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EFFICIENCY OF MULTI-USE MICRO FIBRE FLAT MOPS VERSUS DISPOSABLE MICRO FIBRE FLAT MOPS

Comparative research study into cleaning action, cleaning exertion, dirt-binding capacity, and hygienic action

PUBLICATION

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Comparative research study into cleaning action, cleaning exertion, dirt-binding capacity, and hygienic action

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SUMMARY

Micro fibre materials are commonly used in institutional cleaning [1]. In the past the Cleaning Research Foundation (VSR) has commissioned research studies into the effectiveness and application properties of modern micro fibre flat mops [4, 5]. The most recent research study into micro fibre flat mops determined optimum moisture content [5].

Following the dramatic rise in micro fibre flat mop usage, disposable micro fibre flat mops have also been launched onto the marketplace.

A number of benefits of disposable micro fibre flat mops are self-evident. For example, after use the disposable micro fibre flat mop is removed and the logistics system for transporting and cleaning the used micro fibre flat mops becomes superfluous. Moreover, the hygienic risk is reduced. Simultaneously, it must be noted that the use of disposable material results in increased quantities of waste at the cleaning location, which in turn necessitates additional waste removal.

The purpose of this research study, commissioned by the Cleaning Research Foundation, is to research the effectiveness and application properties of disposable micro fibre flat mops as opposed to multi-use micro fibre flat mops.

During the research study four different multi-use micro fibre flat mops and four disposable micro fibre flat mops for floors were researched and compared on a number of key application properties, namely, the cleaning action, cleaning exertion, hygienic action and dirt-binding capacity. In this comparison the influence of process conditions such as cleaning pressure, floor material and dirt type on these application properties was assessed.

When carrying out this research study the aim was to execute the tests with as much practical relevance as possible. In a former pre-research study practical values were determined for cleaning pressure and wiping movement speed. For the cleaning pressure a value was determined for normal/light cleaning, normal/intensive cleaning and thorough/localised cleaning. The tests were carried out on a linoleum, vinyl and Ultragres tile floor.

Cleaning action

The research study into the cleaning action measures two relevant aspects; cleaning speed and cleanliness. In order to measure these variables, cleaning tests are undertaken using a cleaning robot.

Various dirt stains (chocolate milk, street sweepings and sebaceous matter) are applied to linoleum, vinyl and tiles (Ultragres). Having aged, these stains are then removed by a cleaning

robot under a cleaning pressure for thorough localised cleaning by the various flat mops. The flat mops are dampened with a cleaning detergent. The number of wiping movements required to remove a stain are recorded as measure of the cleaning speed. The result (score) of a visual assessment of the dry, cleaned surface is a measure of cleanliness.

A variance analysis of the complete data set demonstrates that with regard to cleaning speed and cleanliness, there are differences between the flat mops.

When cleaning the **chocolate milk stains**, on average, the multi-use flat mops perform better in terms of cleaning speed and cleanliness than the disposable flat mops. The associated differences between the multi-use flat mops for both cleaning speed and cleanliness are minimal and insignificant. With the removal of this dirt type the associated differences with the disposable flat mops are considerably greater than with the multi-use flat mops; this applies to cleaning speed and the cleanliness. In nigh on all test situations one of the disposable flat mops scores poorer than the other flat mops; whilst a different disposable flat mop scores on the same level as the multi-use flat mops.

With **street sweepings** and cleanliness it concerns significant differences within the disposable flat mop and multi-use flat mop groups. Within its group, multi-use flat mops do not vary significantly in terms of cleaning speed. Taken on average, the multi-use flat mops perform better with street sweepings on cleaning speed and cleanliness than the disposable mops.

With **sebaceous matter** it concerns significant associated differences within the disposable flat mop group and multi-use flat mop groups; this applies both in terms of cleaning speed and cleanliness. Taken on average, the multi-use flat mops perform better with sebaceous matter on cleaning speed and cleanliness than the disposable mops.

Note: Although the multi-use flat mop group scored higher in terms of cleaning action with the different dirt types and test floors than the disposable flat mops, the results also show that a disposable flat mop isn't by definition under par to a multi-use flat mop.

Frictional exertion

The frictional resistance is a measure for the effort that a cleaner has to put in when flat mopping. The frictional resistance is measured by the cleaning robot with vertical cleaning pressures that are representative of normal/light cleaning, normal/intensive cleaning and thorough/localised cleaning. Measurements are taken on linoleum.

The associated frictional resistance of the flat mops differs significantly. The highest cleaning resistances are measured with the disposable flat mops and the lowest with the multi-use. The highest cleaning resistance (disposable) is 70% higher than the lowest (multi-use).

Frictional resistance is significantly related to cleaning pressure; a higher cleaning pressure yields a higher frictional resistance. Broadly speaking, it can be assumed that double the cleaning pressure results in a frictional resistance that is similarly, twice as high.

Dirt-binding capacity

The dirt-binding capacity is a flat mop's attribute of retaining removed dirt. In a simulated practise test it is investigated to which degree a floor is clean after cleaning a set number of m^2 with a flat mop. On a (16 m^2) floor subdivided into 16 black and white squares a defined amount of dust is applied per m^2. The floor is then cleaned with one of the flat mop systems (flat mop with corresponding handle) and then visually assessed for dirtiness. A score is allocated per m^2 that comprises a measure for dirtiness (0=clean, 16=dirty).

The dirtiness of three of the multi-use flat mops increases barely, if not at all, during the cleaning of the 16 m^2; from the first to the last m^2 the scores do not exceed a score of 2. In the case of one of the multi-use flat mops the dirtiness increases (score 4). One possible explanation is that the flat mop insufficiently binds the dirt and during cleaning continues to spread the dirt rather than absorbing it.

A comparable effect is seen with three of the disposable flat mops. The dirtiness of these flat mops however is considerably higher and increases faster than with all the multi-use flat mops. One of the disposable flat mops has a dirt-binding capacity that does not deviate from the multi-use flat mops.

Hygienic effectiveness
To measure hygienic action the laboratory researched how many germs are left behind by the flat mops after cleaning on a pre-contaminated floor surface. A test piece of linoleum floor is added, contaminated with micro-organisms within an organic dirt matrix. The floor surfaces, barring the control surfaces, are for measuring the initial contamination, which are then cleaned by the cleaning robot using the various flat mops. After cleaning the amount of residual germs on the cleaned surfaces is determined.

With one exception, all in all the flat mops remove a stain with a substantial amount of the germs present within it. The log reduction runs from 2.0 to 2.7. This concurs with a removal of 99.0 to 99.8 % of the present germs. The germ reduction of one of the disposable flat mops is very minimal and doesn't significantly deviate from 0. No systematic difference was found between the multi-use and disposable flat mops.

CONTENT

CHAPTER 1 INTRODUCTION

1.1 Background to the research study

Disposable micro fibre flat mops are becoming increasingly commonplace in institutional cleaning of hard floors. At the Cleaning Research Foundation (VSR) Technology Committee brainstorming session on 24 February 2015, a need for substantiated information about the action/effectiveness of disposable micro fibre flat mops compared to the popularly-used multi-use micro fibre flat mops came to the fore. This research study focuses on that question.

1.2 Purpose of the research study

The purpose of the research study is to test the action, i.e., effectiveness of disposable micro fibre flat mops in comparison to multi-use micro fibre flat mops in a controlled laboratory research study, using practical simulation. The effectiveness aspects within this context are: the cleaning action, cleaning exertion, dirt-binding capacity and hygienic effectiveness.

Research study question

The purpose of the research study is operationalised in the response to the following research questions:

What is the performance of:

- disposable flat mops in comparison to multi-use flat mops in the removal of stains on various floor surfaces; the cleaning action?
- disposable flat mops in comparison to multi-use flat mops on the issue of frictional resistance; the cleaning exertion?
- disposable flat mops in comparison to multi-use flat mops on the issue of the dirt-binding capacity?
- disposable flat mops in comparison to multi-use flat mops on the issue of removal of germs from contaminated surfaces; the hygienic action?

CHAPTER 2
MATERIALS AND RESOURCES

2.1 Micro fibre flat mops

The research study looked at various flat mops for cleaning hard floors. In the selection of the flat mops it was decided to include the most delivered multi-use micro fibre flat mops and disposable micro fibre flat mops from three suppliers. Moreover, the most popular multi-use micro fibre flat mop from one supplier, and the most delivered disposable micro fibre flat mop from another supplier was included. The specifications of the 8 different flat mops are listed in table 1.

Table 1: Flat mops in the research study.

