Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Materials Science and Engineering

Álvaro Martín Rodríguez
Sander Næs

Assessment of Disinfection Rate Along the Turf Pile in a Synthetic Turf System.

Vurdering av Desinfeksjonshastighet Langs Gresshaugen i Kunstgressanlegg.

Bachelor's thesis in Chemical Engineering
Supervisor: Ina Merete Stuen
Co-supervisor: Bjørn Aas
May 2024

NTNU
Norwegian University of
Science and Technology

Álvaro Martín Rodríguez
Sander Næs

Assessment of Disinfection Rate Along the Turf Pile in a Synthetic Turf System.

Vurdering av Desinfeksjonshastighet Langs Gresshaugen i Kunstgressanlegg.

Bachelor's thesis in Chemical Engineering
Supervisor: Ina Merete Stuen
Co-supervisor: Bjørn Aas
May 2024

Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Materials Science and Engineering

NTNU
Norwegian University of
Science and Technology

Preface

This bachelor's thesis, written by students majoring in Chemical Engineering at the Department of Materials Science and Engineering, Norwegian University of Science and Technology, is the final project of the authors, and requested by the firm COWI. The study, conducted from January 13th to May 19th, 2024, making use of the laboratories at Kalvskinnet campus, under the purview of NTNU's Department of Materials Science and Engineering.

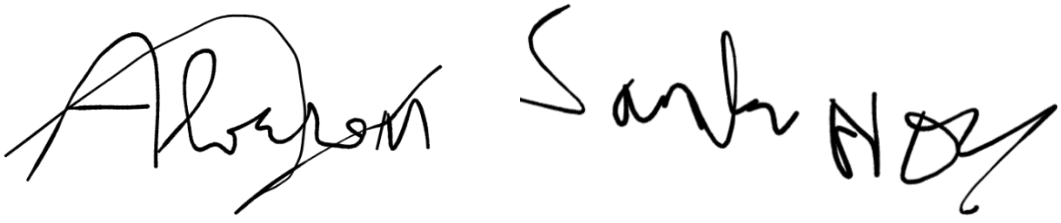
The primary aim of this thesis was to evaluate the efficacy of the disinfectant, Nüscosept PRO, in the task of keeping the turf free of bacteria, that could lead to health problems.

We extend our sincerest gratitude to our internal mentor, Ina Merete Stuen, for her counsel and guidance on how to proceed. We also wish to express appreciation to our external mentor, Bjørn Aas, for trusting in us, and in the project through out journey.

Finally, we acknowledge Hege Sundgård for her indispensable assistance in laboratory operations and facilitating chemical procurement.

Norwegian University of Science and Technology

Trondheim, May 2024



Álvaro Martín

Sander Næs

Abstract

The main topic of this project is artificial turf hygiene, trying to prevent bacterial growth to ensure the safety of people using these types of fields. This is done with a keen focus on *Staphylococcus aureus*, which is frequently mentioned within bacterial infections. All the experiments were conducted at Kalvskinnet laboratory.

Firstly, the experiments started with an examination of the mist-sprayer flow rates, to learn the amount of liquid being sprayed per unit time. Then, the main experiments were conducted with artificial turf, spraying the disinfectant directly upon it.

After observation and analysis, testing different spraying times, samples using swabs were collected, and inoculated onto agar plates. When the incubation of bacterial colonies finished, they were counted and organized into tables.

Within this thesis, a 0.5% Nüscosept PRO in water was tested on artificial turf in order to analyze the disinfection rates at the top and 10mm below, in between the yarns. The results showed a higher disinfection rate at the top than at the bottom. Due to the limited number of tests that could be conducted, along with flaws in the method, some of the data is not usable for further analysis. However, it was possible to observe disparity in disinfection rates across the different experiments, varying type of contamination, amount of disinfectant, and drying time.

Sammendrag

Hovedtemaet til dette projektet er kunstgresshygiene i et forsøk på å forsikre tryggheten til alle som bruker innendørs kunstgress. Dette er gjort med et klart fokus på *Staphylococcus aureus* som ofte er nevnt innenfor bakterieinfeksjoner. Alle eksperimentene ble utført i et laboratorie på Kalskinnet.

Eksperimentene startet med en utforskning av tåkemaskinens strømingshastighet for å lære hvor mye væske som skytes up over tid. Etter dette ble hovedeksperimentene utført ved å spraye kunstgresset direkte med tåkemaskinen.

Etter observasjon og analyse, samt testing av flere mengder spray var prøver samlet med vattpinner og inokulert på agar plater. Når disse platene med bakteriekolonier hadde inkubert var antallet kolonier tellt of organisert.

I denne oppgaven ble 0.5% Nüscosept PRO i vann testet på kunstgress for å finne desinfeksjonsraten på toppen av gresset samt 10 mm under toppen, mellom gresstråene. Resultatene fra disse prøvene viser høyere desinfeksjonsrate på toppen enn mot bunnen. På grunn av det begrensede antallet prøver som kunne bli gjort, sammen med mangel i metoden så er deler av datasettet ikke brukbart for videre analyse. Men det er fremdeles mulig å observere en ulikhet i desinfeskjonsratene fra forskjellige eksperimenter med varierene type kontaminering, mengde desinfeksjonsmiddlel og tørketid.

Contents

1. Introduction

Artificial turf is widely used for football pitches, especially indoors. Flatåshallen is an indoor football pitch utilizing artificial turf with infilling of sand and olive stones (1). Olive stones are one of many organic infill options being tested to attempt to replace SBR-granules in artificial turf due to SBR-granules' negative impact on the environment (2). This organic substitute can consequently lead to greater bacterial growth on the turf (3). An excess of water on the turf can aid in bacterial growth, as water is a more suitable medium for growth (4). To prevent buildup of bacteria on the artificial turf, which could harm users of the turf, it is disinfected regularly. The disinfectant that is currently in use at Flatåshallen is a solution of 0.5% Nüscosept PRO mixed in water (5). The effect of this disinfectant has been tested for the very tip of the synthetic yarns of the turf, yet it is not known to what degree this effect applies to the deeper sections of the yarns.

The aim of this thesis is to find an optimal dose of disinfectant on an artificial turf system that can achieve effective disinfection throughout the yarns rather than just the tip. This evaluation is conducted in a lab at a microbiological level. Having an effective dose for the disinfectant both reduces cost and likelihood of promoting further growth due to excess water remaining in the system (4). This will ensure optimal conditions for sports and other activities using the turf.

Two main research questions were formulated based on this information:

1. **What is an optimal dosage of 0.5% Nüscosept PRO in water to achieve 90%+ disinfection?**
2. **What is the difference in disinfection rate between the top area of the yarns of an artificial turf and the area approximately 10 mm below the top of the yarns?**

2. Theory

This collection of literature is included in order to give relevant background information that is helpful in understanding the contents of this thesis. This includes literature on the disinfectant that was used, and its lethality for bacteria, general information on microorganisms as well as the bacteria *Staphylococcus aureus*. In addition, it includes information about some of the equipment, precautions and statistical methods used for the tests that were done.

2.1 Disinfectant - Nüscosept PRO – usage and toxicity

Nüscosept, is a series of chemicals designed for professional use to disinfect many types of surfaces (6). Nüscosept PRO is a form of Nüscosept that is sold by the chemicals manufacturer Dr. Nüsken Chemie GmbH and is the form that is used for disinfection for the turf used for testing in this project. Nüscosept PRO contains several chemicals toxic to bacteria, such as: didecyldimethylammonium chloride and benzalkonium chloride (7).

In a previous study it was found that 0.5 % Nüscosept PRO in water works well for disinfection of artificial turf (3). This dilution is the baseline which this study will base itself upon for optimalisation of the dosage. Didecyldimethylammonium chloride has a concentration between 5-20% in Nüscosept PRO and benzalkonium chloride has a range of 5-25% (7). Didecyldimethylammonium chloride and benzalkonium chloride are toxic to bacteria at concentrations of 1.3 mg/L and 5 mg/L respectively (8,9). 0.5% Nüscosept PRO in water can therefore be found to be a reasonable dilution as even at the lowest concentration for each in Nüscosept PRO, the final concentration in the dilution would contain 25 mg/L of both didecyldimethylammonium chloride and benzalkonium chloride.

Didecyldimethylammonium chloride, quaternary ammonium compounds such as benzalkonium chloride, benzylakyl dimethyl, and chlorides, which are corrosive and environmentally hazardous substances. However, Nüscosept PRO has been used for, and found safe for, treatment of athletes foot and hand washing (10). Working with and washing with Nüscosept PRO can therefore be considered safe, especially when diluted.

2.2 Artificial turf – structure and maintenance

2.2.1 Structure of Artificial turf

There are 6 components to a professional artificial grass system: the sub-base, backing, infill, seaming, nails and yarn. Each one of these is made of different materials. In this case the infill and the yarn are being focused on (11).

The sub-base is the layer underneath the artificial grass. It is usually made of compacted gravel, and its depth can vary depending on factors such as drainage requirements and site conditions (11). The backing is the main support structure, then, infill materials are added to the turf to help support the yarns, improve stability, and enhance performance. Common infill materials include silica sand, crumb rubber, and organic infills such as cork or coconut fibers (which will be discussed later). Infill also helps to cushion the turf and provide a more natural feel underfoot, also adds durability and protects the backing from sunlight. There are various types of infill materials, like zeolite, sand or rubber. Seaming joins together individual portions of the turf. The yarn are polyethylene fibers which interact during use. Finally, nails are commonly used to keep the turf in place. Figure 1 shows a diagram of the structure of artificial turf, showing the yarns, infill, backing and sub-base.

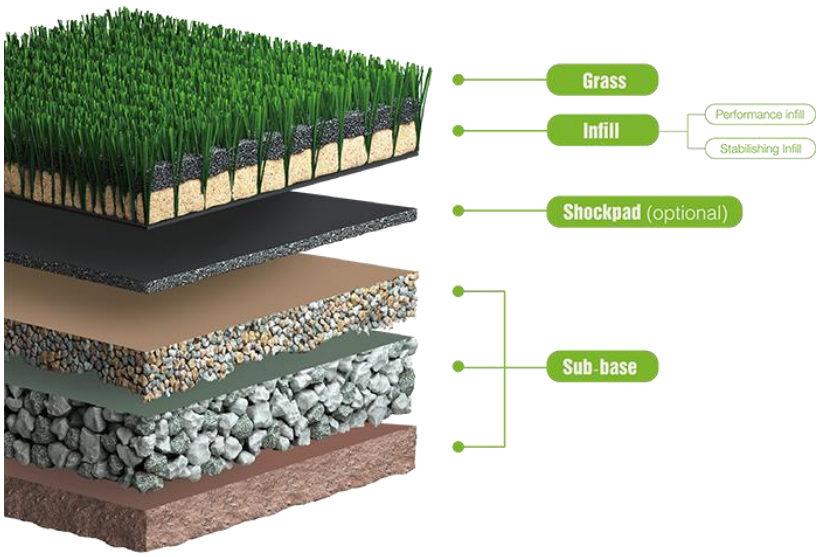


Figure 1: A structure of a piece of turf down to the sub-base layer (12).

