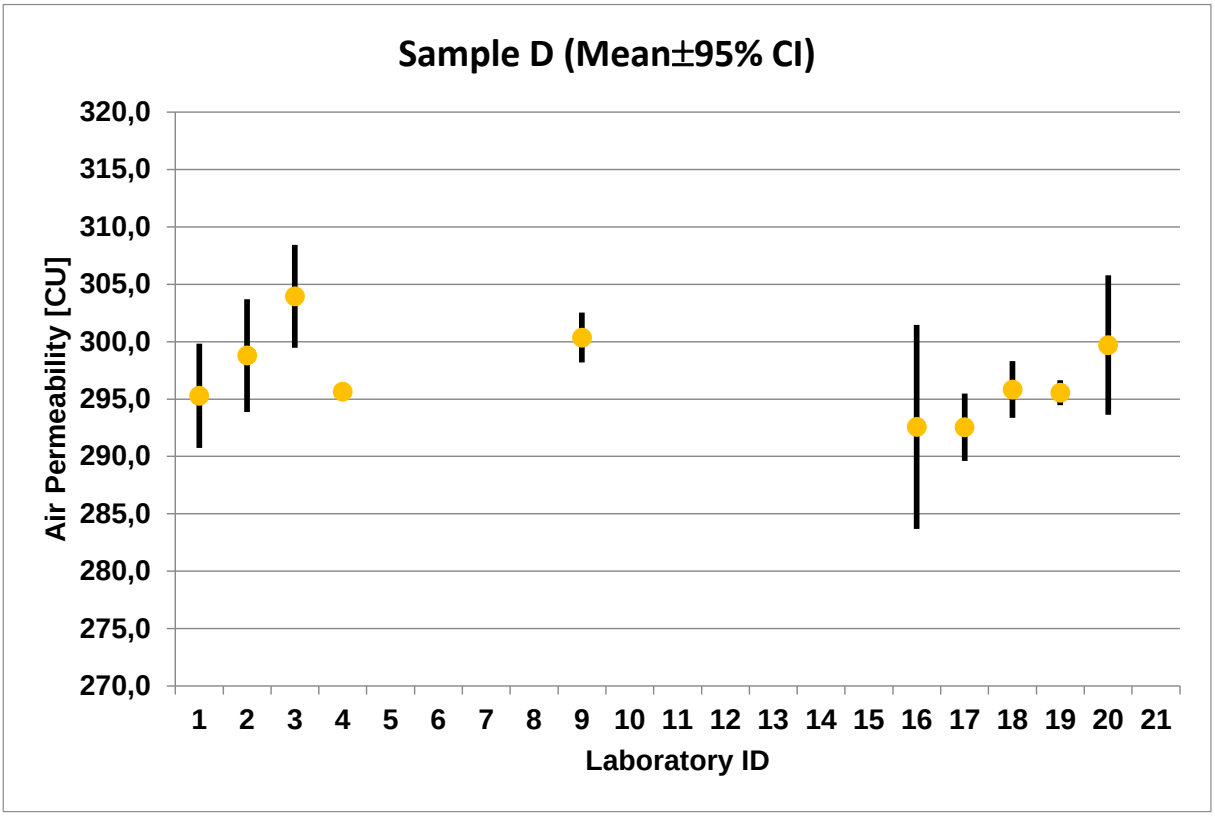
Appendix C.2: Mean value and confidence interval for air permeability over all laboratories for Sample B (cigarette paper).



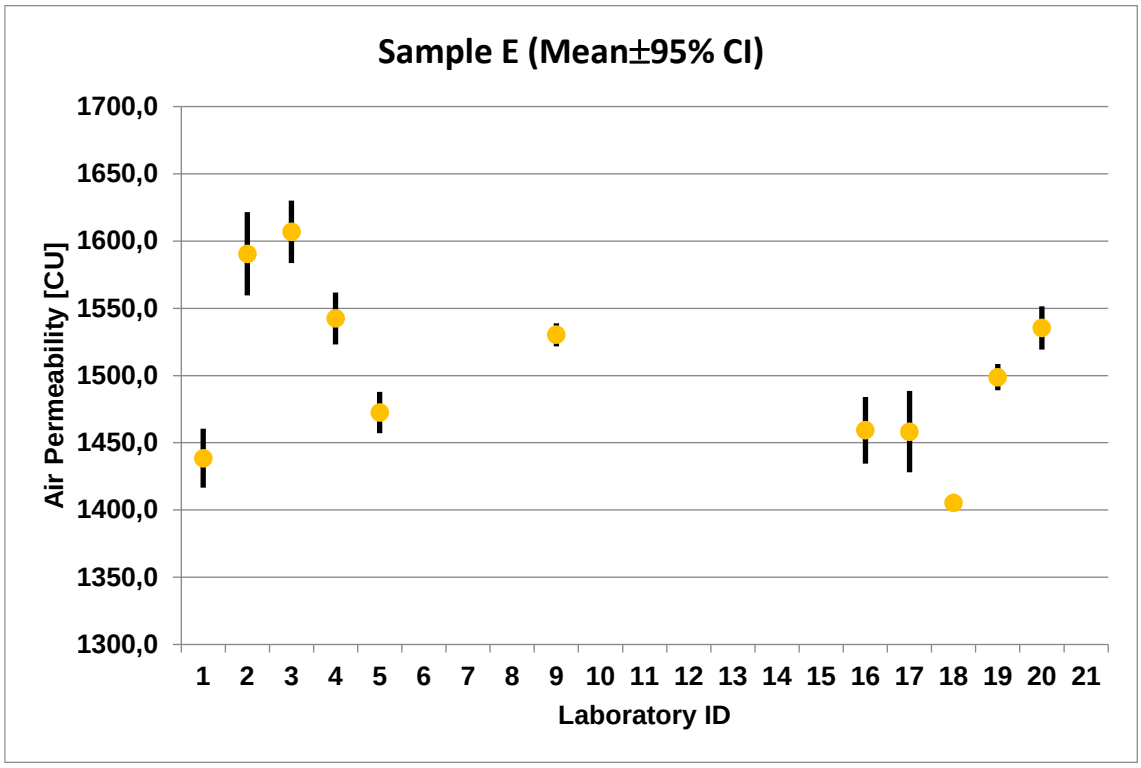
Appendix C.3: Mean value and confidence interval for air permeability over all laboratories for Sample C (plug wrap paper).