Code	Type of flat mop	Micro fibre %[1]	Weight	Thickness
A	Multi-use	50 -75 %	100 - 150 g	5 -10 mm
B	Multi-use	50 -75 %	75 - 100 g	10 -15 mm
C	Multi-use	-	100 - 150 g	5 -10 mm
D	Multi-use	50 -75 %	100 - 150 g	10 -15 mm
E	Disposable	-	10 – 25 g	1 - 5 mm
F	Disposable	75 -100 %	10 – 25 g	1 - 5 mm
G	Disposable	75 -100 %	10 – 25 g	1 - 5 mm
H	Disposable	50 -75 %	10 – 25 g	1 - 5 mm

2.2 Floormaterials

The floor materials used in the research study are: linoleum, vinyl and stone tiles. The material specifications are listed in table 2.

Table 2: Floor materials used.

	Linoleum	Vinyl	Tile
Producer	Forbo Flooring	Forbo Flooring	Mosa
Type	Marmoleum Fresco	Eternal material	Ultragres Terra Maestricht
Dimensions	60x50cm	60x50cm	59,5x14,5cm
Colour	3858	12252 white stone	V200

2.3 Cleaning robot

All the tests, barring the dirt-binding capacity test, are carried out using a cleaning robot. With this surfaces can be cleaned under adjustable and reproducible process conditions. The

[1] In accordance with supplier specifications.

adjustable variables are: the cleaning pressure, the length of the wiping movement and the wiping speed.

The cleaning pressure
The cleaning pressure is defined as the vertical force exerted on the pad holder during a wiping movement. During the research study a pressure of 0.75 N/cm is used. This pressure is representative of increased pressure exerted in order to remove a localised stain. The frictional resistance is also measured at a cleaning pressure of 0.5 N/cm and 0.3 N/cm.

Speed of wiping movement
The speed with which the pad holder moves backwards and forwards across the test floor is set at 400mm/sec; representative of normal cleaning.

Length of the wiping movement
This is the maximum distance that the flat mop moves backwards and forwards when flat mopping. The length of the wiping movement varies in day to day practice, and depends on the type of dirt; long wiping movements with even light dirt and short wiping movement with localised stains. The wiping movement is set at 300 mm, and at 200 mm when measuring the hygienic action.

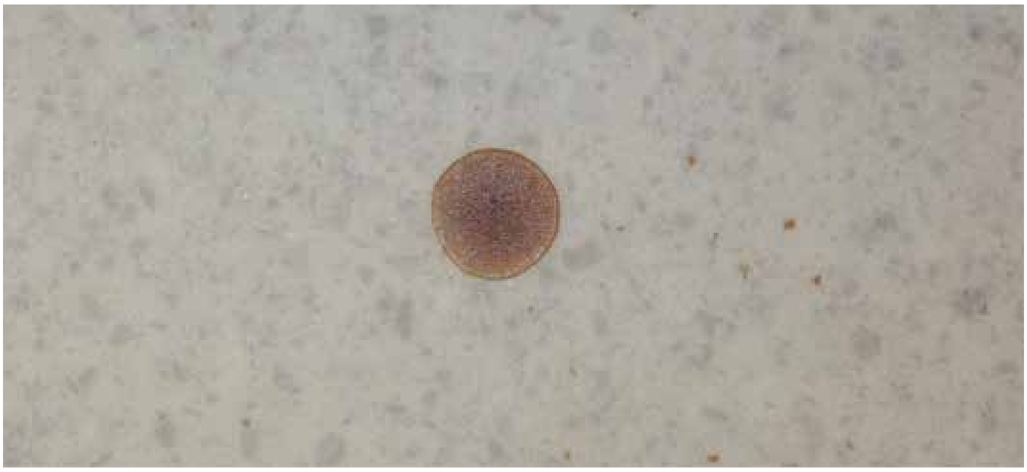
2.4 Test staining

The types of dirt used are: chocolate milk (a mix of primarily pigments, proteins, carbohydrates and fats), sebaceous matter and street sweepings. The specifications of each type of dirt and the way in which these are applied on the floor surfaces are outlined below. The test dirt is continuously applied in such a way that the middle of the flat mop can move completely over the middle of the stain. A spot is made in the place on the test floor where the stain is to be applied.

2.4.1 Chocolate milk staining

Chocolate milk (Chocomel, Friesland foods) is applied in a dilution of 1 part chocolate milk to 3 parts demineralised water. Using a 2 ml pipette each chocolate milk liquid stain is applied to the linoleum and vinyl floor surfaces. This yields a stain with a diameter of around 4 cm. On the tiles a 2ml stain leached too much. A 1.5 ml pipette is therefore used on the tiles, in a pattern of 10 small drops that together form a stain of around ± 5cm in diameter. The stains are dried out over 24 hours at room temperature.

Illustration 1: Chocolate milk staining on linoleum.



2.4.2 Sebaceous matter staining

7.5 g of sebaceous matter is tinted with 0.5 g WfK pigment. This mixture is then diluted with ethanol. The sebaceous matter is hereby first melted and then 30 ml of ethanol 96% added. Agitated and warm, this suspension is applied (0.75 ml) per stain to the floor surfaces. The applied quantity concurs with 0.25 g of sebaceous matter per stain. The stains are dried out over 24 hours at room temperature.

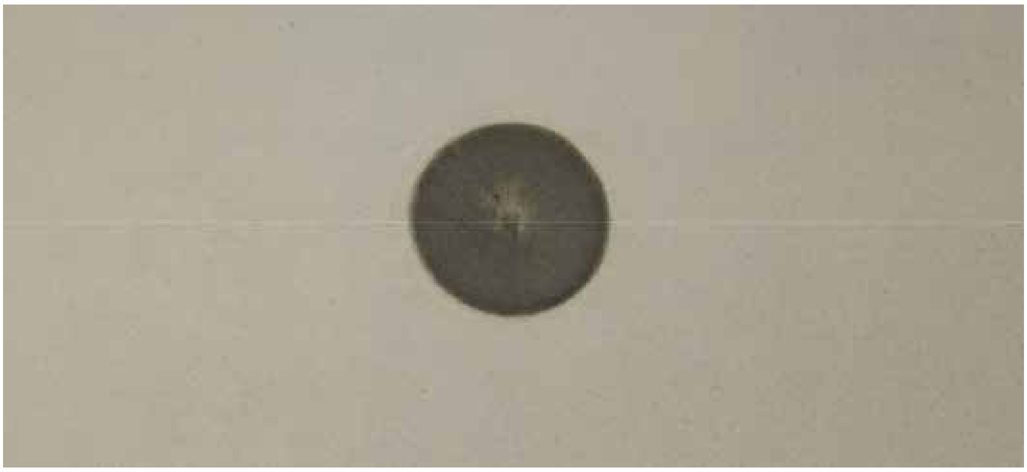


Illustration 2: Sebaceous matter staining on tile.

2.4.3 Street sweepings staining

WfK street sweepings are used comprising the following ingredients:

- Kaolinite 55%
- Quartz 43%
- Soot 1.5%
- Black ferrous oxide 0.5%

Stain preparation: 20 g street sweepings are mixed into an as even suspension as possible, with 15 g demineralised water. Using a brush 0.5 g of this suspension is applied in the middle of the test surface, making a stain of ± 4x4 cm. The stains are dried out over 24 hours at room temperature.

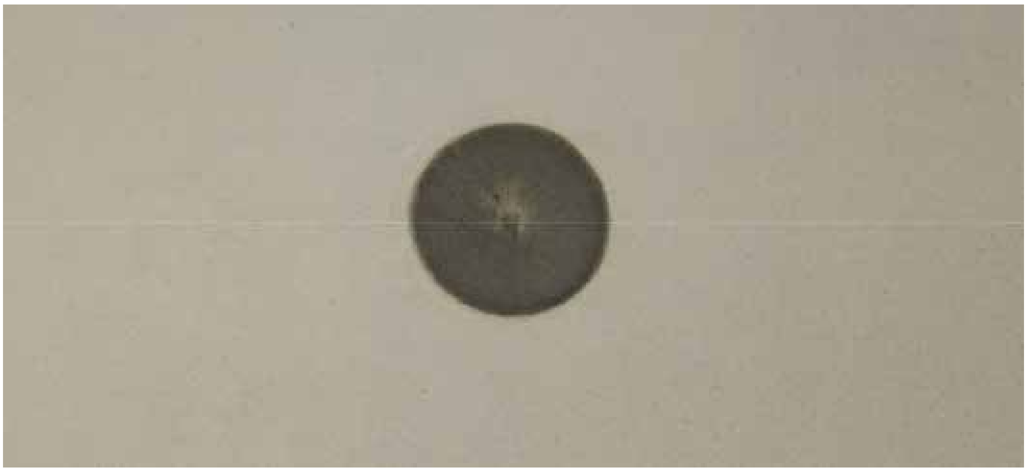


Illustration 3: Street sweepings on vinyl.