For the turf that is used for the investigation each m^2 of turf has 17848 bundles of yarn, with each bundle containing 1 slitfilm yarn and 4 texturized yarns, each stitched on both ends for 2 slitfilm yarns and 8 texturized yarns total per bundle (1). The height of each yarn is 30 mm when stretched and the width of the slitfilm yarn is 11 mm while the texturized yarn has a width of 1.05 mm. Based this information a simple calculation for the area of the turf was made and is shown in Equation 1:

$$17848 * 2 * (8 * 0.03 * 0.00105 + 2 * 0.03 * 0.011) = 32.555 \frac{m^2(fiber)}{m^2(turf)} \quad (1)$$

2.2.2 SBR granules and organic fillers

Recently, the increasing use of tire crumb rubber has raised the alarms specially for being hazardous and causing health problems. The granulate can release dangerous particles into the air, polluting it. Said particles can also attach to clothes leading to a serious health risk. That is why there are some infill recent alternatives: TPE, EPDM, sand and the most important, organic materials (2).

There are several organic infills available with different organic components in combinations with one or more of the following: Coconut fiber, coconut husk, cork, etc. In this case the following will be focused on: Geoplus, cork, sugarcanes granules, cotton or polyester blend and peat moss (2). Organic infills makes the artificial turf more suitable for bacterial growth, as it provides organic material for the bacteria to consume (3).

-Geoplus infill consists of a mixture of organic plant material, derived from defibration of woody plants, being 100% natural and recyclable (2).

-Cork infill is advertised to keep the turf cool because of the low thermal conductivity; the material has good shock absorbing properties and is completely recyclable (add some more).

-Sugarcanes granules are showing great results, but with some challenges, as it is more expensive than cork and also lighter (2).

-Cotton/Polyester Blend, is a mixture of cotton and polyester fibers can be used as infill material in artificial turf to provide cushioning and support while maintaining natural aesthetics (2). This blend offers durability and resilience, making it suitable for high-traffic areas.

-Peat Moss is an organic material composed of decomposed plant matter. It is lightweight, absorbent, and helps to retain moisture in the turf system. Peat moss infill improves shock absorption and provides a natural feel underfoot (2).

2.2.3 Maintenance and cleaning of artificial turf

In a previous study it was found that 50 L of 0.5% Nüscosept in water was sufficient to disinfect 2800 m^2 of artificial turf, with a 90-95% disinfection rate on the top of the yarns (3,5). The current system in place at Flatåshallen, an indoor football pitch for which findings in this report will be compared to, uses a tractor to pull a mist sprayer with two nozzles which sprays the Nüscosept solution onto the turf at low flow rates (5). This system is integrated onto the regular turf grooming equipment, the Hammer HB-240, which uses brushes and rods to disturb the turf and infilling and collect items left on the turf and evenly redistribute the infill as shown in Figure 2 (13). The mist then pushes the finer particles that were flung into the air by the grooming equipment down onto the turf, in addition to disinfecting the turf (1). According to a test of the field for the turf at Flatåshallen the height of the infilling is approximately 10 mm, which means that only 2/3rds of the area of the yarns is disinfected during a washing (14).

50 L of Nüscosept solution spread over 2800 m^2 of turf means a total spread of 17.86 ml/m^2 of turf if no infilling is present (5). Assuming equal coverage over the yarns this would equate to 0.55 ml solution per m^2 of yarns. Since the height of the infilling is 10 mm, the effective area of the yarns will be 21.7 m^2 yarn per m^2 turf surface (14).

Figure 2: The disinfectant spraying equipment on top of the standard grooming equipment used at Flatåshallen (5).

2.3 Microorganisms – General information and *Staphylococcus aureus*

2.3.1 General information about bacteria

Bacteria are single-celled microorganisms which come in various shapes, sizes, and lifestyles. Bacteria are prokaryotic cells since they do not have a nucleus (15). Their genetic material is typically found in a region called the nucleoid. Bacteria inhabit a wide range of environments, including soil, water, air, and even the current topic, which is artificial turf.

Many types of bacteria are harmless, and can be beneficial, but others can cause health problems to organisms, for example *Staphylococcus aureus* which will be talked about later.

In the laboratory, under favorable conditions, the growth rate of bacteria is exponential, given by: 2^n, where n is the number of generations. Four different phases of the bacteria growth cycles can be recognized: lag phase, exponential phase, stationary phase and death phase (16) these phases are shown in Figure 3.

-Lag phase: it occurs immediately after inoculation in the fresh medium. Even though there is no cell division, the cells are growing in volume and mass (16). The length of this phase depends on many factors: time required for synthesis of enzymes, the size of the inoculum, etc.

-Exponential phase: means balanced growth of the cells by binary fission (16). They grow at an exponential rate. The rate of exponential growth of a bacterial culture is expressed as generation time and the doubling time.

-Stationary phase: this phase means that some factor (not enough nutrients or space to grow) limites the growth rate of the bacteria, as exponential growth cannot be continued forever (16). It is during this stationary phase in which the bacteria colonies are counted.

-Death phase: viable cell population declines and decreases exponentially (16).

The growth curve provides valuable information about characteristics of bacteria and is essential for microbiological research, industrial microbiology, and medical diagnostics (16). By understanding the growth curve of bacteria, it is possible to optimize culture conditions, or predict population dynamics.

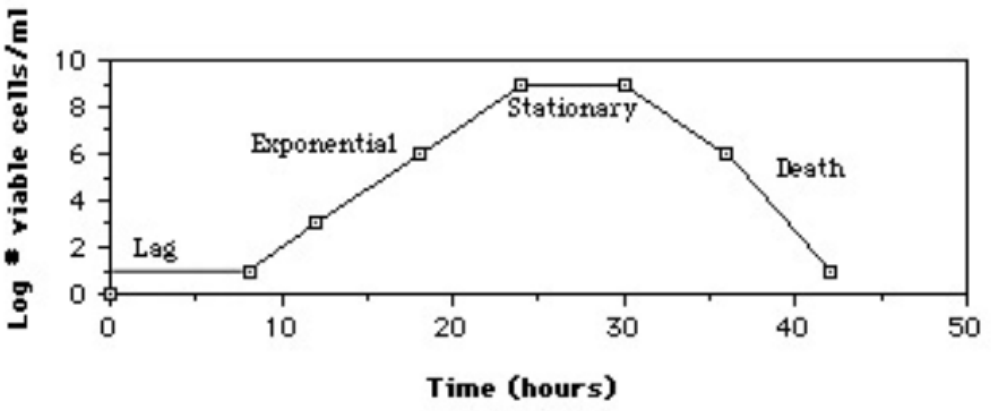


Figure 3: A graph showing the general growth curve for bacterial growth and its phases. The y-axis is the amount of bacteria and the x-axis is the time of growth. (16).

2.3.2 *Staphylococcus Aureus*

The main bacteria found on indoor artificial turf used for sport is *Staphylococcus aureus* (17). *S. aureus* is found on the skin and in the throat of humans and it is unlikely to cause an infection unless given access to the bloodstream. In general, *Staphylococcus aureus* infections are more probable and usually found in people with risk factors, being mostly harmless in healthy people (16).

This bacteria can resist the effect of penicillin, since it has the mec gen, which encodes PBP-2a, that binds penicillin, leading to bacterial growth (18). *Staphylococcus aureus* is difficult to fight, being really problematic for certain groups of people.

Staphylococcus aureus is commonly found on the skin and in the respiratory tract of humans and animals (19). While typically harmless, it can cause various infections ranging from minor skin issues to potentially life-threatening conditions. Infections caused by *Staphylococcus aureus* can manifest in various forms, including skin infections like boils, impetigo, and cellulitis, as well as respiratory infections such as sinusitis and pneumonia. It can also lead to more severe conditions like bloodstream infections and endocarditis. *Staphylococcus aureus* is notorious for its ability to develop resistance to antibiotics (20).

Staphylococcus aureus produces various virulence factors that aid in its ability to cause disease, including enzymes, toxins, and factors that help it evade the immune system (21). It can colonize

the skin and mucous membranes without causing symptoms, potentially leading to infection if it enters the body through a wound or during a medical procedure. Prevention measures include good hygiene practices while treatment typically involves antibiotics (19). Therefore, it is important to try to reduce the number of bacteria on artificial turf, as it may affect the health of the people who use it.

2.4 Microbiological quantification, labwork and techniques

2.4.1Bacteria collection, inoculation, and quantification

Regarding the sample collection, there are two main methods, wipe-rinse and swabbing in surface.

In the swabbing method, the surface is first swabbed, and the bacteria get attached to the swab (22). Then it mixed with the solution inside of the swab tubes and a vortex mixer. This diluent solution is cultivated on agar plates.

The wipe-rinse method was developed specifically for use on the Space Transportation System, but its high efficiency makes it possible to apply to other surfaces contamination control (23). This technique could be used in various areas of environmental microbiology where the ability to quickly, accurately, and economically measure surface contamination is important.

Due to the use of agar plates, counting bacteria will be required (24). One method for doing that is CFU (colony forming units) which is a manual counting method. In this case, these results are given in CFU/cm^2 using Equation 2 which is given as:

$$\frac{CFU}{cm^2} = \frac{\left(\frac{avrg.CFU}{plate} \cdot dilution\ factor\right)}{Sample\ area\ (cm^2)} \quad (2)$$

The recommended counting range is 25-250 CFU/plate (24).

2.4.2 Aseptic technique and cleanliness scale

It is crucial to prevent contamination in the culture medium in petri dishes (25). While allowing some airflow, the petri dish lid simultaneously serves as a barrier against contamination by other microorganisms. Placing the removed lid on the benchtop could contaminate the lid, while disturbing the air near the lidless plate could contaminate the culture medium contained within.

To maintain aseptic conditions, it is vital to prevent contamination of cultures and samples, and to ensure the safety of the people going into the lab. When removing caps and lids from liquid cultures, the flaming technique generates warm air convection, though it does not sterilize them outright. This convection effectively blocks the entry of particles into the opening (26). Quick and meticulous handling during plating is essential, as is maintaining a clean workspace.

In this case, bacteriological standards and measurements are required. The first one is finding a specific organism on a surface such as *Staphylococcus aureus*. The second standard is a quantitative aerobic colony count of <5 CFU/cm^2, based on a U.S study. Another study from the U.K. suggests that the aerobic colony count should be <2.5 CFU/cm^2 (27). However, the U.S study results are internationally recognized, and can be used as a reference.

2.5 Statistical methods – standard deviation and linear regression

In order to analyze the data, with all its uncertainty and random variation, statistics is used (28). One of the most common ways to validate or analyze data is standard deviation. Standard deviation shows the spread of the data, that is to say the accuracy, by setting it in comparison to the mean result. A high standard deviation means there is a lot of spread in the data, either due to an outlier, too few data points or simply high variance in reasonable results. Standard deviation is calculated as shown in Equation 3.

$$Standard\ deviation = \sqrt{\frac{\Sigma(x - \bar{x})^2}{N}} \tag{3}$$

Regression analysis can be used to quantify the relationship between two or more variables (28). A simple regression is the analysis of the effect that changing one variable has on another variable. While this, especially in controlled conditions, can give an accurate overview of the relationship between the two variables it will never be fully accurate as other variables will change

unintentionally in any real setting. Even still, a regression analysis can be used to show a clear correlation between two variables given enough data points.