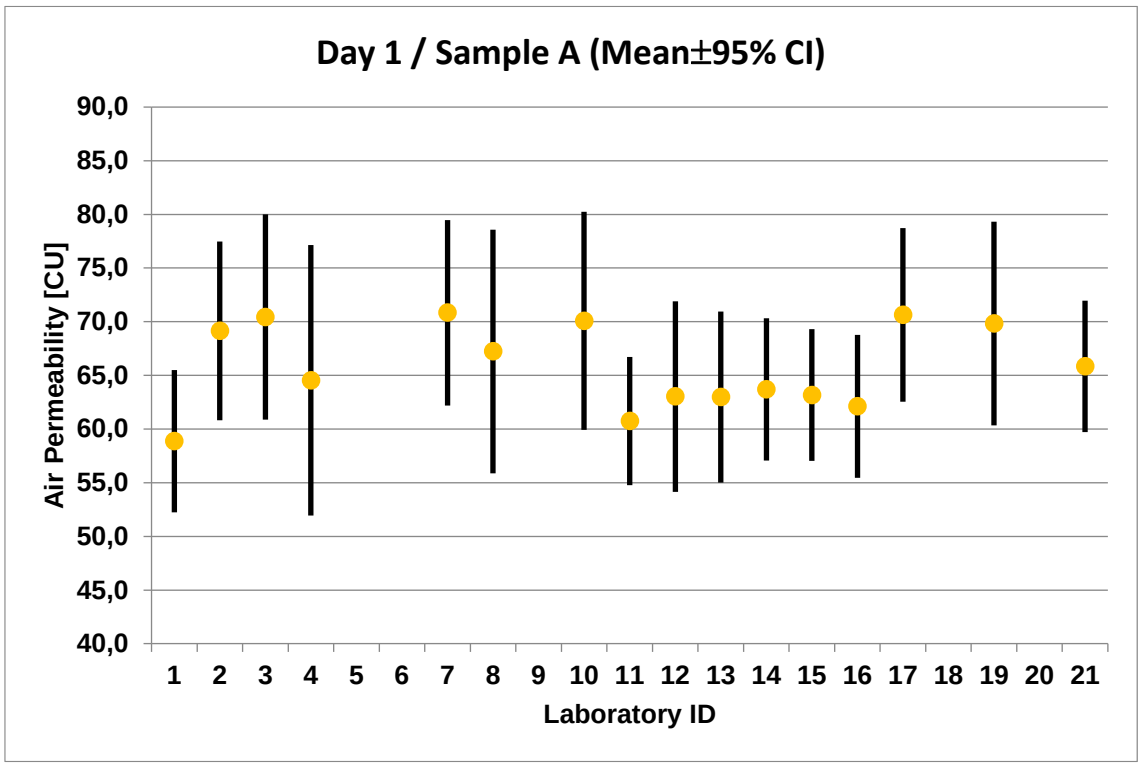
Appendix C.4: Mean value and confidence interval for air permeability over all laboratories for Sample D (tipping paper). Values of lab 5 are too high to be shown.



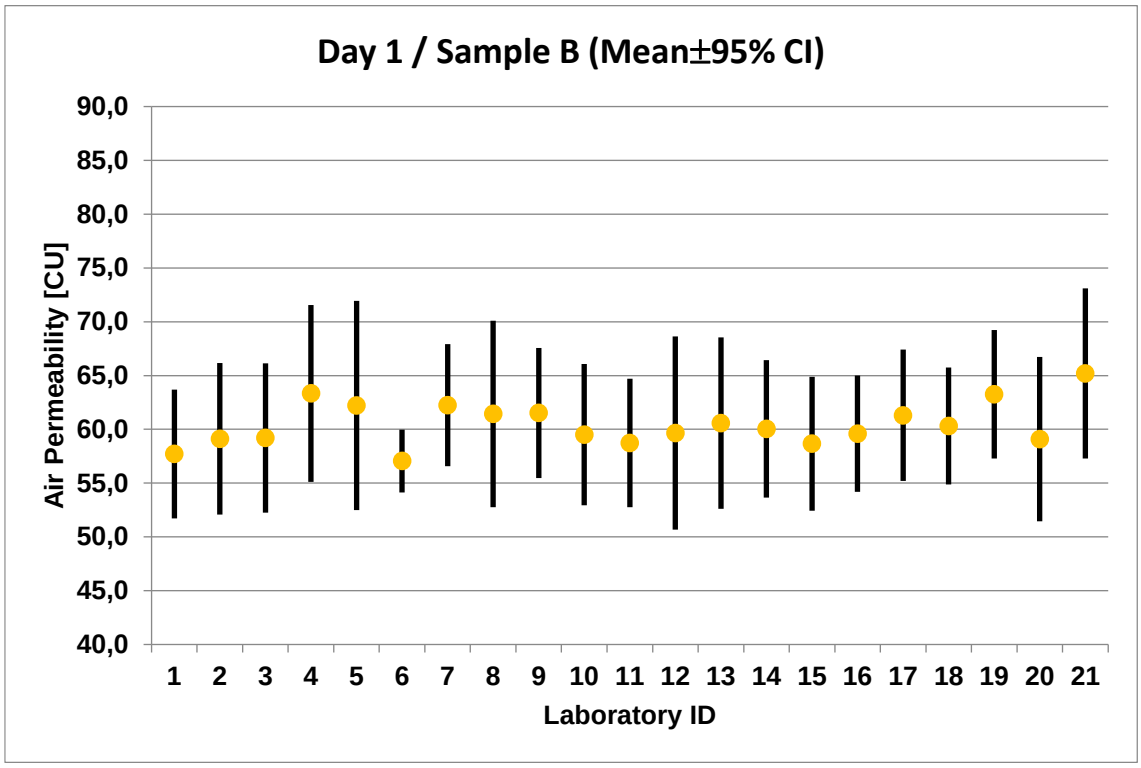
Appendix C.5: Mean value and confidence interval for air permeability over all laboratories for Sample E (tipping paper).