2.4.4 Staining hygiene tests

The surface to be cleaned is stained with culture (Appendix 7.2) that contains a mixture of micro-organisms that can occur in a (large) household environment. The concentration of micro-organisms in this mixture is around 108 kve/ml. The contamination is applied on a test piece of linoleum. Prior to staining the test pieces are cleaned with a 70% ethanol solution.

Each test piece is contaminated with 1ml culture (applied as a 10 fine droplet raster). The stained test pieces are then left to age for 24 hours.

2.5 Conditioning of the flat mops

All sustainable flat mops are pre-washed five times on a colour wash programme at 60°C with IEC A* base control washing detergent (without adding sodium perborate or Tetraacetylethylenediamine (TAED)), and one time on the selfsame wash but without detergent. The flat mops are then dried (lying down). The flat mops are then cut into 20 cm test pieces, removing all labels and other superfluous materials.

The tests are carried out using test pieces with 150% moisture content. Just prior to starting a test the flat mops are submerged in cold water containing run-of-the-mill floor detergent (dose: 12.5 ml/l), then wrung out once and then re-submerged and wrung out to 150% moisture content.

2.6 Conditioning of the floor surfaces

A test piece for use as the linoleum and vinyl test floors in the cleaning robot is obtained by cutting 50x60 pieces. A new piece of test floor is used for each measurement. In the tile test, for each measurement a test floor is constructed by fixing a stained test tile on either side of two clean tiles of the same type, thus creating a test surface area of around 44x60 cm. All test surfaces are cleaned with alcohol prior to staining.

CHAPTER 3 EXECUTION

3.1 Stain removal measurement; cleaning action

When measuring the cleaning action the floor surfaces are first conditioned, stained and the dirt aged. Then the cleaning robot is programmed.

The test settings for the cleaning tests are:

Cleaning pressure	0.75 N/cm (Increased pressure exerted to remove a localised stain)
Wiping speed	400 mm/sec
Wiping movement length	300 mm
Number of wiping movements	3 per cycle

After placing a conditioned flat mop and test floor, the wiping movements are initiated. During the flat mopping and after each cycle of 3 wiping movements, the stain removal is visually assessed. The number of wiping movements required to fully remove the stain is recorded. In this regard dirt that is spread out across the floor is discounted; in measuring the number of requisite wiping movements it only concerns the removal of the dirt in the spot where it was applied. Once the cleaning is finished, the cleanliness of the cleaned surfaces is visually assessed on a 4 point scale. The assessment criteria are listed in table 3. Each measurement is carried out in duplicate on two different days. Upon results analysis additional measurements are undertaken in the event of too much result variation or inconsistencies.

Table 3: Assessment scale: visual assessment of cleanliness.

Dirt type	Score R	Criterion
Street sweepings	4	Fully clean
	3	Light streaks of dirt residue
	2	Light and dark streaks of dirt residue, more light
	1	Thick, dark strips of dirt residue, sometimes with a few lighter streaks in between
Sebaceous matter on vinyl and linoleum	4	Fully clean
	3	Light grey stains/streaks at the ends of the wiping movement
	2	Light grey in the middle, with darker streaks at the end of the wiping movement
	1	Dark grey surface with darker streaks
Sebaceous matter on tile	4	Fully clean
	3	Light grey stains/streaks at the ends of the wiping movement
	2	Light grey in the middle, with darker streaks at the end of the wiping movement
	1	Dark grey surface with darker streaks
Chocolate milk	4	Coating over the breadth of the stain
	3	Light residue
	2	Moderate residue
	1	Heavy residue

3.2 Frictional resistance measurement; cleaning exertion

The ease of use of a flat mop is to a large degree determined by the ease with which the flat mop can be moved across a floor. The frictional resistance is defined as the force required to power a flat mop of a standard width and defined cleaning pressure. As such, the frictional resistance is an indicator for the ease with which the flat mop can be powered across a floor surface.

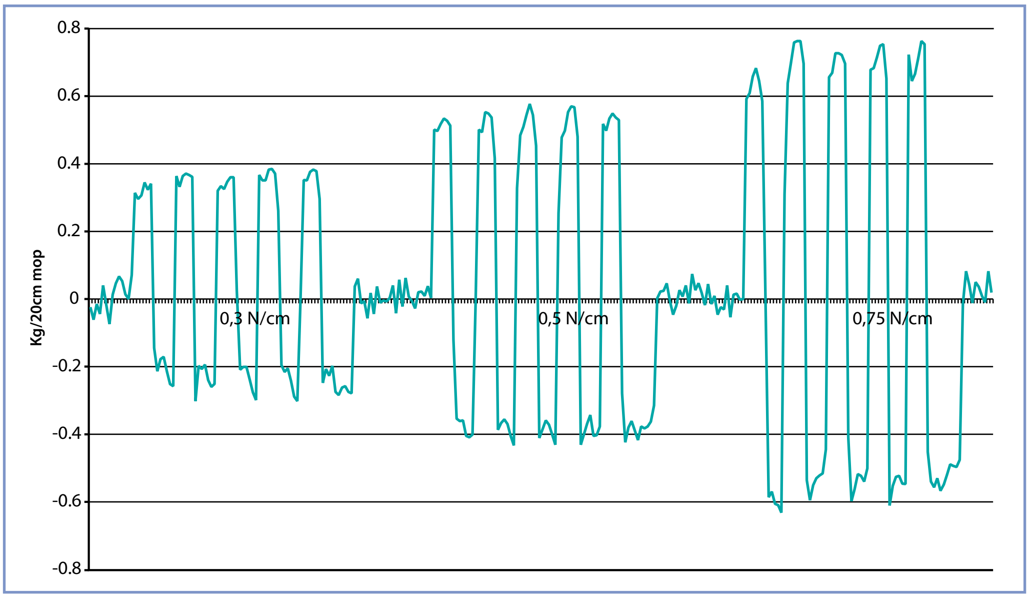
With all the flat mops the frictional resistance is measured on linoleum with three different cleaning pressures when flat mopping. The test robot is set as follows with these measurements:

Cleaning pressure	0.3, 0.5 or 0.75 N/cm
Wiping speed	400 mm/sec
Wiping movement length	400 mm
Number of wiping movements	5 per cycle

To take a measurement a conditioned flat mop is secured to the pad holder and 5 wiping movements are then carried out under an initial cleaning pressure of 0.3 N/cm. The frictional force is measured using a force gauge and is registered as a function of the time. After the first series of wiping movements the pressure is increased to 0.5 N/cm and the measurement is repeated. Finally, the measurement is repeated under a pressure of 0.75 N/cm. All measurements are carried out in duplicate. An example of the measurement registration is depicted in illustration 2.

Once the measurements have been taken from a series of 5 complete wiping movements for each cleaning pressure, the frictional resistance is calculated. The frictional resistance is indicated in Newton per meter.

Illustration 1: Frictional force during flat mopping; measurement series with increasing cleaning pressure.



3.3 Dirt retention meaurement; dirt-binding capacity

In the laboratory it is assessed after how many square meters a floor is no longer clean, with a fixed number of m² having been cleaned with a flat mop. Clean in this instance implies no visible dirt streaks once dried. To this a defined quantity of dirt is applied onto a black/white chequered floor totalling 16 m^2. The floor is then manually cleaned using one of the flat mop systems (flat mop with corresponding handle), and then visually assessed for cleanliness.

3.3.1 Floor and staining

In this measurement a 16 m^2 black/white chequered floor sheet is used. Each square measures 25x25cm. Each square meter comprises 8 white and 8 black squares. Prior to the measurement being taken the floor is cleaned with a floor detergent solution (dose: 12.5 ml/l) and then sluiced with water. The floor is then air-dried prior to being stained. The floor is artificially stained with hoover dust. The dirt is sieved so that only the finest dust remains. Then, 0.08 grams of dust is applied per square meter; divided over two squares (see appendix). The dirt is weighed out on a watch glass and then applied through a tea strainer.

3.3.2 Cleaning

Just before taking a measurement the flat mops are submerged in cold water containing a floor detergent (dose: 12.5 ml/l), then wrung out once and then re-submerged and wrung out again to 150% moisture content.
Then the stained floor is manually cleaned. The flat mop is moved across the floor in such a way that the entire floor is cleaned. Once a square meter has been cleaned, the next square meter is cleaned, until the entire floor (16 m^2) has been cleaned. Any assessments are postponed until the floor is dry.

3.3.3 Assessment

The assessments are made by a researcher who assesses all the floors for cleanliness once they have been cleaned. Each square meter is assessed for stains that have dried clean and without streaks. During assessment the floor is viewed at eye height. The score for each square meter comprises the number of squares that haven't dried clean or that have visible dirt remaining after cleaning. A high score therefore equals a poor result.
After each measurement the floor is fully cleaned with cold water containing a floor detergent (dose: 12.5 ml/l) and then sluiced with water. Then the floor is dried with a clean cloth.