2.5 Nozzle parameters of the mist sprayer, droplet size and behavior

2.6.1 Behavior of a liquid on a surface

To know the coverage of a liquid on a surface it is important to know the behavior of the liquid on the surface given the amount of liquid applied and application method. There are two main ways to calculate the area covered by a liquid these are: by assuming a certain thickness of the layer of liquid while knowing the volume of liquid applied, this is most accurate if the surface attracts the liquid such as water on a hydrophilic surface (29). The other way is to assume the water remains as individual droplets with a contact angle that is dependent on the interactions between the liquid and the surface, this is most accurate if the surface partially repels the liquid such as water on a partially hydrophobic surface. This is showcased in Figure 4, where the angle shown is the contact angle of the liquid on the surface.

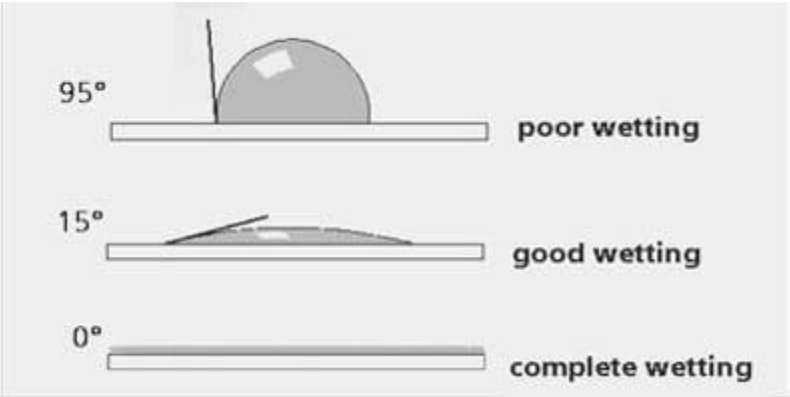


Figure 4: Examples of wetting for droplets at different contact angles (29).

2.6.2 Nozzle parameters and behavior

The nozzle used for testing has the parameters shown in Table 1 (30). Since droplet size decreases when flow increases, this means that the average droplet would be smaller than the mean value of D_v if flow rate is towards the high end of the shown spectrum and vice versa (31).

Table 1: Mist stream parameters for the Elergy GM-04 nozzle (30).

MEDIUM PRESSURE SYSTEM - MIST STREAM PARAMETERS					
Working pressure [bar]	:	3	6	8	10
Droplet size D_v [µm]			20 - 80		
Average K flow factor	:		0,15		
Flow rate* [dm³/min]	:	0,28	0,40	0,46	0,52
Effective stream range** [m]	:	0,8	-	1,2	-

Droplet size from a nozzle follows a normal distribution around the center point (32). This means that any coverage calculation that assumes that the water remains as droplets with constant volume, the coverage will be affected by not only the mean size of the droplet, but also the range.

2.6.3 Calculations for coverage

Polyethylene is fairly hydrophobic so the contact angle of water on it is 126° (33). It is unknown what the contact angle of 0.5% Nüscosept in water has on a polyethylene surface since a difference in surface tension would change the contact angle (34).

Using various formulas used for calculating the volume of a spherical cap Equations 4, 5, 6, 7 and 8 were devised (35). For these formulas α and θ are internal angles dependent on the contact angle of the droplet, $V_{original}$ is the volume of the drop and V_{cap} is the volume of a spherical cap that a drop of this volume would have if it were to land on a surface and have an angle α, $V_{theoretical}$ is the total volume of these, and being the volume for the theoretical droplet that has the same radius as the droplet on a surface with the internal angle α, this radius is $R_{theoretical}$, a_{real} is the radius of the surface area the droplet takes up. If a_{real} is assumed to be a perfect circle Equation 9 can be used to find the surface area covered by a droplet. Using these formulas, a known contact angle and known original volume the surface area taken up by a droplet can be calculated.

$$V_{original} = \frac{4 * V_{cap}}{2 - 3\sin\alpha + \sin^3\alpha} - V_{cap} \quad (4)$$

$$V_{theoretical} = V_{cap} + V_{original} = \frac{4}{3} * \pi * R^3_{theoretical} \quad (5)$$

$$\alpha = contact\ angle - 90° \quad (6)$$

$$\theta = 90° - \alpha \quad (7)$$

$$a_{real} = \sin\theta * R_{theoretical} \quad (8)$$

$$Covered\ area = \pi * a^2_{real} \quad (9)$$

At a contact angle of 126°, that is to as an α of 36°, it can be found by Equations 4 and 5 that $V_{theoretical}$ is 1.1235 times larger than $V_{original}$. This means that $R_{theoretical}$ is 1.0395 times larger than $R_{original}$, which further means that since θ is 54°, a_{real} is 84.10% of the length of $R_{original}$.

3 Materials and Methods

The materials used for all conducted experiments, as well as the procedure for said experiments are listed in this section. All experiments were conducted in a lab, as field testing was not required for the goals that were set forth to be achieved.

3.1 Equipment and Chemicals

Table 2 shows the equipment and chemicals used for tests done for this thesis. It also includes the producer and product number for these materials.

Table 2: List of materials and chemicals used for this thesis, including producer and product number.

Materials and chemicals	Producer	Product number
TSB	Sigma Aldrich	22092-500G
Agar	VWR Chemicals	20767.298
Nüscosept PRO	Dr. Nüsken Chemie GmbH	UN1903
Staphylococcus aureus pellets	Microbiologics	0179L
Autoclave	TOMY Digital Biology	TOMY SX-700E
Incubator	Termaks	B 9051
1 mL swab samplers	Copan	4E053S.A
Mist sprayer	Elergy	Elergy EFOG
Artificial turf	FieldTurf	Purefield Ultra HD 30-17 Alveo 3001-12

3.2 Method

3.2.1 Media preparation – making and plating of tryptic soy agar

Tryptic Soy Agar that was composed of 30 g Tryptic Soy Broth and 15 g agar powder in 1000 ml of deionized water. The solution was heated and stirred in a Pyrex bottle until all the powder was dissolved. It was then autoclaved in the same bottle at 121 °C for 15 minutes. The bottle was cooled slowly in the autoclave until 60 °C at which point it was removed and the solution was poured into petri dishes so that the solution filled 1/3rd of the volume of the dish while on a sterilized bench, making sure to heat up the mouth of the bottle with a flameboy between each dish. The dishes were left on the bench for 20 minutes to make sure the agar had set, at which point the lid was put on each dish and they were flipped. The dishes were then stored on a workbench overnight in an open plastic bag. The day after, the dishes were checked for condensation, and after making sure

there was none, they were stored in a closed plastic bag in a refrigerator at 4 °C to use later. This method was based on former laboratory work within microbiology (36).

3.2.2 Preliminary and proper flow tests

To assess the flow capacity of the mist sprayer, a sample of measurements spanning lengths from 5 seconds to a minute was recorded. This gave a linear relationship between the time and the volume, so flow was found to be consistent. These tests were performed by letting the mist sprayer run and seeing the difference in volume of the 2 L measuring cylinder it was taking water from when it was turned on to when it was turned off.

To see how much water would hit the pieces of turf a container/tray of size 10 cm by 20 cm was placed under the mist sprayer nozzle which was held up by a stand. The height of the nozzle was placed 45.5 cm above the tray. The mist sprayer was left running for 10-60 seconds for the tray to collect water and after the flow had stopped the volume of liquid in the tray was measured with a measuring cylinder, then the results were tabulated. Since the pieces of turf are 10 cm by 10 cm, two pieces of turf would be placed next to each other in the same spot as the tray used to collect the liquid was previously for the disinfection.

This test was repeated each day samples were taken to ensure proper values, as the setup will have minor differences each time. If, during the flow test or during the disinfection of the turf, the flow of the mist sprayer had clearly changed then a new flow test was conducted. The turf would also be moved for tests that required smaller amounts of disinfectant, so that a more accurate amount could be distributed since the mist sprayer would be active for less than a second had the turf not been moved. Regression analysis with the trendline forced through origin was used to find the flow over time.

When switching the flow from water to Nüscosept the hose sucking up the liquid was emptied before being put in the Nüscosept to not change the concentration of the Nüscosept solution. Each time the mist sprayer was changed between water and Nüscosept solution it was left on for enough time for all the liquid in the system to be replaced. This was done by seeing when regular flow resumed after the change of liquid, at which point the mist sprayer was left on for a few seconds

to make sure the liquid inside had been replaced. The setup of the hose of the mist sprayer and the collection tray inside of the fume hood is shown in Figure 5.

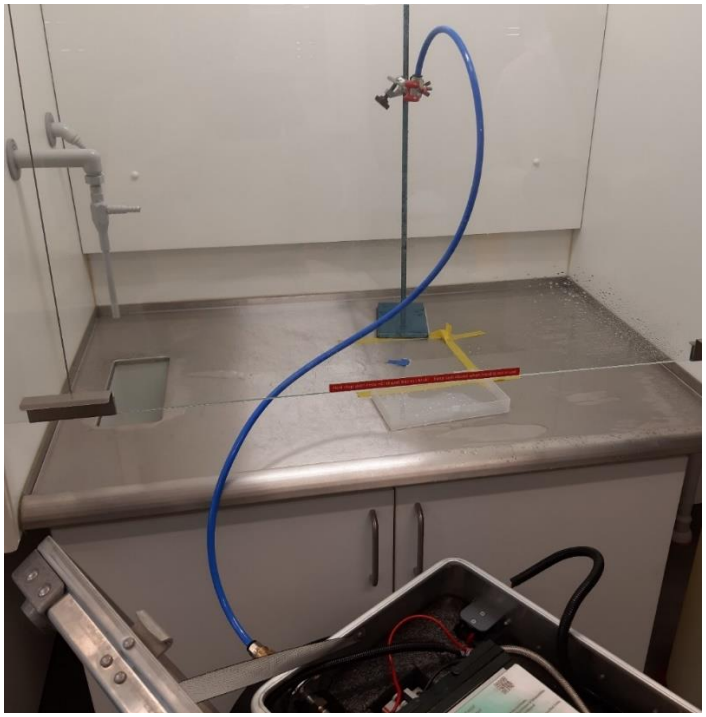


Figure 5: Picture of the experimental setup, the blue tape marks the point below the nozzle and the yellow tape is a 20 cm by 20 cm square around the center which the collection tray is placed in accordance with.

3.2.3 Sample collection, turf contamination, disinfection and agar plate incubation

To collect the samples a cotton swab was run across the top of the larger, slitfilm, yarns of the artificial turf as well as in-between the slitfilm yarns, across the smaller, texturized, yarns as separate runs. These layers are shown in Figure 6, with the top of the taller, thicker yarns being the upper layer and the top of the thinner more crumpled yarns are the lower layer. The swab was run along the yarns in the pattern shown in Figure 7, with the long stretches being along the 20 cm length of the turf. Three parallels were done for each collection run for each set of turf. All tests were taken while the turf was on a sterilized bench. Then the turf was placed in a fume hood and sprayed with Nüscosept for a specified amount of time decided on based on desired theoretical coverage and used the measured flow as the way to find said time. For the tests some of the pieces of turf were left in an ambient atmosphere and some were artificially contaminated in order to

attempt to simulate the amount of bacteria that would be found on a real football pitch. This was done in multiple ways, such as by spitting on the turf, stepping on the turf for a few minutes or applying a *Staphylococcus aureus* solution. The *Staphylococcus aureus* solution was made by solving a *Staphylococcus aureus* pellet in 250 mL of water. The type of contamination each turf received is given in Table 3.