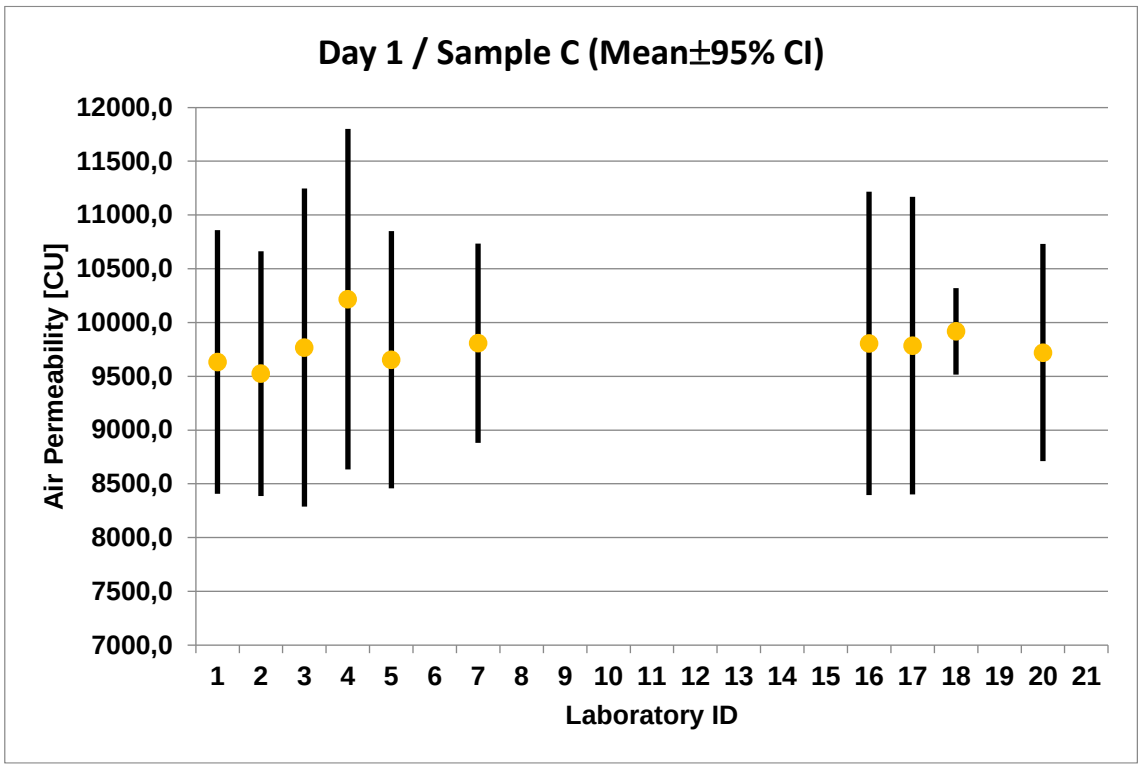
Appendix C.6: Mean value and confidence interval for air permeability over all laboratories for Sample A (cigarette paper) for Day 1.



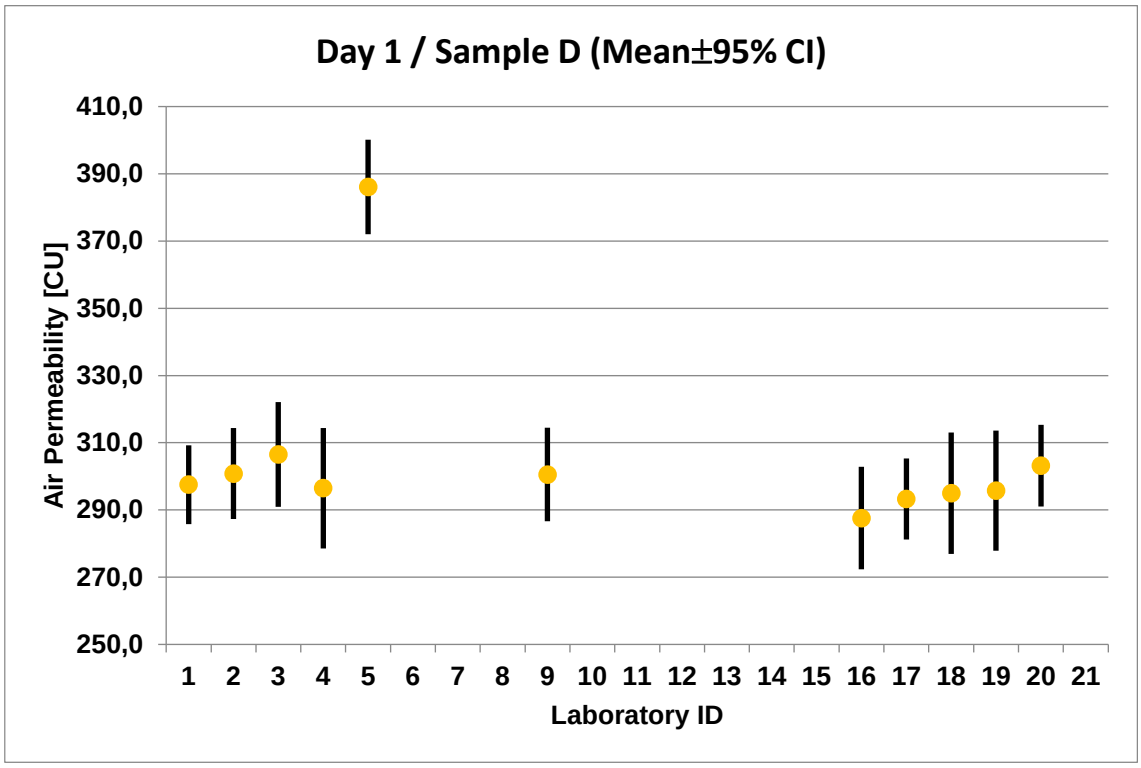
Appendix C.7: Mean value and confidence interval for air permeability over all laboratories for Sample B (cigarette paper) for Day 1.