3.4 Hygenic action measurement

When measuring the hygienic action in the laboratory it is assessed how many germs are left behind after flat mopping a contaminated floor surface. A test piece of linoleum floor is contaminated with micro-organisms within a dirt matrix. The test pieces, barring the control surfaces for measuring the initial contamination, are then cleaned in the cleaning robot with the various flat mops.
The cleaning robot is set as follows with these measurements:

Cleaning pressure	0.75 N/cm *(increased pressure exerted to remove a localised stain)*
Wiping speed	400 mm/sec
Wiping movement length	200 mm
Number of wiping movements	3 *(this is the number required to (visually) fully remove the stain)*

3.4.1 Sampling

The number of germs upon the cleaned surface is determined post-cleaning.
The sampling occurs across the entire cleaned surface by damp-swabbing. After sampling the swab is returned to a neutral buffer. The samples are diluted in Peptone Saline Broth

(Biotrading) within 5 minutes, and then placed on the total germ count. Dilutions 0 to –6 are placed on PCA (Biotrading) and incubated at 30°C for three days. All arising colonies are counted.

3.4.2 Data processing

The colonies on the plates are counted and the germ count is calculated using the following formula:

$$N = \frac{\sum a}{(N_1 + 0{,}1 N_2)d}$$

whereby

N = Germ count in dilution 0

$\sum a$ = Sum of the number of colonies counted

n_1 = Number of countable plates of the most diluted sample

n_2 = Number of countable plates of the least diluted sample

d = Dilution factor n_1

The calculated germ counts are converted into logarithms (log 10) of the number of colony-forming units per surface. The logarithm of the germ count quotient before and after cleaning is called the log reduction and comprises a measure for the hygienic effectiveness.

CHAPTER 4 RESULTS

4.1 Cleaning action

The measurement results of the cleaning tests are first screened for incorrect measurement data (outliers). Then a statistical analysis is undertaken of the remaining set of measurement data.

A variance analysis of the entire data set shows significant differences between the flat mops and the types of dirt in the number of wiping movements. Moreover, it appears the flat mops and the dirt types significantly impact the assessed cleanliness.

4.1.1 Chocolate milk

The results of the cleaning tests with chocolate milk staining on different floor surfaces are listed in tables 3 and 4, and are shown in illustration 3.

Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	7.3	1.5	4.0	0	8.3	0.6
B	6.5	0.7	4.0	0	9.0	0.0
C	7.0	1.0	3.5	0.7	7.5	0.7
D	8.5	0.7	4.0	0	8.5	0.7
E	6.7	1.2	4.0	0	7.3	0.6
F	20.5	2.1	11.0[2]	0	29.5	14.4[3]
G	10.5	0.7	6.5	0.7	13.0	1.4
H	11.0	0	5.0	2	13.5	0.7

Table 4: Number of wiping movements (N) required for the removal of chocolate milk staining.

[2] In relation to high dispersion additional measurements are undertaken.
[3] In relation to high dispersion additional measurements are undertaken.

Chocolate milk on linoleum: F requires significantly *(Multiple Range Tests: LSD test with significance level .05)* more wiping movements than the other flat mops. G and H require significantly more wiping movements than B, E, C and A respectively.

Chocolate milk on tile: F requires significantly more wiping movements than the other flat mops. G requires significantly more wiping movements than A, B, C D and E respectively.

Chocolate milk on vinyl: F requires significantly more wiping movements than the other flat mops.

Table 5: Assessed cleanliness (R) once the chocolate milk staining has been cleaned.

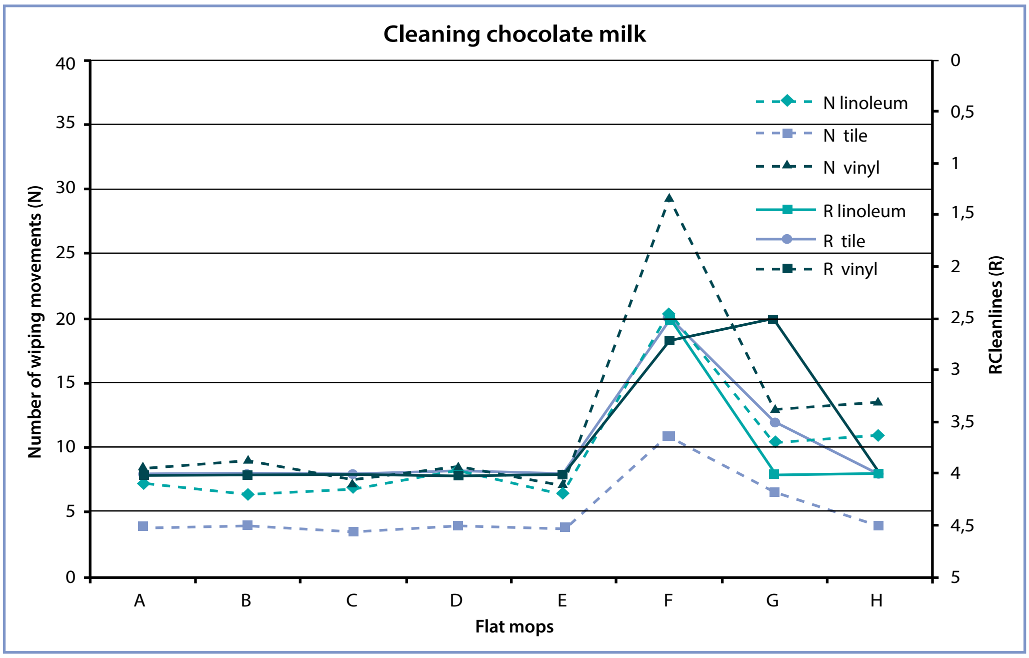
Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	4	0	4	0	4	0
B	4	0	4	0	4	0
C	4	0	4	0	4	0
D	4	0	4	0	4	0
E	4	0	4	0	4	0
F	2.5	0.7	2.5	0.7	2.7	0.5
G	4	4	3.5	0.7	2.5	0.7
H	4	0	4	0	4	0

On linoleum with chocolate milk F yields a significantly (Multiple Range Tests: LSD test with significance level .05) lower cleanliness score than the other flat mops.

On tile with chocolate milk F yields a significantly lower cleanliness score than the other flat mops.

On vinyl with chocolate milk F and G yield a significantly lower cleanliness score than the other flat mops.

Illustration 2: Number of wiping movements (N) required to remove a chocolate milk stain and the cleanliness (R)once different floor surfaces have been cleaned.



4.1.2 Street sweepings

The results of the cleaning tests with street sweepings on different floor surfaces are listed in tables 6 and 7, and are shown in illustration 3.

Table 6: Number of wiping movements required for the removal of street sweepings staining.

Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	3.2	1.0	3.5	0.6	2.8	0.5
B	3.0	0	2.5	0.7	2.5	0.7
C	2.0	0	2.0	0	3.0	0
D	3.0	0	3.0	0	3.0	0
E	2.8	0.5	4.8	3.1	3.3	0.5
F	8.5	0.7	7.5	0.7	9.5	0.7
G	6.0	0	5.0	0	6.5	0.7
H	4.5	0.7	4.0	0	5.0	1

Linoleum and street sweepings: F requires significantly more wiping movements than all the other flat mops. G requires significantly more wiping movements A, B, C, D, E and H respectively. H requires significantly more wiping movements than A, B, C, D and E.

Tile with street sweepings: F requires significantly more wiping movements than flat mops A, B, C, D and H.

Vinyl with street sweepings: F requires significantly more wiping movements than flat mops A, B, C, D, E, G and H. G requires significantly more wiping movements than flat mops A, B, C, D, E and H. H requires significantly more wiping movements than flat mops A, B, C, D and E.

Table 7: Assessed cleanliness once the street sweepings staining has been cleaned.