Figure 6: Side profile of a segment of artificial turf. The top of the thicker white yarns is the top layer, and the top of the thinner white yarns is the lower layer.

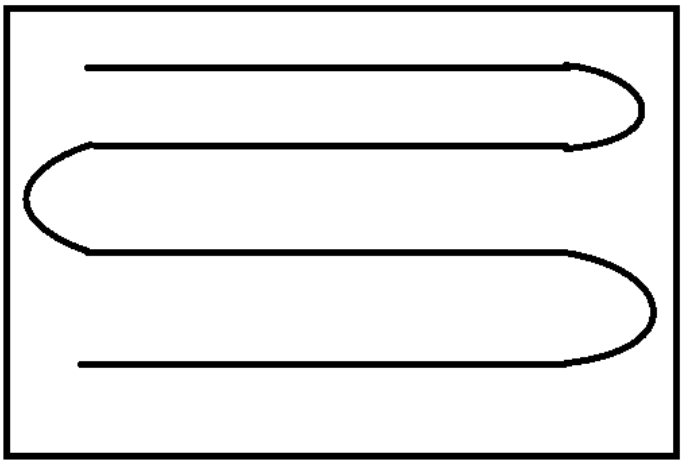


Figure 7: The pattern the swab samplers were brushed across and through the artificial turf.

After the turf had been disinfected it was allowed to dry, with time waited varying from 10-30 minutes, samples were collected the same way, three parallels each. Then the samples were vortexed for 5 seconds before 75 µL of the samples were dripped onto agar plates and spread using

a glass rod which was sterilized with spirit and a flameboy. Since the total amount of liquid in the samples was 1 mL the tests have a dilution factor of 0.075. After the suspension had settled the plates were put in an incubator set to 36 °C. After 24 hours the plates were checked to see whether they were growing as they were supposed to and counted if they looked likely to become overgrown. After 48 hours of incubation the number of bacterial colonies on each plate was counted using a marker and a clicker. For some plates there were smaller colonies inside of a larger colony of a different bacteria, when this occurred both colonies were counted.

Each turf was introduced to external bacteria in different ways. The way each turf was contaminated is listed in Table 3. Table 3 also shows which flow curve was used, and how long it was sprayed. An explanation of the flow curves is given in section 4.2.2 and the flow curves are given in Appendix 1. Along with the curve, it is possible to calculate the volume of water in the turf. Lastly, Table 3 has the time each turf was drying before being tested for bacteria.

Table 3: Information about the process used for the disinfection of each turf. This includes how each turf was exposed to contamination, which flow curve measured the volume of disinfectant on the turf based on the amount of time it was sprayed, which is also included in the table, and it includes the time each turf spent drying before being sampled the second time.

Turf	Contamination method	Flow curve	Spray time (s)	Drying time (min)
1	Ambient atmosphere	CW1	2.0	10
2	Ambient atmosphere	CW2	1.2	10
3	Ambient atmosphere	CW2	3.1	10
4	Stepping with shoes used outdoors	CW3	1.1	10
5	Stepping with socks	CW3	2.4	15
6	Saliva	CW3	1.2	20
7	*S. aureus* solution	CW4	1.3	30
8	*S. aureus* solution	CW4	3.0	30
9	Saliva	CW4	1.3	30
10	Saliva	CW4	3.2	30

4 Results and Discussion

The results from microbial testing, shown in section 4.1, as well as the parameters of each washing based on Table 3 in section 3.2.3, shown in section 4.2 are presented in this section. The rest is either calculations made off of the numbers presented in sections 4.1 and 4.2 or discussions regarding these results and calculations. Equation 2, shown in section 2.4.1, is used in the calculation of CFU/cm^2 and Equation 3, shown in section 2.5, is used to calculate standard deviation.

4.1 Quantification of bacterial colonies on the agar plates

The amount of colony forming units counted on each plate is shown in Table 4. There are three main terms used for this data: turf, which is for each piece of turf both before and after disinfection, series, which is a subset of the turfs, and parallel, which is a subset of the series. In total there are 10 turfs with each turf having four series, totaling 40 series, with each series having three parallels for a total of 120 parallels.

For each series the three numbers represent a different aspect of the set of samples. The first number represents whether the samples were taken before or after the disinfection, with 1 being before and 2 being after. The second number represents whether the samples were taken on the upper part of the yarns or the lower part, with 1 being the upper part and 2 being the lower part. The third number represents which piece of turf the samples were taken from, ranging from 1-10. For example 1,1,1 means the sample was taken from the top of the yarns and before disinfection from turf 1. Each of these series had three parallel samples taken, shown in Table 4 as parallel 1, 2 and 3. The red cell is an estimation based on partial counting due to overgrowth of a difficult to count bacteria on the agar plate. These results are used for calculations later on in section 4.4.

Table 4: Bacteria colonies counted on all plates throughout the experiment. The series represents if the turf was before or after the disinfection, whether it was swabbed on the upper- or lower layer and which turf it was respectively. The red cell is from an overgrown plate and is thus estimated.

Parallel	1	2	3
Series	CFU/plate		
1,1,1	3	2	6
1,2,1	5	3	2
2,1,1	0	1160	2
2,2,1	3	10	5
1,1,2	16	586	16
1,2,2	6	3	2
2,1,2	2	0	0
2,2,2	2	15	3
1,1,3	1	0	40
1,2,3	22	5	1
2,1,3	1	53	8
2,2,3	2	4	2
1,1,4	30	37	6
1,2,4	89	73	122
2,1,4	29	5	17
2,2,4	48	62	457
1,1,5	21	27	20
1,2,5	126	93	67
2,1,5	7	5	131
2,2,5	75	61	2
1,1,6	1892	2350	2188
1,2,6	4028	3386	3077
2,1,6	1572	73	534
2,2,6	1891	1450	2790
1,1,7	50	40	195
1,2,7	2	5	2
2,1,7	4	15	0
2,2,7	40	12	5
1,1,8	5	1	59
1,2,8	123	4016	6
2,1,8	2	5	0
2,2,8	3	1	1
1,1,9	1740	1813	811
1,2,9	1063	2778	1028
2,1,9	60	167	82
2,2,9	807	821	383
1,1,10	1284	1407	993
1,2,10	983	2610	1982
2,1,10	119	270	244
2,2,10	857	1593	1915

4.1.1 Evaluation of colony counting method and colony counts

One major issue with the colony counting is that many of the plates, while not overgrown, had enough colonies that the count would necessarily become inaccurate past a certain point as they far exceeded the 25-250 CFU/plate range (24). This could have been mitigated by further diluting the solution in the swab samplers or by applying less of the solution onto a plate. But this was not done since it was impossible to know whether the sample would have a high or low CFU count before incubation, so the risk was deemed not worth potentially losing data.

4.1.2 Significant values and outliers for CFU counts

The most important values for interpreting the data in Table 4 are that of turf 6, 9 and 10. As shown in Table 3 turfs 6, 9 and 10 were contaminated with saliva, the added significance of these values will be elaborated upon in section 4.2.1.1 and 4.4.2.1. Additionally, some of the series in Table 4 contain clear outliers, these series are 2,1,1, 1,1,2, 1,2,8.

4.2 Additional information about each turf sample

4.2.1 Contamination and spray parameters of each turf

As shown in Table 3 in section 3.2.3, each turf was contaminated in a different way, as well as having a different flow curve, spray time under said flow curve and drying time. Turfs 1-3 were contaminated in an ambient atmosphere, turfs 4 and 5 were contaminated by stepping on the turf shortly before sampling, turfs 6, 9 and 10 were contaminated with saliva, and finally turfs 7 and 8 were contaminated with a *Staphylococcus aureus* solution.

4.2.1.1 Evaluation of contamination methods and drying time

As shown through Tables 3 and 4, saliva gave the best results, compared to stepping on the turf or ambient conditions. Of course, the pieces of turf left in ambient conditions had considerably fewer colonies. The main reason for this is that they did not have any serious contamination, since they were left in the lab with few people getting near them, reducing the possibilities of collecting bacteria while any preexisting bacteria on the turf died.

It is a difficult task to count how many bacteria live inside a human's mouth, but some studies have shown that it can go as high as 20 billion bacteria, with 500-650 species, including *Streptococcus*, *Neisseria*, *Veillonella*, *Prevotella*, and *Haemophilus*, which are the most common ones (37). This can surely change depending on a person's diet and hygiene, and the bacteria can live in the teeth, tongue, mucosa, etc. Regarding their growth, while observed in a petri dish, these bacteria can grow rapidly within 20 minutes, even doubling their numbers. To understand how many bacteria can inhabit a mouth, it has been proven that one person swallows 1 Liter of saliva containing about 100 million bacteria (38). A mouth is warm, wet and a rich organic environment, which is ideal for bacterial growth. Even though bacteria can form totally different colonies depending on the part of the mouth that is from, it is saliva that connects all of them, and is the fluid that contains most of them (39).

Now regarding bacterial formation on the shoes or socks, a study conducted by Good Morning America and the University of Arizona, showed that a shoe can be more contaminated and with more living bacteria, with around 66 million bacteria and 9 different species, than a toilet seat, with roughly 1000 bacteria (40). Comparing these numbers of bacteria, with the amount found inside a human mouth, it is only natural that the tests conducted with saliva had more colonies.

Finally, it is worth mentioning that little time passed since the infection of the turf and the spraying. As mentioned before, bacteria collected inside petri dishes can increase their numbers rapidly. However, this is not a problem while on the turf since bacteria need specific conditions to grow, such as moisture, temperature, and a source of energy, which they do not have at ambient conditions, compared to a petri dish in an incubator (41).

4.2.1.2 Reasoning for variation in parameters

Each turf has different parameters which alter the efficacy of the disinfection, reliability of the data from the samples as well as the ability to compare different series. Due to the different parameters no two turfs underwent the same procedure and so they cannot be directly compared without considering how these differences would affect the results from each turf. As a consequence of the method not being properly tested before use there were no consistent parameters for the tests, and so, each parameter was iterated upon throughout the course of the experiments.

4.2.2 Flow curves

Figure 8 shows the volume of liquid collected in the tray used to measure the flow rate at a specific spot in the fume hood. Linear regression forced to intercept origin was used to find the relationship between how long the mist sprayer was active and the volume of liquid collected at the location of the tray. The curve given in Figure 8 is referred to as CW1 in Table 3. The point of the flow curves is to see the relationship between the time the mist sprayer is active and the volume of liquid that lands in the area the turf occupies. This makes it possible to find the volume of liquid given the time is known.