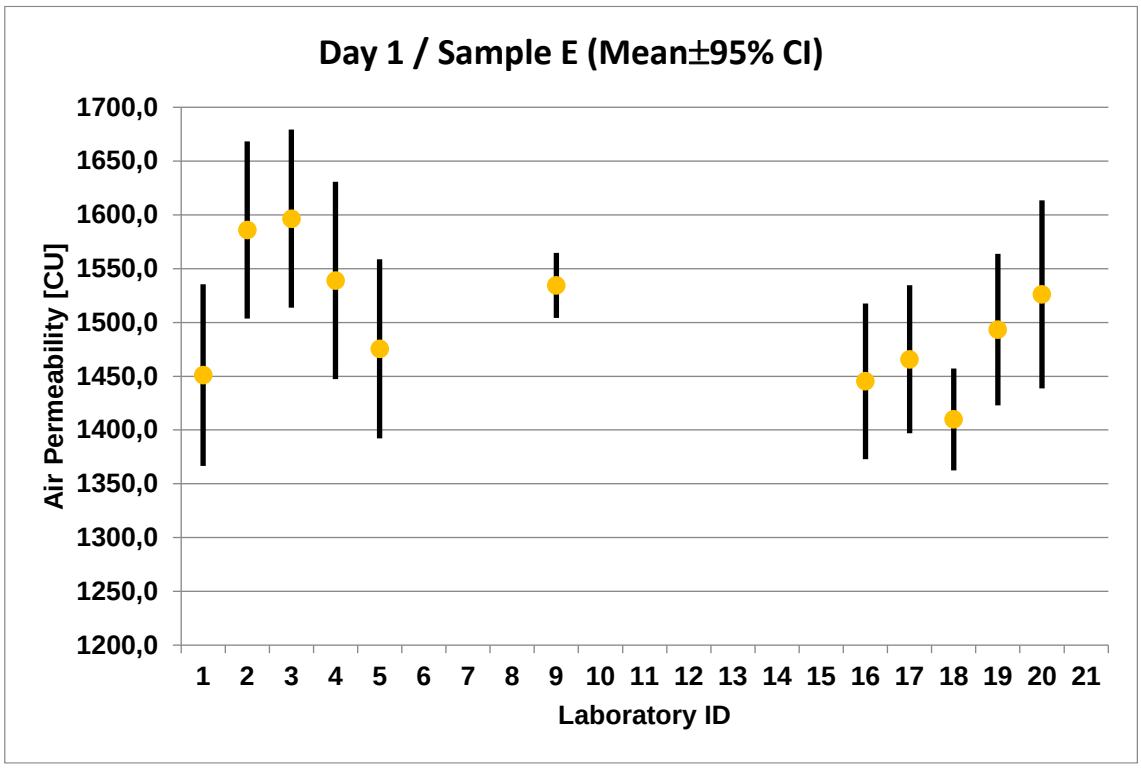
Appendix C.8: Mean value and confidence interval for air permeability over all laboratories for Sample C (plug wrap paper) for Day 1.



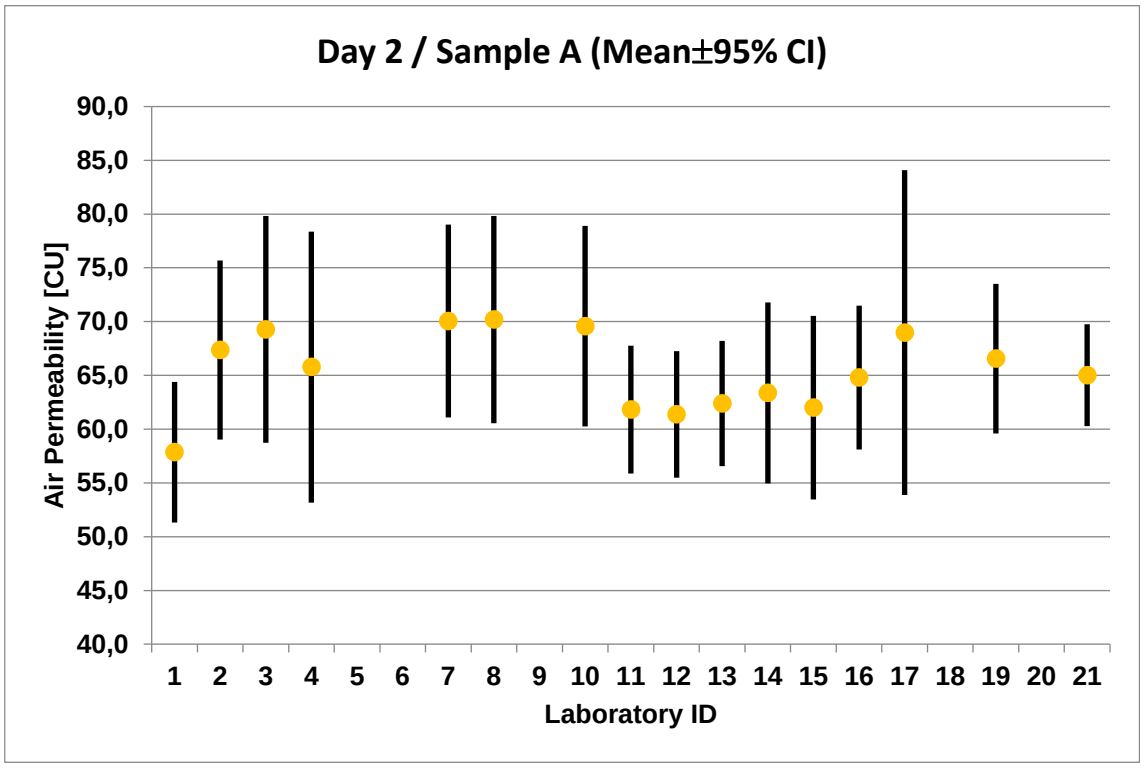
Appendix C.9: Mean value and confidence interval for air permeability over all laboratories for Sample D (tipping paper) for Day 1.