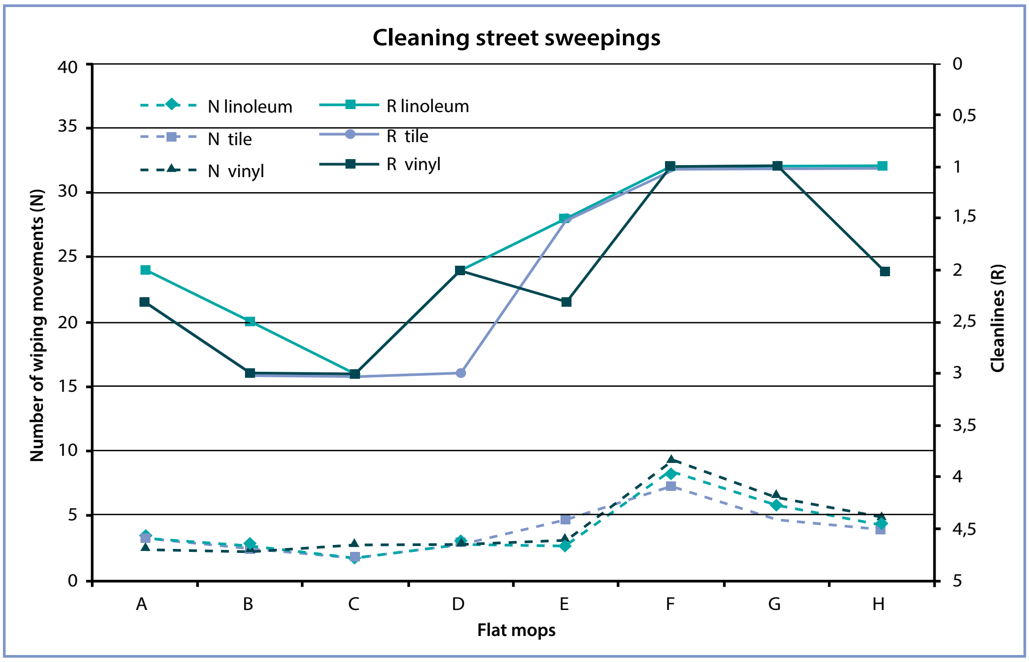
Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	2.0	0	2.3	0.5	2.3	0.5
B	2.5	0.7	3.0	0	3.0	0
C	3.0	0	3.0	0	3.0	0
D	2.0	0	3.0	0	2.0	0
E	1.5	0.6	1.5	0.6	2.3	0.5
F	1.0	0	1.0	0	1.0	0
G	1.0	0	1.0	0	1.0	0
H	1.0	0	2.0	0	2.0	0

On linoleum with street sweepings C yields a significantly higher cleanliness score than flat mops A, D, E, F, G and H. B yields a significantly higher cleanliness score than flat mops E, F, G and H. D yields a significantly higher cleanliness score than flat mops F, G and H. A yields a significantly higher cleanliness score than flat mops E, F, G and H.

On tile with street sweepings B, C and D yield a significantly higher cleanliness score than flat mops A, E, F, G and H. A yields a significantly higher cleanliness score than flat mops E, F and G. H yields a significantly higher cleanliness score than flat mops F and G.

On vinyl with street sweepings B and C yield a significantly higher cleanliness score than the other flat mops. A, D, E and H yield a significantly higher cleanliness score than flat mops F and G.

Illustration 3: Number of wiping movements (N) required for the removal of street sweepings and the cleanliness (R) once the different floor surfaces have been cleaned.



4.1.3 Sebaceous matter

The results of the cleaning tests with sebaceous matter on different floor surfaces are listed in tables 8 and 9, and shown in illustration 4.

Table 8: Number of wiping movements (N) required to remove sebaceous matter staining

Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	6.7	0.6	10.4	2	6.7	0.6
B	3.0	0	3.5	0.7	2.5	0.7
C	4.5	0.7	5.5	0.7	3.5	0.7
D	11.0	1.4	11.0	1.4	9.5	0.7
E	10.2	3.0	9.3[4]	1.5	11.7	7.2[5]
F	15.3	17.9[6]	5.6	1.5	4	1.0
G	17.4	3.5	38.0	2.8	10	1.7
H	4.5	0.7	6.5	0.7	5.7	1.2

[4] In relation to high dispersion additional measurements are undertaken.

[5] In relation to high dispersion additional measurements are undertaken.

[6] In relation to high dispersion additional measurements are undertaken.

Linoleum with sebaceous matter G requires significantly more wiping movements than flat mops A, B, C and H.

Tile with sebaceous matter: G requires significantly more wiping movements than the other flat mops. A and D require significantly more wiping movements than B, C, F and H respectively. E requires significantly more wiping movements than B, C and F.

Vinyl with sebaceous matter: E requires significantly more wiping movements than flat mops B, C, F and H. G requires significantly more wiping movements than flat mops B, C and F. D requires significantly more wiping movements than flat mop B.

Mop	Linoleum		Tile		Vinyl	
	average	SD	average	SD	average	SD
A	2	0	3	0	3	0
B	3	0	3	0	3.5	0.7
C	3	0	3	0	3.5	0.7
D	2	0	2.5	0.7	3	0
E	2	0	2	0	2.7	0.6
F	1	0	1	0	2	0
G	1	0	2	0	1	0
H	2	0	2	0	2	0

Table 9: Assessed cleanliness (R) once the sebaceous matter staining has been cleaned.

On linoleum with sebaceous matter all discerned differences in cleanliness are significant.

On tile with sebaceous matter A, B and C yield a significantly higher cleanliness score than flat mops D, E, F, G and H. D yields a significantly higher cleanliness score than flat mops E, F, G and H. E, G and H yield a significantly higher cleanliness score than flat mop F.

On vinyl with sebaceous matter B and C yield a significantly higher cleanliness score than flat mops E, F, G and H.

A, D and E yield a significantly higher cleanliness score than flat mops F, G and H. F and H yield a significantly higher cleanliness score than flat mop G.

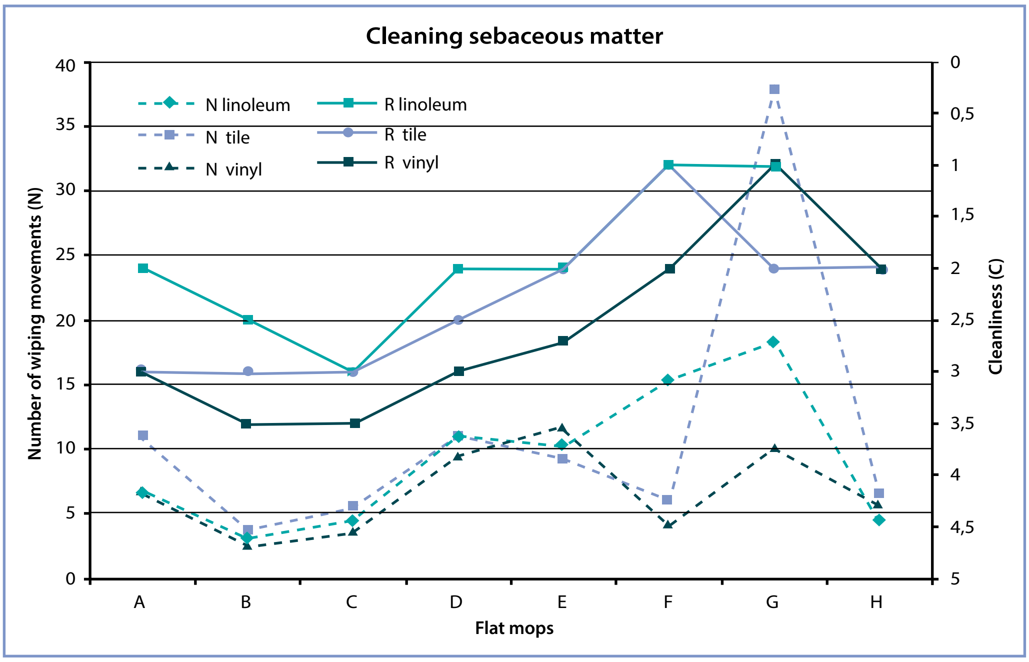


Illustration 4: Number of wiping movements (N) required for the removal of sebaceous matter and the cleanliness (R) once the different floor surfaces have been cleaned.

4.1.4 Conclusions cleaning action

Number of wiping movements: The multi-use flat mops require an associated comparable amount of wiping movements for the removal of this dirt. It is striking in this regard that the dirt removal on tile requires less wiping movements than on linoleum and vinyl. The disposable flat mops differ within their group. Flat mop E scores comparably with the multi-use

flat mops. Flat mops G and H require more wiping movements whilst flat mop F requires significantly more wiping movements than all the other flat mops.
Assessed cleanliness: In relation to cleanliness it is noteworthy that the multi-use flat mops and disposable flat mop E score comparably. Flat mops F and G have the lowest cleanliness scores. The disposable flat mop group scores poorer than the multi-use mops.

Cleaning street sweepings
Number of wiping movements: On all three floor types the multi-use flat mops require the same number of wiping movements for this type of dirt. The disposable flat mops differ within their group. Flat mop E scores comparably with the multi-use flat mops. Statistically, flat mop F requires significantly more wiping movements than all the other mops.
Assessed cleanliness: With regard to cleanliness both the multi-use flat mops and the disposable flat mops differ within their groups. In no instance after cleaning is the surface fully clean. The multi-use flat mop group scores better on cleanliness than the disposable flat mop group.