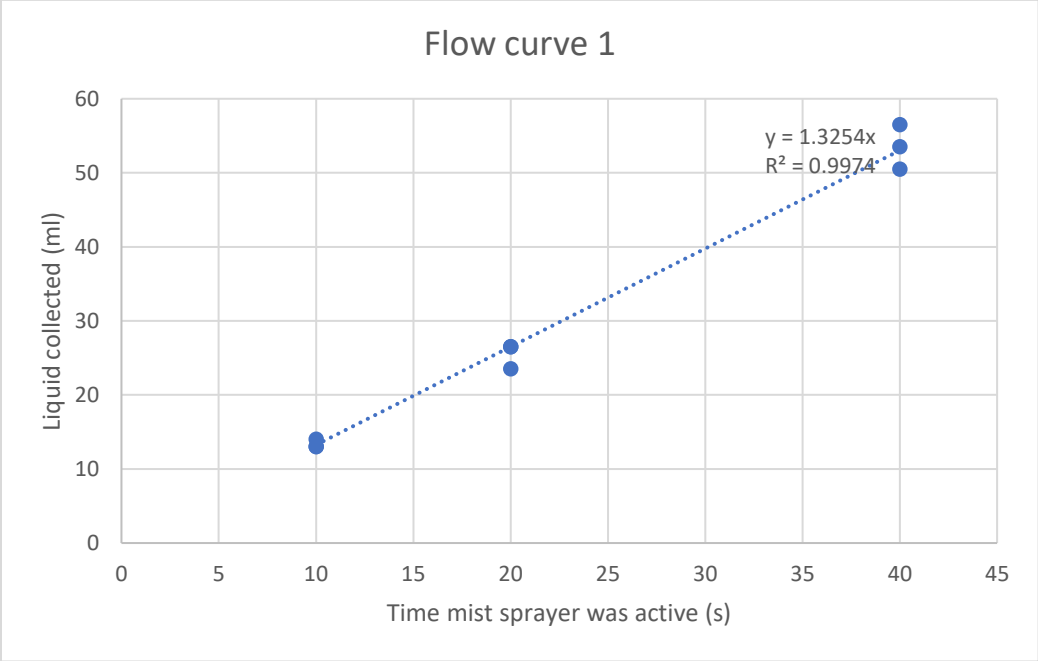


Figure 8: Flow curve labelled CW1. This curve is a linear regression fit through origin of the flow tests taken on the day the turf 1 was disinfected.

4.2.2.1 Evaluation of flow curves

Due to erratic behavior of the mist sprayer, which is elaborated upon later in section 4.6.4.2, each flow curve is made up of fewer data points than would be ideal to be sure the curve is fully consistent. This is largely the case for CW2 and CW3 as the mist sprayer was not exhibiting consistent behavior for very long when those tests were taken so the number of tests had to be small. CW4 had a similar issue, though it seemed more erratic in the short term and so the

individual test results exhibit large variation. CW2, CW3 and CW4 are all shown in Appendix 1 along with CW1.

There is undoubtedly some error in the measurement of the liquid in the tray, not only from the measuring cylinder used to measure the volume of water but also from a discrepancy in how the collection tray was set up. This is further elaborated on in section 4.6.1. To try to make up for this error the flow curve was forced to intercept the origin. This was also done to make the results more accurate to the theoretical value, which would necessarily be 0 ml collected at 0 seconds. While forcing a curve to intercept the origin is not always correct even if it is closer to theory (42). It was also required to be able to use the flow curves at the shorter timeframes needed for disinfection.

4.2.3 Calculation of surface coverage

By using the flow curve and spray time given in Table 3 the volume of Nüscosept solution sprayed onto the turf for each test can be calculated. The calculated values for the volume of Nüscosept solution can be used to find the volume of liquid per m^2 if the turf were a flat surface as well as the volume of liquid per m^2 of yarns. By assuming a constant value for the diameter of the droplets of 40 µm the coverage of the polyethylene yarns can be calculated by using Equation 1, Equations 4-9 as well as and the values shown previously in Table 5. With the assumption that the droplets have a constant diameter of 40 µm the value for the radius of the surface covered by the droplet will be equal to 16.82 µm as shown in section 2.6.3 in the theory Since each droplet takes up roughly $3.351*10^{-8}$ ml of space this means that there are $2.984*10^{7}$ droplets in a milliliter of liquid. By using Equation 9 it can be found that each droplet covers $8.889*10^{-10}$ m^2 which means that each milliliter of liquid covers 0.0265 m^2 of area.

Table 5: Calculated values for volume of Nüscosept solution sprayed onto turfs 1-10, the volume of water per m^2 of a 200cm^2 flat surface as well as that surface of artificial turf, and the theoretical coverage of this volume of Nüscosept. The values for each turf is based on the values shown in Table 4 and the flow curves shown in Appendix 1.

Turf	Total volume of water on turf (ml)	ml/m2 (turf)	ml/m2 (yarns)	Percentage of surface area covered (yarns)
1	2.651	132.540	4.071	10.79923
2	1.190	59.496	1.828	4.847678
3	3.074	153.698	4.721	12.52317
4	0.442	22.121	0.679	1.802398
5	0.965	48.264	1.483	3.932505
6	0.483	24.132	0.741	1.966253
7	0.550	27.495	0.845	2.240267
8	1.269	63.450	1.949	5.169846
9	0.550	27.495	0.845	2.240267
10	1.354	67.680	2.079	5.514503

4.2.3.1 Discussion of surface coverage

The calculations for the numbers in Table 5 were done with an assumed droplet diameter of 40 µm and assuming that the droplets remain as droplets on the surface of the yarns due to their hydrophobicity, as opposed to assuming full wetting (29). The reason 40 µm was chosen as the diameter is because the flow from the mist sprayer was toward the upper end of the values shown in Table 1, so a value just below the average within the range of diameters shown in Table 1 was used (30,31). Additionally, due to the low amount of Nüscosept in the water it is assumed that the contact angle would not deviate from that of water and so a contact angle of 126° is used.

In reality, the surface coverage values are different for three reasons: the contact angle for 0.5% Nüscosept in water would be slightly different than 126°, the actual droplets are in a range of diameters instead of just 40 µm, and lastly, the disinfectant interfaces with the yarns at an angle so that the surface covered by the droplet would not be the theoretical ideal (32,34). Each of these incongruities means that the value deviates, but not by much, as a small change in contact angle will not change the area covered by a droplet by a large amount and it is outside the scope of this project to investigate the contact angle, so the assumption must be made. In addition, the choice to assume a constant diameter for the droplets was made largely due to convenience, and since the exact number would once again not change by much by making this assumption it was deemed to be an appropriate assumption. Lastly, the shape of the surface covered by the droplet would change

due to the verticality of the yarns as shown in Figure 9 (43). Having any amount of verticality to the surface that the droplet is resting on will distort the surface it covers, so the theoretical calculations done for a droplet on a horizontal surface do not hold. Since the exact shape of a droplet of 0.5% Nüscosept in water on angled polyethylene is not known, the assumption had to be made.

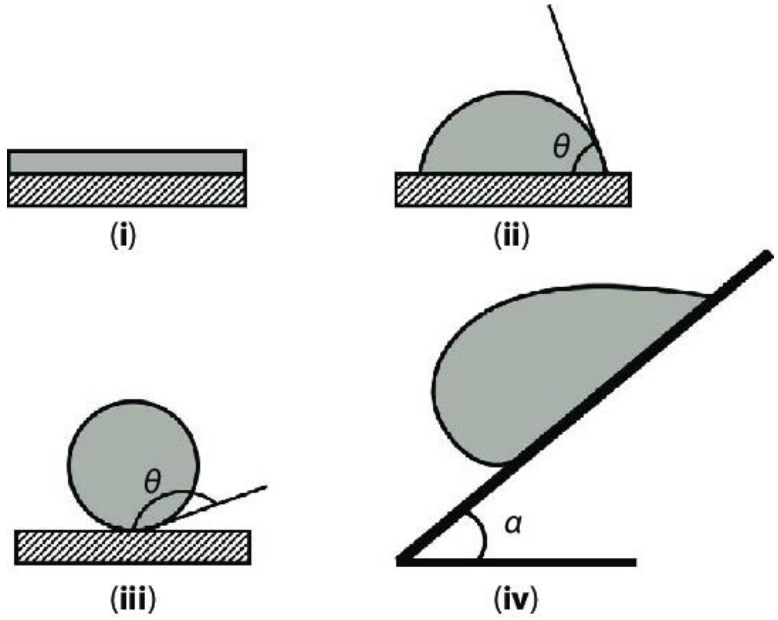


Figure 9: Examples of behavior of droplets on different surfaces, including an angled surface (43). (i) shows the case of complete wetting. (ii) shows the case of a droplet with a contact angle less than 90°. (iii) shows the case of a droplet with a contact angle of more than 90°. (iv) shows the case of a droplet on an angled surface, and that this affects the shape of the droplet.

The assumption most likely to cause a discrepancy between the real coverage value and the calculated coverage value is the assumption that the droplets remain as lone droplets and do not merge nor fully wet the surface. However as previously stated, investigating the behavior of 0.5% Nüscosept in water on Polyethylene is outside the scope of this project.

Although the momentary coverage is shown in Table 5, due to the movement of the disinfectant over time, the disinfectant would come into contact with more than the stated percentage of the yarns surface area. Since 0.5% Nüscosept in water is well above the threshold for lethality for bacteria the parts of the yarns that the disinfectant comes into contact with momentarily would still be disinfected, even if not entirely (7-9). This allows the effective coverage of the disinfectant to be higher than what is shown in Table 5, though to what extent is not known.

Additionally, a turf with infilling would have a higher theoretical coverage. Taking the turf at Flatåshallen as an example, the theoretical coverage would be 50% higher since the infill would cover one third of the surface area of the yarns (14). The real effect of this difference is small as will be shown later and discussed properly in section 4.6.2.

4.3 Appearance of agar plates

Pictures of agar plates from series 4-6 are shown in Figure 10 and series 7-10 are shown in Figure 11. In both pictures the plates are laid out in no particular order.

The numbers on the plates shown do not match up with the numbers shown in Table 4 for two reasons. 1. The numbering system that was used was different but was changed during the writing of the thesis to be clearer and more general. 2. During the tests the second turf that was sampled was erroneously sprayed for too long, which resulted in unusable data as it was unknown how much liquid was sprayed onto the turf and choosing not to sample the turf after disinfection. Despite this, the turf was kept in the data and so each later turf has a number one higher than what is shown in the results presented.