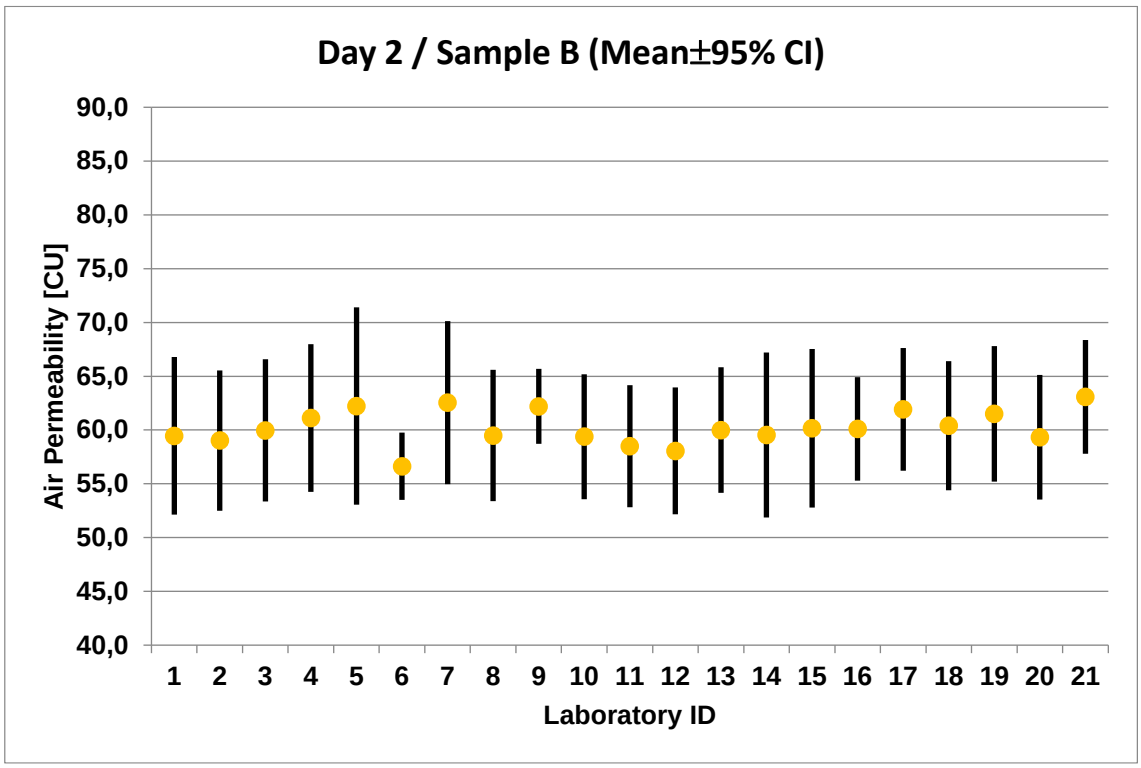
Appendix C.10: Mean value and confidence interval for air permeability over all laboratories for Sample E (tipping paper) for Day 1.



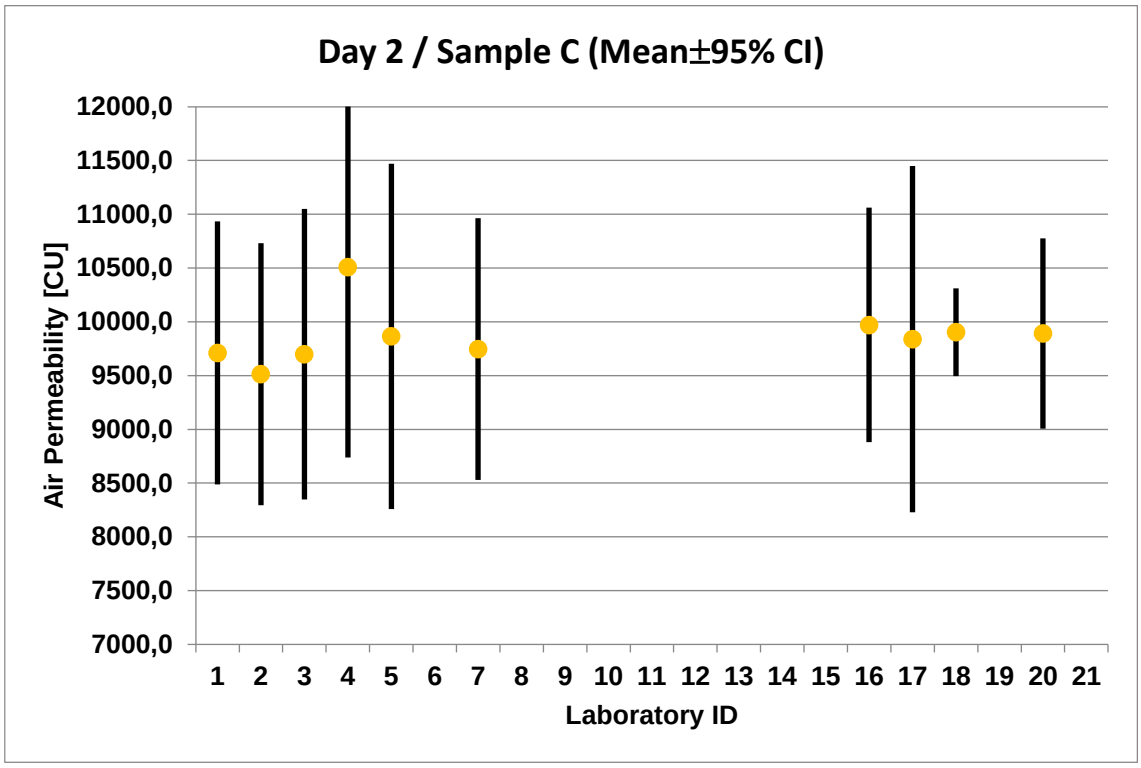
Appendix C.11: Mean value and confidence interval for air permeability over all laboratories for Sample A (cigarette paper) for Day 2.