Cleaning sebaceous matter
Number of wiping movements: On sebaceous matter the multi-use flat mops differ within their group as regards the number of wiping movements required for the removal of this dirt. The disposable flat mops also differ within their group; in fact, considerably more than the multi-use flat mops. The poorest scores are measured with flat mop G.
Assessed cleanliness: After cleaning none of the flat mops have fully cleaned the surface. In regard to cleanliness the flat mops clearly differ within their group. Flat mops F and G score lower than the other flat mops.

4.2 Cleaning exertion; frictional resistance

The measured frictional resistances under different cleaning pressures are listed in table 10 and are shown in illustration 5.

Table 10: Frictional resistance of the flat mops in kg/m.

Mop	Cleaningpressure 0.3 N/cm	Cleaningpressure 0.5 N/cm	Cleaningpressure 0.75 N/cm
A	1.2	1.9	3.0
B	1.2	2.0	3.0
C	1.7	2.4	3.6
D	1.3	1.9	2.7
E	2.2	3.1	4.4
F	1.6	2.3	3.4
G	1.3	2.2	3.7
H	2.2	3.2	4.7

A variance analysis of the entire data set indicates significant differences between the cleaning resistance of the flat mops. In addition, it appears cleaning pressure has a significant effect; increasing pressure yields a higher frictional resistance. The frictional resistance of disposable flat mops E and H is higher with all three cleaning pressures than of the other mops. The lowest frictional resistances are measured with multi-use flat mops A and D. The frictional resistance increases with increased cleaning pressure with each flat mop.

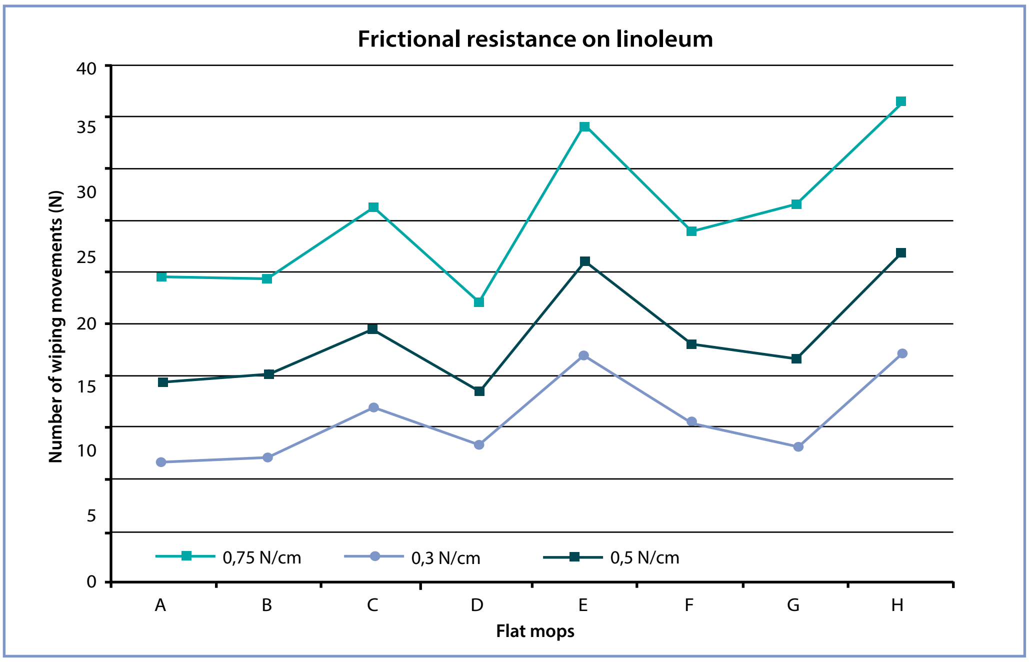


Illustration 5: Frictional resistance in kg/m during flat mopping.

4.2.1 Conclusions cleaning exertion

The associated frictional resistance of the flat mops differs significantly. The highest cleaning resistances are measured with the disposable flat mops and the lowest with the multi-use. The highest cleaning resistance (disposable flat mop H) is 70% higher than the lowest (multi-use flat mops A and D).

With increased cleaning pressure the frictional resistance increases. Broadly speaking, it can be presupposed that double the cleaning pressure results in a frictional resistance that is similarly, twice as high.

4.3 Dirt-binding capacity; dirt retention

The research study into dirt retention yielded a different result than anticipated. The expected judicious moment after which the flat mops no longer absorb dirt and subsequently smear or leave behind the dirt, was not discerned. The initially selected measuring method that focused on determining the number of square meters up to the point at which the floor was no longer clean, was not applied therefore.

Further to this finding it was opted to record the results differently. For each of the sixteen square meters successively cleaned in the test, the number of not fully cleaned stains was determined. As such, for each square meter 0 dirty stains is the lowest, and 16 dirty stains, the highest attainable score. The average values of the two measurement ranges for each flat mop are listed in table 11, and shown in illustration 6.

With the disposable flat mops E (insignificant), F (p=0.056), and H and G, the number of dirty stains (linear regression) increases with the number of square meters cleaned by the flat mop. This also applies for multi-use flat mop A.

Whilst cleaning the 16 square metres, the number of dirty stains with multi-use flat mops B, C and D remains low and constant.

4.3.1 Conclusions dirt retention

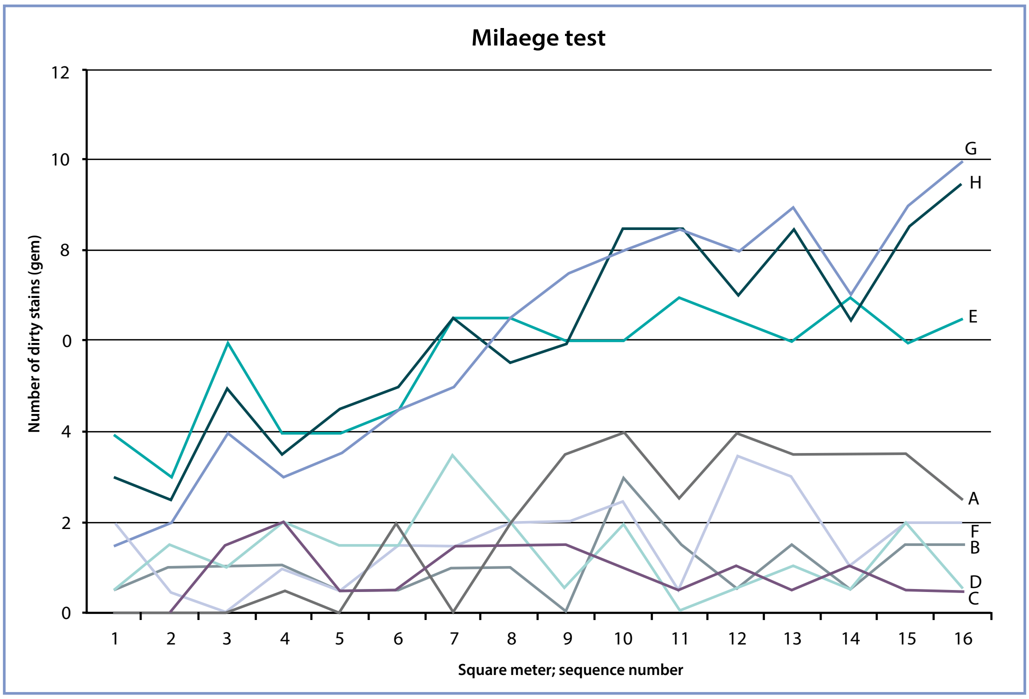
The scores of multi-use flat mops B, C and D do not increase during cleaning of the 16 m^2; the scores do not exceed a score of 2 from the 1st to the last m^2. This does not apply to multi-use flat mop A. With this one the score increases during flat mopping. One possible explanation is that the flat mop can only bind the dirt to a limited degree, and when measured increasingly spreads the dirt rather than absorbing it.

A similar, yet stronger, effect is also discerned with disposable flat mops E, G and H. The scores for these flat mops though are considerably higher than those of the multi-use flat mops. The scores of disposable flat mop F deviates in this regard, and falls within the same range as the multi-use flat mops.

Table 11: Number of dirty stains per m^2 on 16 successively cleaned m^2.