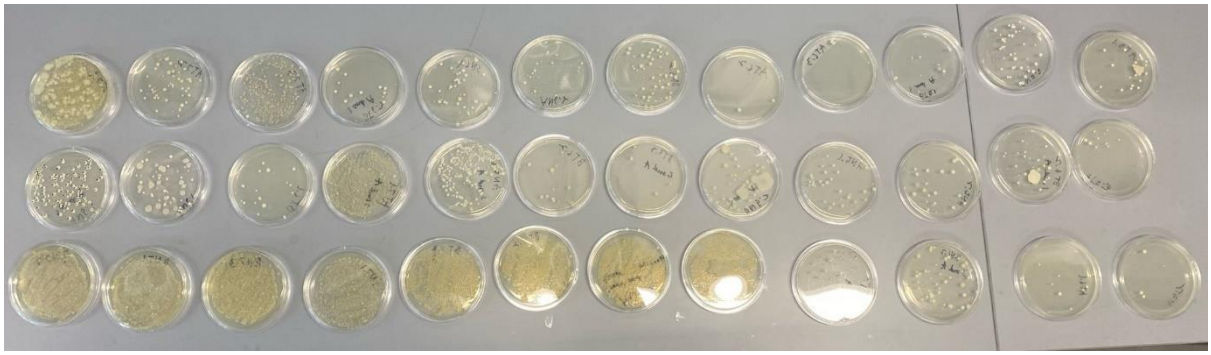


Figure 10: Agar plates from series 4-6 laid out in no particular order.

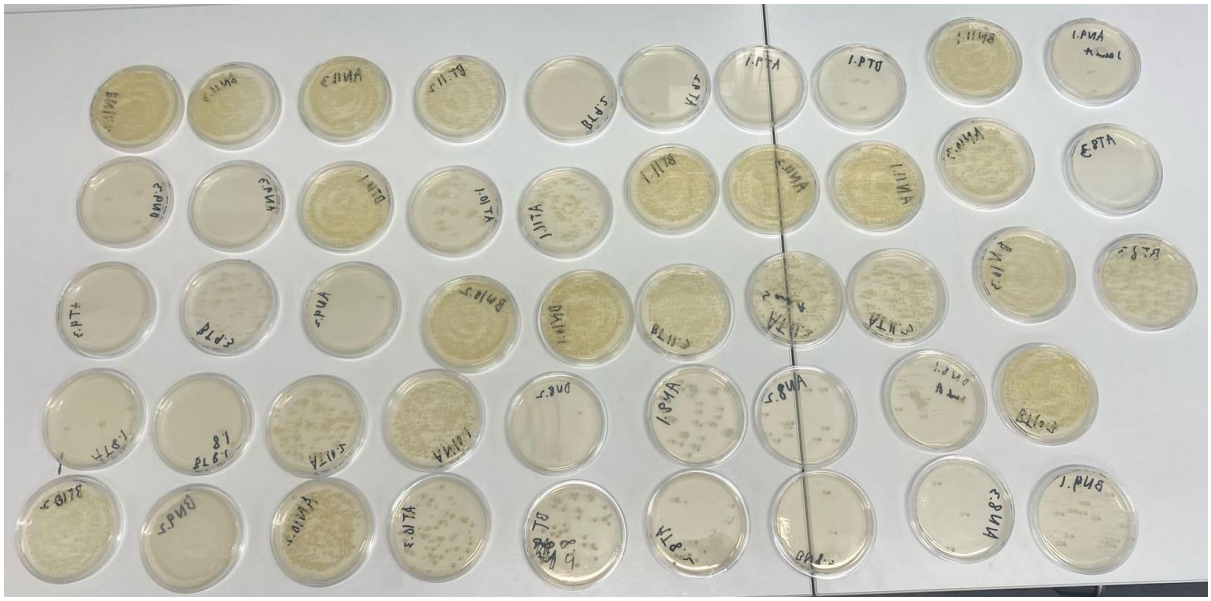


Figure 11: Agar plates from series 7-10 laid out in no particular order.

4.3.1 Evaluation of results of agar plates

After preparing the agar solution and the agar plates, the plates were kept in cold storage for later use. When collecting the plates to inoculate the samples after disinfection and sampling it was found some of the plates in the bags of plates used for turfs 4-6 were contaminated with bacteria, these clearly contaminated plates were discarded. This suggests that some mistakes were made while storing them or while preparing the agar plates.

Another possible cause for incorrect plate counts is that the plates were not in a bag or other enclosed space when incubated, which could have caused them to dry out, leading to lower CFU counts than what they really were (44). This is likely not a large issue since the plates were only incubated for 48 hours.

4.4 Calculations of colony forming units

4.4.1 CFU/cm^2 for each series

In order to visualize the number of colony forming units present on each piece of turf, as well as show the standard deviation for each turf, the charts shown in Figures 12-15 were made.

For each value in Table 4 the CFU/cm^2 was calculated using Equation 2. By taking the average of each parallel for a series the average CFU/cm^2 was then found for each series. This, as well as the standard deviation, calculated by using Equation 3 for these same values, are shown in Figures 12-15 (28). The columns are the average CFU/cm^2 for a series, while the vertical lines represent the standard deviation for that same series. For each column, if the standard deviation line falls below 0 then the standard deviation for that series is larger than the average CFU/cm^2. Otherwise, the standard deviation is as high as the line goes above or below the top of the column.

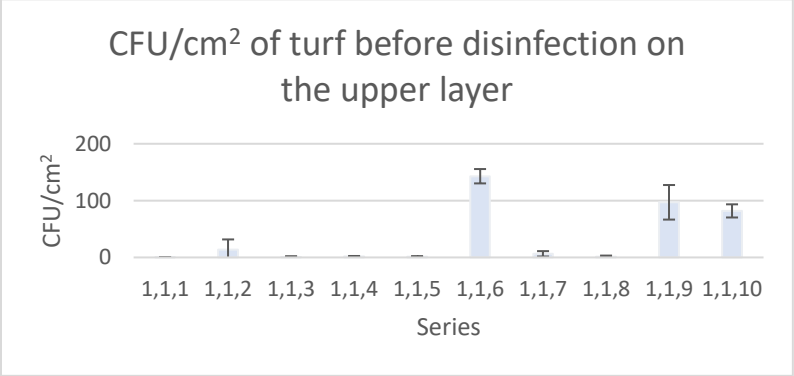


Figure 12: Calculated CFU/cm^2 with standard deviation of all series taken from the top part of the yarns before disinfection.

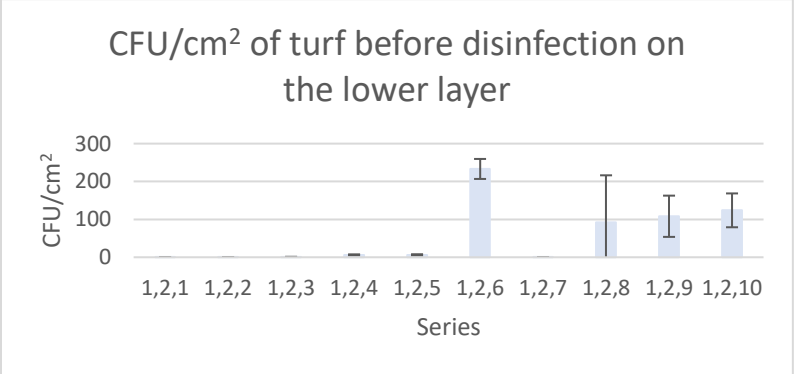


Figure 13: Calculated CFU/cm^2 with standard deviation of all series taken from the lower part of the yarns before disinfection.

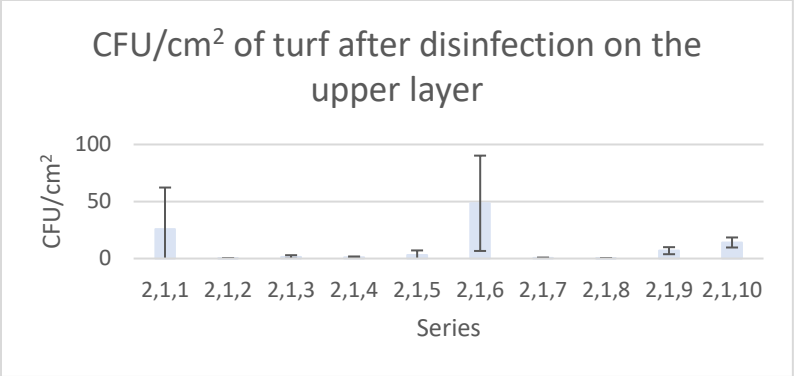


Figure 14: Calculated CFU/cm² with standard deviation of all series taken from the top part of the yarns after disinfection.

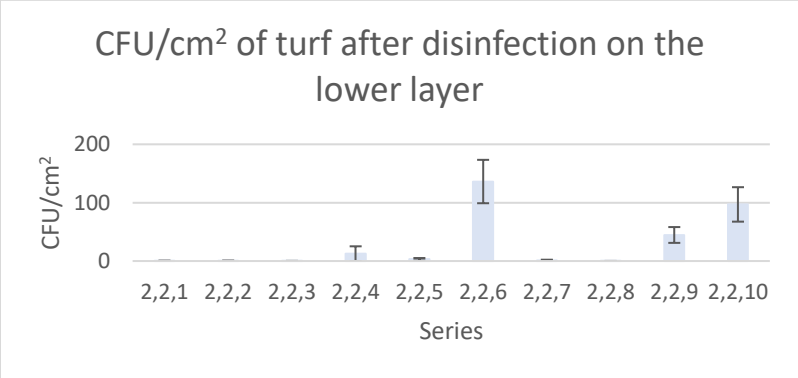


Figure 15: Calculated CFU/cm² with standard deviation of all series taken from the lower part of the yarns after disinfection.

4.4.1.1 Evaluation of standard deviation and outliers

Aside from a few series in which one value was an outlier, as well as series 2,1,6, the standard deviation generally lies around 30-50% of the value, though for some of the smaller values the standard deviation is well over 100% (28). Given the low number of parallels for each series this is a fairly low standard deviation, though the low number of overall trials and parallels makes it difficult to say whether this is a fluke or high consistency.

The reason outliers were not removed from the dataset is because the series that contained outliers are not the ones that are important for further analysis. Additionally, while the removal of these outliers would likely make later data, such as the values in Table 6 of section 4.4.2 more accurate, the affected values would still be largely inconsistent with the rest of the dataset.

4.4.2 Remaining colony forming units left on turf after disinfection

Table 6 shows the percentage of colony forming units left on each of the ten turfs after disinfection both on the upper part of the yarns and on the lower part.

Table 6: Percentage of bacteria colonies left on turfs 1-10 after disinfection on both the top and lower layer.

Turf	% left after on top	% left after on bottom
1	10563.6364	180
2	0.3236246	181.818182
3	151.219512	28.5714286
4	69.8630137	199.647887
5	210.294118	48.2517483
6	33.8880249	58.4405681
7	6.66666667	633.333333
8	10.7692308	0.12062726
9	7.08065995	41.3021154
10	17.1824104	78.2959641

4.4.2.1 Evaluation of remaining CFU/cm^2

For the discussion of the colony forming units in Table 4, many parameters are going to be compared for each of the turfs, such as the type of contamination and drying time (Table 3), and total amount of liquid sprayed on the turf (Table 6).