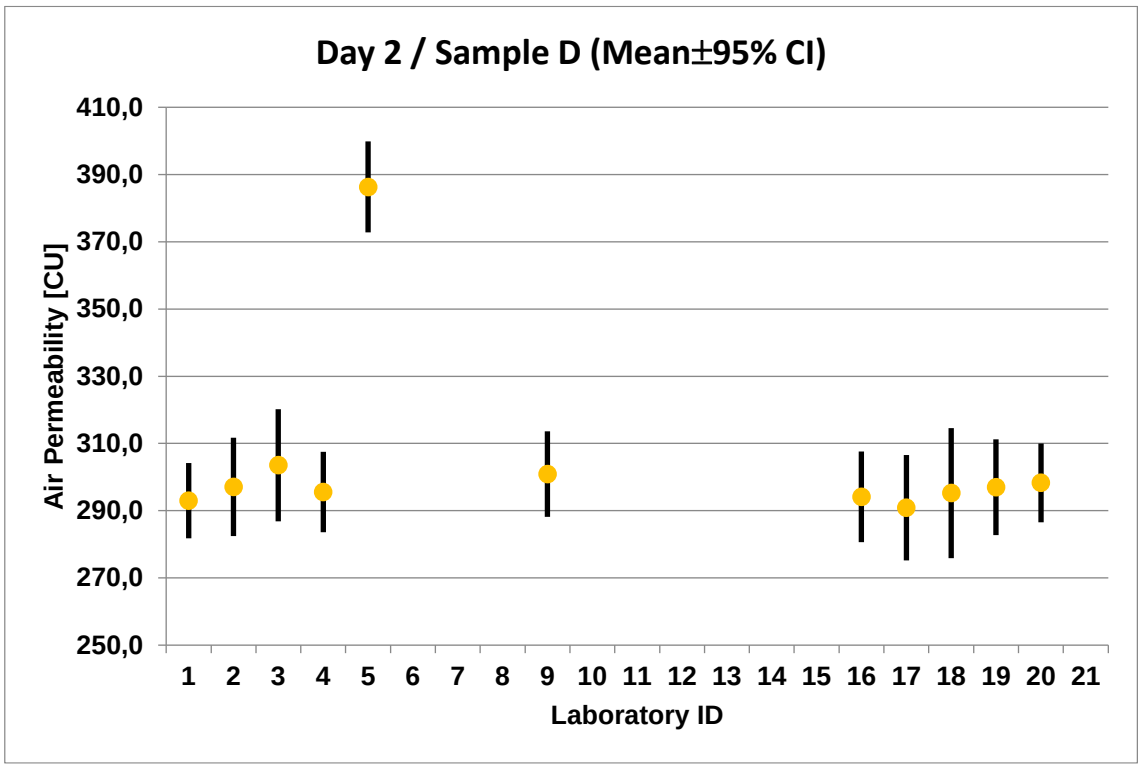
Appendix C.12: Mean value and confidence interval for air permeability over all laboratories for Sample B (cigarette paper) for Day 2.



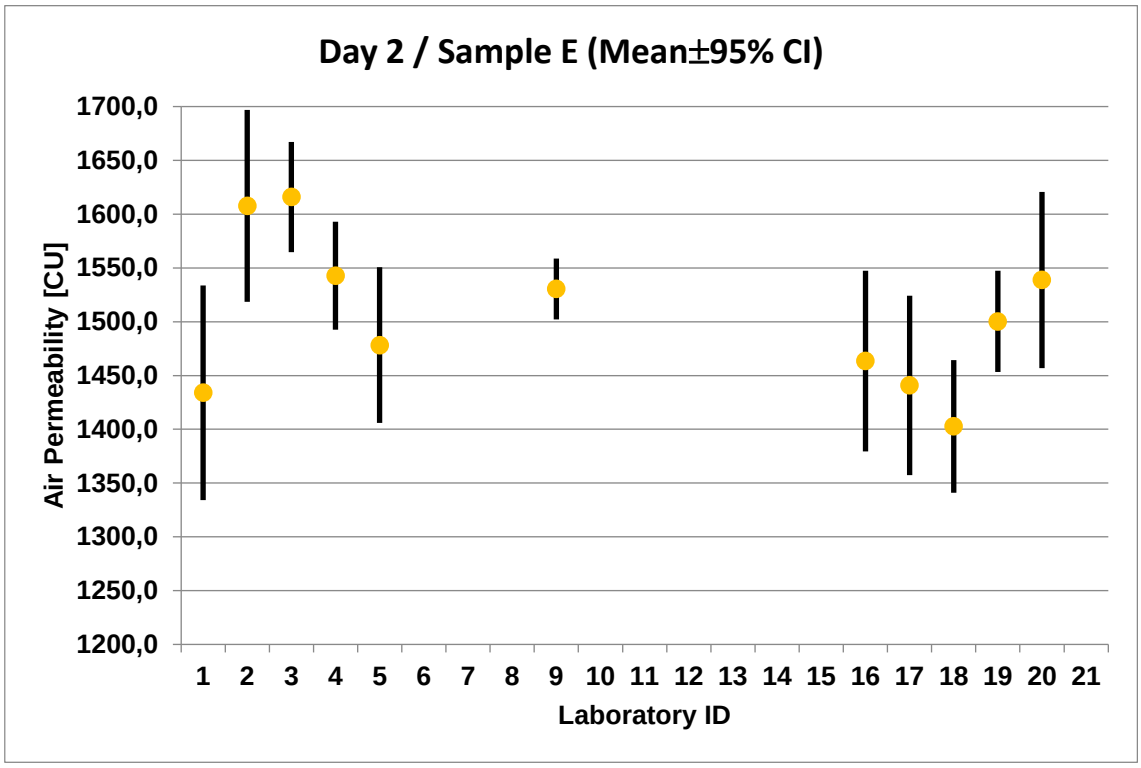
Appendix C.13: Mean value and confidence interval for air permeability over all laboratories for Sample C (plug wrap paper) for Day 2.