Mop	Number of dirty stains (N/m^2)															
	1st m^2	2nd m^2	3rd m^2	4th m^2	5th m^2	6th m^2	7th m^2	8th m^2	9th m^2	10^{t} m^2	11^{t} m2^2	12^{t} m^2	13^{t} m^2	14^{t} m^2	15^{t} m^2	16^{t} m^2
A	0.5	1.5	1	2	1.5	1.5	3.5	2	3.5	4	2.5	4	3.5	3.5	3.5	2.5
B	0.5	1	1	1	0.5	0.5	1	1	0	3	1.5	0.5	1.5	0.5	1.5	1.5
C	0	0	1.5	2	0.5	0.5	1.5	1.5	1.5	1	0.5	1	0.5	1	0.5	0.5
D	0	0	0	0.5	0	2	0	2	0.5	2	0	0.5	1	0.5	2	0.5
E	4	3	6	4	4	4.5	6.5	6.5	6	6	7	6.5	6	7	6	6.5
F	2	0.5	0	1	0.5	1.5	1.5	2	2	2.5	0.5	3.5	3	1	2	2
G	1.5	2	4	3	3.5	4.5	5	6.5	7.5	8	8.5	8	9	7	9	10
H	3	2.5	5	3.5	4.5	5	6.5	5.5	6	8.5	8.5	7	8.5	6.5	8.5	9.5

Illustration 6: Number of dirty stains per m^2 on 16 successively cleaned m^2.



4.4 Hygenic action

Table 12 depicts the number of germs (log value) left behind on the cleaned floors, as well as the reduction in germs (log reduction). With one exception, all log reductions fall between 2 and 3 log units. The reduction in germs with the disposable micro fibre flat mops does not radically deviate from those of the multi-use mops. The cause of F's strongly deviating value is unknown.

Table 12: Reduction of the number of germs on a surface cleaned with a flat mop.

Mop	Germs (TPC) after cleaning Log N (kve/surface)	Spread Sdev logN	Reduction in germs log reduction
A	3.8	0.3	2.4
B	4.1	0.0	2.1
C	3.5	0.5	2.7
D	3.9	0.4	2.3
E	4.1	0.0	2.1
F	5.5	0.2	0.7
G	3.8	0.2	2.4
H	4.2	0.1	2.0
Ref	6.2	0.4	

4.4.1 Conclusions hygienic action

With one exception, all in all the flat mops remove a stain with a substantial amount of the germs present within it. The log reduction runs from 2.0 to 2.7. This concurs with a removal percentage of 99.0 to 99.8 % of the applied germs.
The reduction in germs by flat mop F is very minimal and does not deviate significantly from 0.

CHAPTER 5 DISCUSSION AND SUMMARY

5.1 Discussion

5.1.1 Theoretical deliberations

In terms of cleaning performance, in the research study the disposable flat mops performed less well than the multi-use flat mops. This could in part be explained by the fact that the assessed disposable flat mops have a non-woven, even surface, and moreover, the mops are thinner. The surface of the multi-use flat mops is formed by fibres and threads that stand perpendicular to the mop's surface. This forms a pliant and moveable surface that can adequately follow the floor surface, and which can absorb and fix the dirt. Moreover, the multi-use flat mops better distribute differences in pressure caused by potential unevenness by the mop holder across the surface to be cleaned, due to its thickness and pliant structure. And finally, with the same moisture percentage (3 to 14x), the multi-use flat mops absorb more moisture, as a result of which the mop dries out less quickly and the dirt is possibly better bound/dispersed.

The reduction in germs measured in this research study is in line with expectations. The measured reduction in germs from 2 to 2.7 log units was found to be one to two log units lower than in laboratory scenarios (3, 5) yet higher than that measured in the VSR research study into toilet hygiene within primary education (4). Possibly, the relatively few stubborn dirt matrices within which the germs occur are partially the cause of this.

5.1.2 Comparison with the 2009 VSR research study results

In the current research study a number of test components relating to measuring method and research study conditions are comparable to those of the 2009 VSR research study: Micro fibre flat mops; impact of the moisture content on functionality (4). The brands and types of flat mops assessed in both research studies vary. In the 2009 research study six multi-use micro fibre flat mops were assessed. It is interesting to see how the results of the comparable test components in both research studies relate to each other. Table 13 depicts the results of the comparable test components of both research studies. With the stain removal the range and average number of wiping movements for the flat mops in both research studies is incorporated. With the frictional resistance the average of the flat mops under the three cleaning pressures is incorporated in both research studies.

Noticeable is that with the cleaning action the range and average value of the number of wiping movements measured in both research studies into multi-use micro fibre flat mops concur well, despite it relating to other flat mops. Additionally, the frictional resistances measured in both multi-use micro fibre flat mop research studies also concur well.

The overview also clearly shows that, as a group, the disposable micro fibre flat mops, score lower than the multi-use variant.

Table 13: 2015 and 2009 results.

		2009 research study	2015 research study
Stain removal		**Wiping movements range / average**	**Wiping movements range / average**
	Sebaceous matter on linoleum	5 - 6.5 / 3.8 multi-use	3-11 / 3.8 multi-use 4.5-17.4 / 11.9 disposable
	Sebaceous matter on tile	4.5 - 10.5 / 7.5 multi-use	3.5-11 / 7.6 multi-use 6.5-38 / 14.9 disposable
Average frictional resistance		**Cleaning pressure:** 0.3 / 0.5 / 0.75 N/m	**Cleaning pressure:** 0.3 / 0.5 / 0.75 N/m
	Linoleum	1.7 / 2.4 / 3.3 multi-use	1.4 / 2.1 / 3.1 multi-use 1.8 / 2.7 / 4.0 disposable

5.2 New insights:

For day-to-day use the research study yields a number of new insights:

- **On average** the multi-use micro fibre flat mops clean with fewer wiping movements and with a higher cleanliness score than disposable micro fibre flat mops,
  In this respect however, a good disposable micro fibre flat mop isn't any less under par on cleaning action than an **average** multi-use micro fibre flat mop,

- On average the cleaning resistance of a multi-use micro fibre flat mop is lower than that of a disposable micro fibre flat mop,
  In this respect, a good disposable micro fibre flat mop need not have a higher cleaning resistance than an average multi-use micro fibre flat mop,

- On average, the dirt retention capacity of a multi-use micro fibre flat mop is higher than that of a disposable micro fibre flat mop,
  In this respect, a good disposable micro fibre flat mop need not have a lower dirt retention capacity than an average multi-use micro fibre flat mop,

- There is no systematic difference between the hygienic effectiveness of disposable micro fibre flat mops and multi-use micro fibre flat mops.

- No *'best micro fibre flat mop for all applications"* can be indicated; different micro fibre flat mops all have strong and weak points, meaning that the most appropriate micro fibre flat mop must be selected for a specific cleaning problem,

- For optimum cleaning results the selection of a specific type of flat mop must reflect both the type of dirt and the type of floor,

The purpose of this research study isn't to compare the performance of individual micro fibre flat mops, i.e., a comparative product research study. It isn't therefore possible in this research study, based on the results, to judge the quality of the individual flat mops.

In this research study micro fibre flat mops were researched, all with varying micro fibre gradings. As the flat mops also differ on other salient points, for example structure and moisture, the impact of the micro fibre content on the mops' properties cannot be judged.

5.3 Summary

Micro fibre materials are commonplace within institutional cleaning (1). In the past the Cleaning Research Foundation (VSR) has had research studies carried out into the effectiveness and application properties of modern micro fibre flat mops (4, 5). The most recent research study into micro fibre flat mops determined optimum moisture content (5).

Following the dramatic rise in micro fibre flat mop usage, disposable micro fibre flat mops have also been launched onto the marketplace.

A number of benefits of disposable micro fibre flat mops are self-evident. For example, after use the disposable micro fibre flat mop is removed and the logistics system for transporting and cleaning the used micro fibre flat mops becomes superfluous. Moreover, the hygienic risk is reduced. Simultaneously, it must be noted that the use of disposable material results in increased quantities of waste at the cleaning location, which in turn necessitates additional waste removal.

The purpose of this research study, commissioned by the Cleaning Research Foundation, is to investigate the effectiveness and application properties of disposable micro fibre flat mops in relation to multi-use micro fibre flat mops.

During the research study four different multi-use micro fibre flat mops and four disposable micro fibre flat mops for floors were researched, and compared on a number of key application properties, namely, cleaning action, cleaning exertion, hygienic action and dirt-binding capacity. In this associated comparison the influence of process conditions such as cleaning pressure, floor material and dirt type on these application properties was researched.

When carrying out this research study the aim was to execute the tests as practically relevant as possible. In a former pre-research study practical values were determined for the cleaning pressure and speed of the wiping movement. For the cleaning pressure a value was determined for normal/light cleaning, normal/intensive cleaning and thorough/localised cleaning. The tests were carried out on linoleum, vinyl and Ultragres tile flooring.

Cleaning action

The research study into the cleaning action measured two relevant aspects; cleaning speed and cleanliness. In order to measure these variables, cleaning tests were undertaken with a cleaning robot.