Regarding the first three turfs, their trials were conducted with the same drying time after disinfection. Comparing the results based on the spraying, it would make sense that the piece of turf with the lowest amount of liquid sprayed on it had the highest ratio of CFU left, and the piece of turf with the highest spray time had the lowest ratio of CFU left. However, since the results from the first turfs (ambient conditions) were not conclusive, they do not follow what was said above. In theory, turf 3, should have the lowest percentage of CFU left after disinfection, which is true for the bottom layer, but not for the top. In the bottom layer, turfs 1 and 2 have similar percentage of bacteria remaining (Table 6). In the top layer, the second turf had the highest effective disinfection rate, with almost 100% of disinfection, which does not make sense, since this turf had the lowest spray time; and the first turf having an unreasonably high amount of CFU, even more than before disinfection. Turfs 1, 2 and 3 are all unreliable tests, as they have both high standard deviations across the board, but also have small enough CFU values to be greatly affected by random error.

In turf 4, the turf was contaminated differently, stepping with shoes used outdoors. As expected, turf 4 has more CFU than turf 2, with a shoe having way more bacteria (40), than ambient conditions inside a lab, where the only contamination comes from people walking by. It is worth mentioning that the percentage of remaining bacteria (Table 6), reflects this difference in CFU, since both turfs had the same spraying time, turf 4 have more bacteria left after disinfection on top, which is the most affected zone by the disinfectant.

Turfs 6 and 9 had a similar volume of disinfectant sprayed, as well as type of contamination (saliva). For number 6, the turf was left drying for 20 minutes, and number 9 for 30 minutes. Turf 9 having 7.08% remaining on the top of the yarns while turf 6 has 33.88% remaining means that turf 9 had an 79% more effective disinfection at the top of the turf. This could be caused by either the longer drying time leaving the disinfectant with more time to take effect, the slightly larger volume of disinfectant on the turf or simply by random error. Which of these is the main cause, or if it is a combination of all three is unknown since it is a comparison of two results.

Comparing turfs 7 and 8, both contaminated with *Staphylococcus aureus*, and a drying time of 30 minutes. These two sets of turf gave inconsistent results, with the pieces of turf having less bacteria left in number 7 on the top layer, with a spraying time of 1.3 seconds, which is a third of the sprayed time of turf 8. For said turf, there is a highly inconsistent result in the sampling collection of the bottom layer before disinfection, counting thousands of colonies (Table 4), and decreasing to 1 colony after disinfection. This led to a disinfection rate of almost 100%. Neglecting the abnormal result from turf 8, the percentage of remaining colonies after disinfection increases. Again, between turfs 9 and 10, the same type of contamination was used (saliva), and drying time equal to 30 minutes. Just as in the previous case, turf 9 was sprayed for a third of the time in number 10, and against expectations, had less of its bacteria left.

Turfs 7 and 9, and 8 and 10, have similar total amounts of disinfectant sprayed and drying time, with different types of contamination. Saliva was more efficient contamination-wise in turfs 9 and 10, with thousands of colonies. Turfs 7 and 8, in which the turf was sprayed with a *Staphylococcus aureus* solution, had slightly less bacteria remaining on top, compared to 9 and 10. Regarding the small difference, and that 7 and 9, and 8 and 10, were conducted in similar conditions, it is possible that during the experiment, some human error was made while configuring the set-up, or taking

samples. Results in the bottom layer, are again inconsistent with too much difference to be compared.

4.4.2.2 Incongruent data in Table 6

In general, the disinfection rates for the top of the layer of the turf is more consistent than the bottom layer. This is likely due to the lower disinfection rates for the bottom layer being lower, and so more prone to random error. Some of the causes of this error is discussed further in 4.6.3. The cause of the lower disinfection rates is likely that the distance from the top at which the samples in the bottom layer were collected, was too large for the Nüscosept to reach all the way and make a real difference before and after disinfection. Because the disinfectant has a hard time reaching the lower layer, this means that the disinfection rate itself is prone to random error, not just error in the collection of the bacteria. Now, comparing results in each turf individually, it would be expected to have a percentage of remaining bacteria inferior to 100%, so that there would be less bacteria after disinfection, meaning that the amount of Nüscosept sprayed was sufficient. This was not true in some of the turfs (Table 6). The most irregular value came from turf 1, in the top layer, with 10563.64% of bacteria left. If the outlier that is parallel 2,1,1,2 was to be removed from the dataset this value would be 27.27%, which is a realistic value.

For each other turf with more than 100% bacteria remaining after disinfection in Table 6, such as turfs: 1, 2 ,3, 4, 5 and 7 the difference is less significant, compared to each previous series. For these series it is likely that mistakes were made during the procedure, or while counting the colonies, though the results may be within random error. Some possible causes of the inconsistencies within this section are errors during the flow tests conducted before the disinfection trials, human mistakes with the sampling collection methods, problems with the stored agar plates, or differences in the set-up for the experiments conducted in separate days. Especially, the first three turfs were inconsistent with the results, the main cause for this was, besides the mentioned reasons, the “contamination phase”, which took place in the laboratory, with barely any contact with people or anything that could cause a greater contamination. Another explanation would be that since the CFU count is lower in the first three pieces of turf, it is more susceptible to random error, and could have caused the incongruent results.

4.4.2.3 Height difference and lopsided distribution

Each piece of turf that was sampled and disinfected had a slight difference in height of both the upper level of the yarns as well as the lower level due to different amounts of bending of the yarns. This difference is largest for the upper level of the yarns, as these are not bunched up as tightly as the lower level. This might cause random error in the results, as the disinfectant will be more or less likely to reach the lower level of the yarns before evaporating.

Another issue that could cause the disinfection to be inconsistent is that with the experimental setup used for this experiment the disinfectant did not cover each section equally. As the water was being collected for the flow tests this was noticed but was accepted as a fairly unintrusive flaw of the setup. The effect of this is amplified as the turf is moved further from the nozzle in order to have a lower effective flow rate. This means that certain parts of the turf would likely be more disinfected than others, however since CFU/cm^2 measures an average of the surface it minimizes the error, though it does not eliminate it.

4.5 Evaluation of overall results of the experiment

Focusing on turfs 6, 9 and 10, there is shown in Table 6 to be a clear difference between the disinfection rate of the top of the yarns and the disinfection rate approximately 10 mm below the top of the yarns. Though while the individual results for each series could be deemed to be trustworthy due to the fairly low standard deviation as shown in Figures 12-15 the overall results are less so. No clear relationship between the disinfection rate of the top of the yarns and the disinfection rate approximately 10 mm below the top of the yarns has been found.

There has not been shown a clear correlation between the dosage and the disinfection within the small amount of tests performed and so no clear conclusion can be drawn for whether the dose was too much or too little, or by how much. Additionally, the random error for the results is considerably high, so the number of parallels per series is likely too few.

4.6 Method validation

4.6.1 Experimental complications due to the sides of the collection tray

The discrepancy between the experimental conditions and the "real-world" conditions of dispersing disinfectant on a football pitch is an important aspect to consider in interpreting the results obtained. The use of a tray with edges or walls to collect the disinfectant liquid could influence the amount of liquid collected and so, the results. While conducting the experiments, many different positions for the tray were tested. One of them was laying the tray directly underneath the nozzle, and for the others, it was set around the nozzle. For the first case the walls of the tray could act as obstacles that interfere with the dispersion of the disinfectant, causing a significant amount of liquid to accumulate in the tray, whereas for a turf in the same position the liquid would disperse to a greater degree as it is not blocked from doing so.

On the other hand, if the tray is laying far from the nozzle, the particles may hit the outside part of the wall, meaning that liquid is being lost during the experiment, and therefore not being measured. This can affect the results, since the measurement of the liquid collected inside the tray helped in the task of trying to overcome the changing behavior of the mist sprayer and obtaining the exact amount of disinfectant being sprayed afterwards. Both losing liquid on the outside of the tray, as well as accumulating too much liquid inside it could lead to errors as the volume is not congruent with what is collected on the turf in later tests. Despite this, collecting water in a tray, or similar, was necessary in order to find the flow rate toward the specific spot where the turf was to be placed. The amount of random error decreases with the amount of time the mist sprayer is running. This means that in some cases the error is negligible, while in others where the sprayer was running for 5 or 10 seconds, the error will be higher.

However, this is the only method the group could use or at least thought of, which is why experiments had to keep going with the knowledge that there may be a slight error margin, with it being impossible to avoid.

4.6.2 Difference between setup and reality

There are many differences between the experimental setup devised for this experiment and the conditions of disinfection at a real football pitch. One difference in the way the disinfectant is applied is that the experimental setup aims the nozzle straight down whereas the regular grooming equipment aims diagonally down, as can be seen in Figure 5 and 2 respectively (5). The angle here could affect the disinfectant's ability to reach lower areas on the yarns. Another difference is that the turf in the experimental setup is not groomed moments prior to disinfection like the turf at Flatåshallen is (13). This means that the disinfectant does not push down dust particles as it is being sprayed onto the turf, which could possibly affect the way in which the liquid interacts with the yarns, and how well it spreads. It is not known whether this interaction with dust particles aids the disinfectant in covering more area.

Finally, the lack of any form of infill in the experimental setup makes the area of the yarns that the disinfectant can lay itself upon significantly larger (14). How outsized of an effect this difference has is difficult to determine since it has been clearly shown that the disinfectant, to a large degree, does not reach the lower third of the turf where the infill is located. Though it is possible that the interaction with the dust in the air caused by the grooming equipment would cause this effect to be greater than would be believed by looking purely at the data from these trials (13).

4.6.3 Troubles of collecting below the yarns

One possibly major issue with the data is that the samples collected on the lower level is that the head of the swab was in contact with the side of the slitfilm yarns in addition to the top of the texturized yarns as it was collecting samples. This means that the overall surface area the swab collected samples from is larger than that of the upper-level samples. How large of a difference this makes is unknown as no way to avoid this issue directly was found, and no similar tests were done for the upper level. One possible solution to this issue could be to also have the upper-level samples be taken from in between the yarns, so as to have a similar amount of area covered, while keeping a height difference between the sample collection spots.

4.6.4 Possible sources of error due to equipment

4.6.4.1 Expired swabs and Nüscosept

For the project, the use of swabs for sampling collection was needed. Unfortunately, the ones that were provided at the lab were expired, and it is not possible to be sure whether or not this affected the results, since there are no unexpired swabs to compare to.

Either way, usage of expired swabs can lead to problems with the results, if the equipment or packaging was deteriorated, or the capacity to collect and preserve microbiological samples was compromised. Besides, the liquid inside the vials can evaporate resulting in the dilution factor and thus CFU/cm^2 being inaccurate (45). It is unlikely that a decrease in the ability to preserve the microbiological samples would lead to a large error since the samples were not in the sample liquid for long.

In this case the Nüscosept disinfectant was expired by two months. Specifically, Nüscosept PROs primary active ingredients are Didecyldimethylammonium chloride and benzalkonium chloride as mentioned in the section 2.1 of the theory (7). Benzalkonium chloride, present in many different types of sanitizers, can be used safely after expiration date (46). Didecyldimethylammonium chloride, which is classified as a biocide, can also be used some months after its expiration date and phasing out (47).

Because of this it is improbable that the expired Nüscosept could have affected the results, or at least did not do so in a way that can compromise the reliability of said experiments, though the efficacy might be slightly lower than intended, but not noticeably so.