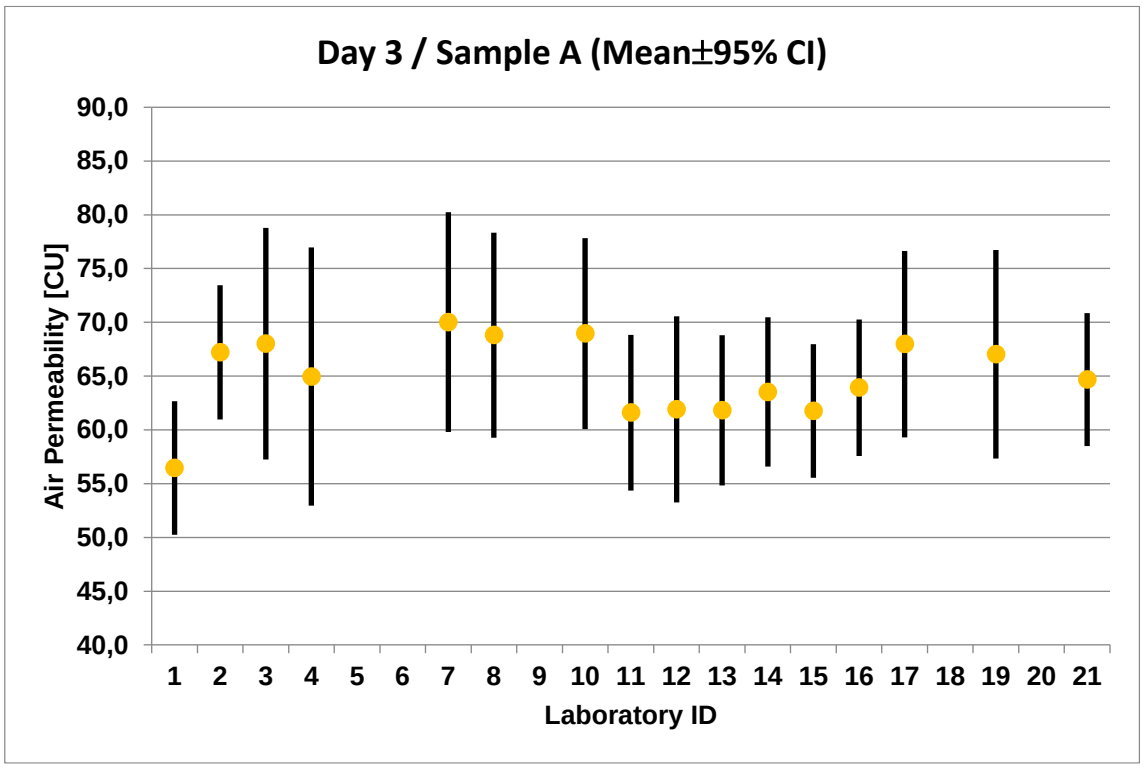
Appendix C.14: Mean value and confidence interval for air permeability over all laboratories for Sample D (tipping paper) for Day 2.



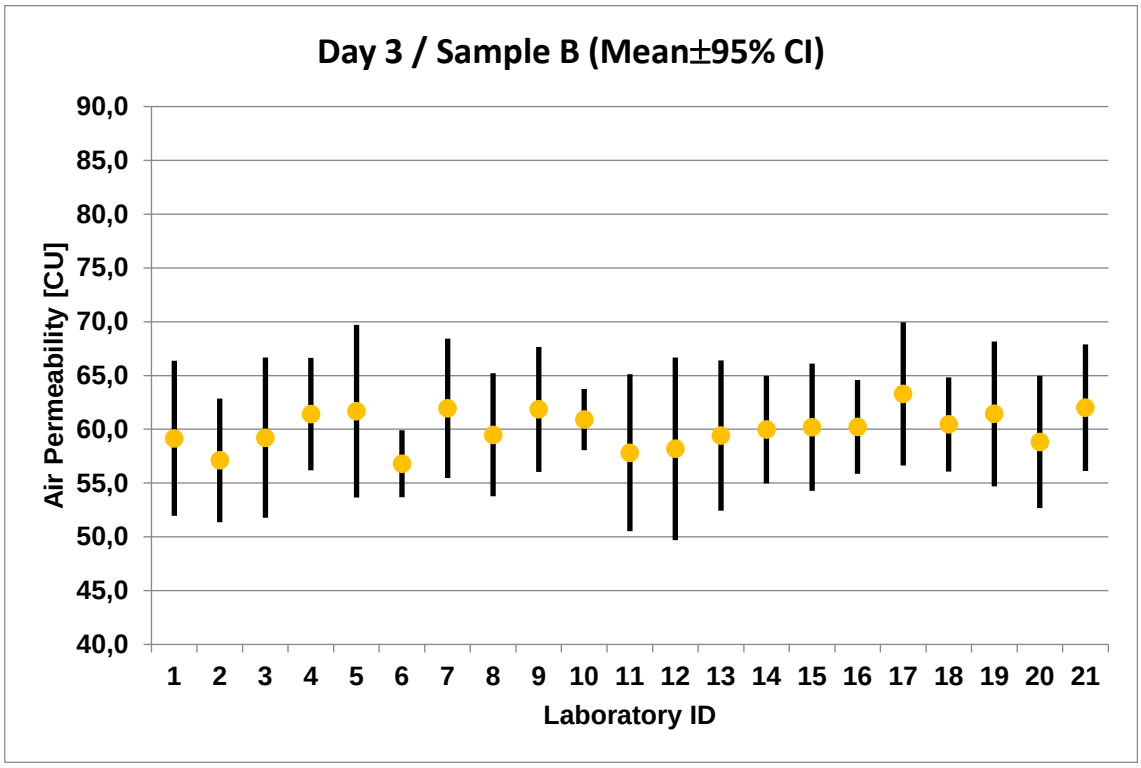
Appendix C.15: Mean value and confidence interval for air permeability over all laboratories for Sample E (tipping paper) for Day 2.