Various dirt stains (chocolate milk, street sweepings and sebaceous matter) were applied to linoleum, vinyl and tiles (Ultragres). Following ageing these stains were then removed by a cleaning robot under a cleaning pressure for thorough localised cleaning using the various flat mops. The flat mops were dampened with a detergent solution. The number of wiping movements required to remove a stain was recorded as a measure of cleaning speed. The result (score) of a visual assessment of the dry, cleaned surface was a measure for cleanliness.

A variance analysis of the complete data set demonstrates differences between the flat mops with regard to cleaning speed and cleanliness.

When cleaning the **chocolate milk stains**, on average, the multi-use flat mops perform better in terms of cleaning speed and cleanliness than the disposable flat mops. The associated differences between the multi-use flat mops for both cleaning speed and cleanliness are minimal and insignificant. With the removal of this dirt type the associated differences with the disposable flat mops are considerably greater than with the multi-use flat mops; this applies to cleaning speed and cleanliness. One of the disposable flat mops scores in nigh on all test situations poorer than the other flat mops. Whilst a different disposable flat mop scores on the same level as the multi-use flat mops.

With **street sweepings** it concerns significant differences in cleanliness within the disposable flat mop group and within the multi-use flat mop group. The multi-use flat mops do not significantly vary in their group in terms of cleaning speed. Taken on average, the multi-use flat mops perform better with street sweepings on cleaning speed and cleanliness than the disposable mops.

With **sebaceous matter** it concerns significant associated differences within the disposable flat mop group and within the multi-use flat mop group; this applies both in terms of cleaning speed and cleanliness. Taken on average, the multi-use flat mops perform better with sebaceous matter on cleaning speed and cleanliness than the disposable mops.

Note: Although the multi-use flat mop group scored higher in terms of cleaning action with the different dirt types and test floors than the disposable flat mops, the results also show that a disposable flat mop isn't by definition under par to a multi-use flat mop.

Frictional exertion

The frictional resistance is a measure for the effort that a cleaner has to put in when flat mopping. The frictional resistance is measured by the cleaning robot with vertical cleaning pressures that are representative of normal/light cleaning, normal/intensive cleaning and thorough/localised cleaning. Measurements were taken on linoleum.

The frictional resistance of both the multi-use and the disposable flat mops differs significantly within their respective groups. The highest cleaning resistances are measured with the disposable flat mops and the lowest with the multi-use. The highest cleaning resistance (disposable flat mop) is 70% higher than the lowest (multi-use flat mops).

The frictional resistance is significantly related to the cleaning pressure; a higher cleaning pressure yields a higher frictional resistance. Broadly speaking, it can be assumed that double the cleaning pressure results in a frictional resistance that is similarly, twice as high.

Dirt-binding capacity

The dirt-binding capacity is the attribute of a flat mop of retaining removed dirt. In a simulated practise test it was assessed to which degree a floor is clean after cleaning a set number of m^2 with a flat mop. On a (16 m^2) floor subdivided into 16 black and white squares a defined amount of dust is applied per m^2. The floor is then cleaned with one of the flat mop systems (flat mop with corresponding handle) and then visually assessed for staining. A score is allocated per m^2 that comprises a measure for dirtiness (0=clean, 16=dirty).

The dirtiness of three multi-use flat mops increases barely, if not at all, during the cleaning of the 16 m^2; from the first to the last m^2 the scores do not exceed a score of 2. In the case of one of the multi-use flat mops the dirtiness increases (score 4). One possible explanation is that the flat mop insufficiently binds the dirt and during cleaning continues to spread the dirt rather than absorbing it.

A comparable effect is seen with three disposable flat mops. The dirtiness of these flat mops however is considerably higher and increases faster than with all the multi-use flat mops. One of the disposable flat mops has a dirt-binding capacity that does not deviate from the multi-use flat mops.

Hygienic effectiveness
To measure hygienic action in the laboratory it was researched how many germs are left behind by the flat mops after cleaning on a pre-contaminated floor surface. A test piece of linoleum floor is added, and contaminated with micro-organisms within an organic dirt matrix. The floor surfaces, barring the control surfaces, are for measuring the initial contamination, which are then cleaned by the cleaning robot using the various flat mops. After cleaning the amount of residual germs on the cleaned surfaces is determined.

With one exception, all in all the flat mops removed a stain with a substantial amount of the germs present within it. The log reduction runs from 2.0 to 2.7. This concurs with a removal of 99.0 to 99.8 % of the present germs. The reduction in germs in one of the disposable flat mops is very minimal and doesn't significantly deviate from 0. No systematic difference was found between the multi-use and the disposable flat mops.

CHAPTER 6 REFERENCES

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CHAPTER 7 APPENDICES

7.1 Dirt retention test: dirt dispersion across the floor

					X								X		
		X								X					
						X								X	
	X								X						
					X								X		
		X								X					
						X								X	
	X								X						
					X								X		
		X								X					
						X								X	
	X								X						
					X								X		
		X								X					
						X								X	
	X								X						

X= THE SPOT WHERE 0.04 GRAM OF DIRT IS DISPERSED ON THE FLOOR

7.2 Culture composition

Ingredient	Concentration g/l
Pepton	5
Proteose pepton	5
Sodium chloride	5
Disodium phosphate	3,1
Potassium dihydrogenphosphate	0,75
Calf brain infusion	6,25
Beef infusion	2,5
Glucose	1

7.3 Cleanliness examples post stain removal

Illustration 4: Cleaning effect sebaceous matter on tile; flat mop F above, B under.

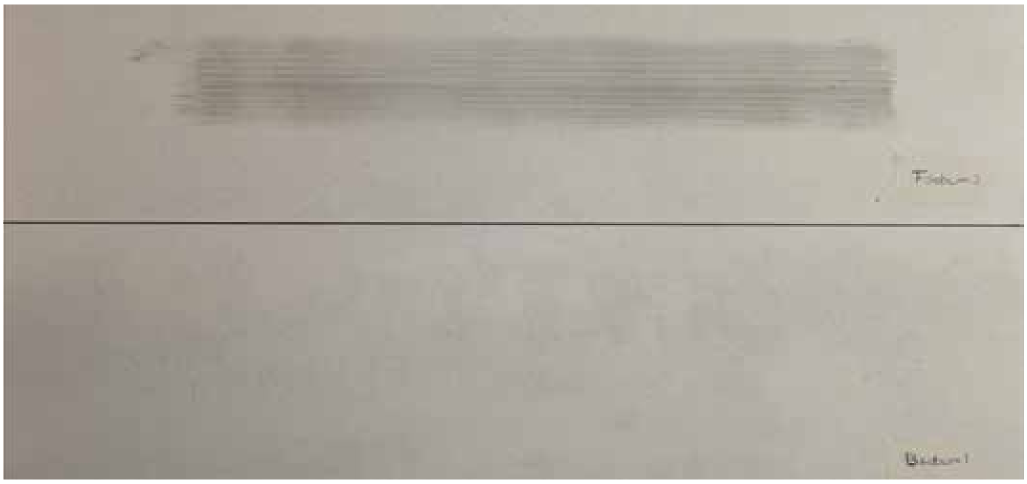

Illustration 5: Cleaning effect chocolate milk on tile; flat mop F above, E under.

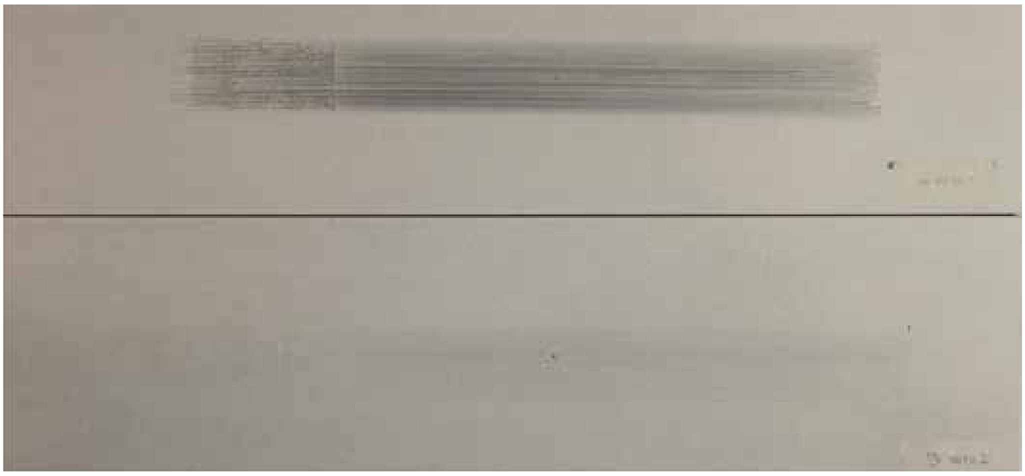

Illustration 6: Cleaning effect street sweepings on tile; flat mop G above, B under.

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