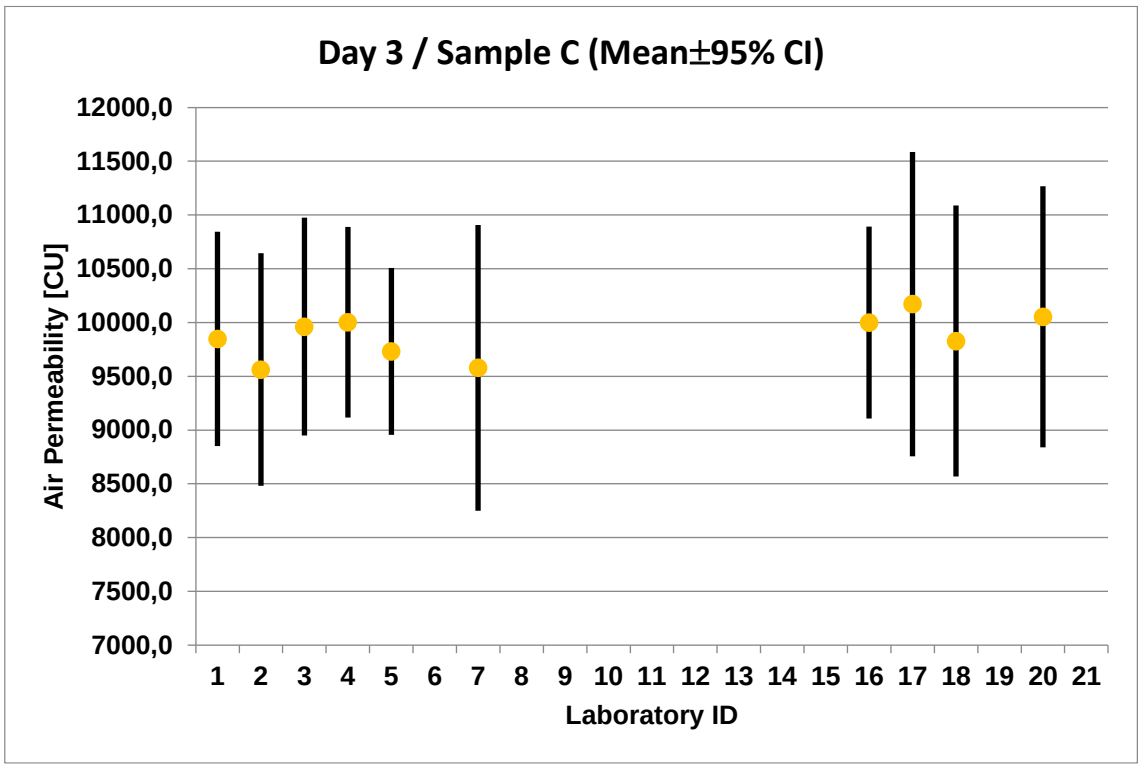
Appendix C.16: Mean value and confidence interval for air permeability over all laboratories for Sample A (cigarette paper) for Day 3.



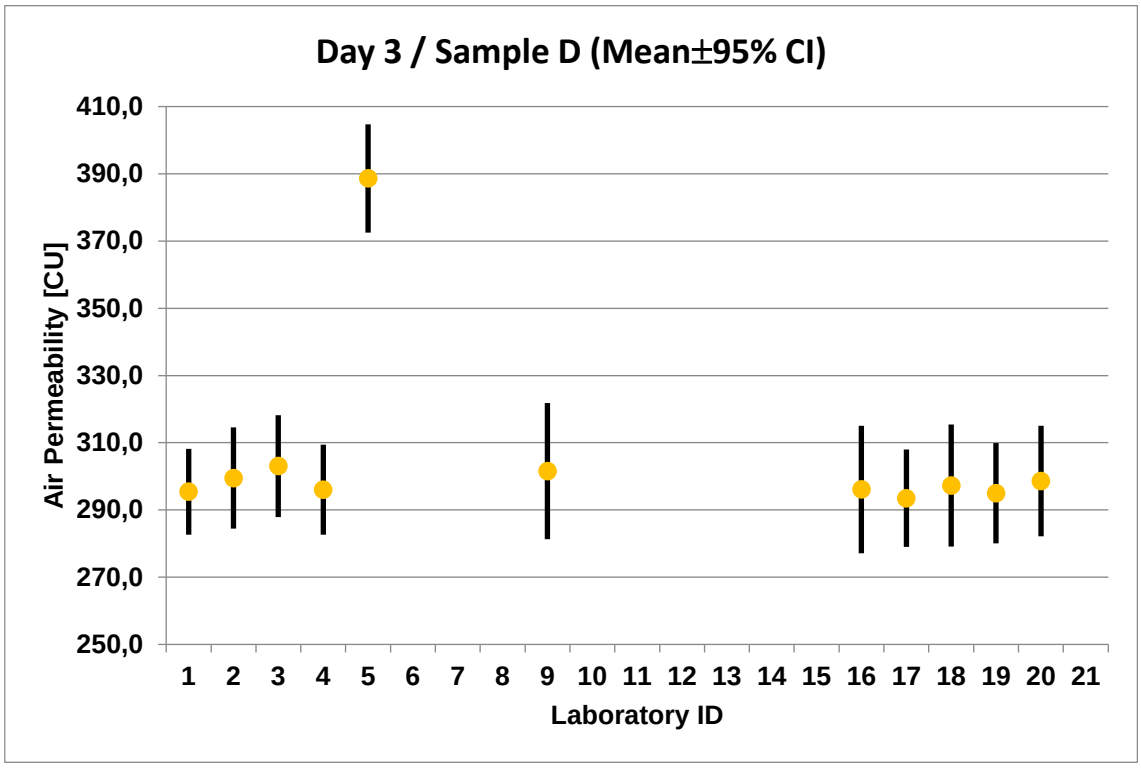
Appendix C.17: Mean value and confidence interval for air permeability over all laboratories for Sample B (cigarette paper) for Day 3.



Appendix C.18: Mean value and confidence interval for air permeability over all laboratories for Sample C (plug wrap paper) for Day 3.



Appendix C.19: Mean value and confidence interval for air permeability over all laboratories for Sample D (tipping paper) for Day 3.



Appendix C.20: Mean value and confidence interval for air permeability over all laboratories for Sample E (tipping paper) for Day 3.