4.6.4.2 Changing behavior of the mist sprayer

Another problem during the lab experiments was the mist sprayers behavior, which kept changing temporarily. This change in the behavior affected the flow. That means that flow tests needed to be done each time before disinfecting the turf to minimize the error as much as possible. This flow test was explained in section 3.2.2. Since the turf spraying experiments only lasted 1-5 seconds, it is unlikely that the mist sprayer behavior changed within those seconds.

Either way, it is worth mentioning that after the flow tests, it was necessary to empty the sprayer to get all the water out so that Nüscosept entered the system. During this process, there is the

possibility that the mist sprayer changed behavior again, but as previously mentioned, it is not possible to avoid this problem unless Nüscosept solution is used for the flow tests, which would be wasteful and unnecessarily dangerous. In addition, if during the experiment with the turf the flow was obviously different from the flow test that it was clear a new flow test was needed then one was conducted. If the mist sprayer behavior changed during an ongoing flow test, a new one was started to ensure the same behavior during and after the flow test.

4.6.4.3 Lack of results

Perhaps the biggest issue of this whole investigation is that there have not been a large number of successful trials and as such the conclusions drawn are far from conclusive. The reason for this low number of trials is a low supply of disposable equipment, mainly the swab samplers. Due to poor planning in regards to time and equipment there was not time to resupply this equipment and as such the tests had to be cut short before a large amount of tests could be performed.

This is especially noticeable for turf 10, wherein the disinfection is shown to be less than for turfs 6 and 9, both of which had a smaller dose. Whether this is caused by random error, or is the makings of a trend is impossible to tell due to a lack of repeated tests. In addition, the lack of usable results on most of the turfs would not be an issue if not for the lack of tests done.

4.7 Recommendations for further research

The main recommendation for further research is to redo the work and method outlined in this thesis with far more tests being run and a more systematic approach to the dosage of each turf. In addition, the alteration to the method brought up in section 4.6.3 could be used to check the difference between collecting atop the yarns and in between them.

Previous theses have analyzed the microbial growth on artificial turf of which it was attempted to replicate in this thesis (17). For this thesis this was assumed to be adequate for the relatively low exactness that this setup replicated these real conditions. However, further analysis of bacterial samples would be needed to be able to assume the correct amount of bacterial growth on the turf.

Finding out to what degree the total area of the yarns affects the disinfection of the yarns. Does the surface of the yarns lower than what was investigated here get covered by enough disinfectant to warrant consideration for calculation of an optimal dose?

Analysis of the behavior of 0.5% Nüscosept in water that were not in the scope of this thesis would greatly aid in being able to calculate an optimal dose. This would include the behavior of the solution on vertical strands of polyethylene, and if it does collect as droplets, an investigation of the contact angle. The effect of the angle of the nozzle would also be helpful in order to determine how to best make an experimental setup that replicates real conditions.

The effect of the disinfectant on the turf in the long term could be analyzed in order to determine whether the toxic chemicals in Nüscosept PRO are harmful to the turf or could cause a buildup of either organic material or chemicals.

Finally, another attempt to calculate an optimal dose for a section of artificial turf based on the surface area of the yarns and desired disinfection rates both above and below the top of the yarns should be conducted.

5 Conclusion

This thesis conducted tests of various doses of 0.5% Nüscosept PRO in water on artificial turf to evaluate the relationship between the disinfection rate on the top of the yarns and the section 10 mm below the top of the yarns. For all the samples no exact relationship was found, though it was made clear that that the top of the yarns benefited from a higher disinfection rate than the section below. While the top section had disinfection rates from 66%-89% the lower section only had 22%-59% disinfection rate.

The goal to develop and test an optimal dose of the disinfectant on artificial turf based on the surface area of the yarns ended in failure.

There are many uncertainties in the data that cannot be made up for through statistical analysis, both due to a lack of tests and due to a lack of knowledge regarding the errors' effect on the result. The errors, both inherent to the method, such as errors in the plating and sample collecting, as well as those caused by lack of understanding are significant. Though not significant enough to ignore the stated difference in disinfection rate across the height of the turf.

References

1. Operator of the artificial turf at Flatåshallen; 30.04.2024. Email correspondence.

2. Bauer B, Egebæk K, Aare AK. Environmentally friendly substitute products for rubber granulates as infill for artificial turf fields [Internet]. Norwegian Environmental Agency; November 2017 [Cited 20.05.2024]. Available from: https://www.miljodirektoratet.no/globalassets/publikasjoner/m955/m955.pdf

3. Høiberget SH, Ekroll GH. Microbiological Assessment of Disinfection on Indoor Artificial Turf. [Bachelor's Thesis]. Trondheim: Norwegian University of Science and Technology; 2023.

4. Cabral JP. Water micrology. Bacterial Pathogens and Water. Int J Environ Res Public Health. 2010;7(10):3657-3703.

5.Aas B. Disinfection of synthetic turf surfaces. Trondheim: COWI; 23.06.2023.

6. Dr. Nüsken Chemie GmbH. Desinfektion [Internet]. Bremerhaven: Dr. Nüsken Chemie GmbH [Cited 20.04.2024]. Available from: https://www.drnuesken.de/desinfektion/

7. Dr. Nüsken Chemie GmbH. Nüscosept PRO safety data analysis according to 1907/2006/EC, Article 31, section 2. Dr. Nüsken Chemie GmbH; 24.09.2019 [Updated 19.08.2019; cited 20.05.2024].

8. Yoshimatsu T, Hiyama K. Mechanism of the action of didecyldimethylammonium chloride (DDAC) against *Esherichia coil* and morphological changes of the cells. Biocontrol Sci. 2007;12(3):93-99.

9. Akimitsu N, Hamamoto H, Inoue R, et al. Increase in resistance of methicillin-resistant *Staphylococcus aureus* to beta-lactams caused by mutations conferring resistance to benzalkonium chloride, a disinfectant widely used in hospitals. Antimicrob Agents Chemother.1999;43(12):3042-3043.

10. PPS GmbH. Desinfektionsmittel Nüscosept PRO 10 Liter [Internet]. Münster: PPS GmbH [Cited 20.05.2024]. Available from: https://pps-vertrieb.de/desinfektionsmittel-nuscosept-5-liter.html

11. Purchasegreen. Six Components and Materials to Consider for Your Artificial Grass Installation [Internet]. United States of America: Purchasegreen [Cited 20.05.2024]. Available from: https://www.purchasegreen.com/blog/six-components-and-materials-to-consider-for-your-artificial-grass-installation/

12. CCGrass. Products Series [Internet]. CCGrass [Cited 20.05.2024]. Available from: https://www.ccgrass.com/products-series/

13. Hammer Products. Hammer HB [Internet]. Nøtterøy; Hammer Products [Cited 20.05.2024]. Available from: https://hammer-turf.com/hammer-hb/

14. Gabrielsen M. Nordic Test Certicicate Flatåsen – 7er – Trondheim. Trondheim: Kiwa ISA Sport Nordic; 11.03.2019. 91180149-B.

15. BBC. Cell structure-Edexcel [Internett]. London: BBC [Cited 20.05.2024]. Available from: https://www.bbc.co.uk/bitesize/guides/zg9mk2p/revision/3

16. Todar K. The Growth of Bacterial Populations (page 3). Madison, Wisconsin: Todar K; 2020 [Cited 20.05.2024]. Available from: https://textbookofbacteriology.net/growth_3.html

17. Eikeland E, Skorpen ME. Forekomst av *Staphylococcus aureus* på kunstgressbaner [Bachelor's thesis]. Trondheim: Norwegian University of Science and Technology; 2020.

18. Lowy FD. *Staphylococcus aureus* Infections. N Engl J Med. 1998;339:520-532.

19. MedlinePlus. Staphylococcal Infections [Internet]. Bethesda: U.S. Department of Health and Human Services [Updated 08.11.2023; cited 20.05.2024]. Available from: https://medlineplus.gov/staphylococcalinfections.html

20. Minnesota Department of Health. Antimicrobial-Resistant *Staphylococcus aureus* [Internet]. Minnesota: Minnesota Department of Health [Updated 20.10.2022; cited 20.05.2024]. Available from: https://www.health.state.mn.us/diseases/staph/resistant.html

21. Cheung GYC, Bae JS, Otto M. Pathogenicity and virulence of *Staphylococcus aureus*. Virulence. 2021;12(1):547-569.

22. Salo S, Laine A, Alanko T et al. Validation of the Microbiological Methods Hygicult Dipslide, Contact Plate, and Swabbing in Surface Hygiene Control: A Nordic Collaborative Study. J AOAC Int. 2000;83(6):1357-1365.

23. Niskanen A, Pohja MS. Comparative Studies on the Sampling and Investigation of Microbial Contamination of Surfaces by the Contact Plate and Swab Methods. J Appl Bacteriol. 1977;42(1):53-63.

24. Sutton S. Counting Colonies [Internet]. New York: The Microbiology Network; 01.2006 [Cited 20.05.2024]. Available from: http://microbiologynetwork.com/counting-colonies.asp

25. Calleja AB. How To Prevent Cell Culture Contamination [Internet]. Technology Networks; 29.03.2018 [Cited 20.05.2024]. Available from: https://www.technologynetworks.com/cell-science/how-to-guides/how-to-prevent-cell-culture-contamination-htg-299231

26. LSUMC. General Microbiological Techniques [Internet]. Lafayette: the Department of Microbiology, Immunology and Parasitology [Cited 20.05.2024]. Available from: https://www.medschool.lsuhsc.edu/microbiology/DMIP/dmex05.htm

27. Dancer SJ. How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals. J Hosp Infect. 2004;56(1):10-15.

28. Løvås GG. Statistikk for Universiter of Høgskoler. 4th edition. Oslo: Universitetsforlaget; 2021

29. TeachEngineering. Wetting and Contact Angle [Internet]. Colorado: Regents of the University of Colorado [Updated 13.06.2021; cited 20.05.2024]. Available from: https://www.teachengineering.org/lessons/view/duk_surfacetensionunit_less3

30. Elergy. Data Sheet Elergy GM-04 Nozzle. Oslo: Elergy AS; 24.04.2020 [Cited 20.05.2024]

31. Nuyttens D, Baetens K, Sonck B et al. Effect of nozzle type, size and pressure on spray droplet characteristics. Biosyst Eng.2007;97(3):333-345.

32. Fan S, Chen S, Wu Z et al. Analysis of droplet size distribution and selection of spray parameters based on the fractal theory. J Clean Prod. 2022;371:133315.

33 Lock EH, Walton SG, Fernsler R. Preparation of Ultra Thin Polystyrene, Polypropylene and Polyethylene Films on Si Substrate Using Spin Coating Technology [Internet]. Washington: Naval Research Laboratory; 04.01.2008. [Cited 20.05.2024]. Available from: https://www.researchgate.net/publication/235182245_Preparation_of_Ultra_Thin_Polystyrene_Polypropylene_and_Polyethylene_Films_on_Si_Substrate_Using_Spin_Coating_Technology

34. Linseis. Contact angle – Measuring surface tension [Internet]. Selb: Linseis [Cited 20.05.2024]. Available from: https://www.linseis.com/en/properties/contact-angle/

35. Weisstein EW. Spherical Cap [Internet]. Wolfram [Updated 16.05.2024; Cited 20.05.2024]. Available from: https://mathworld.wolfram.com/SphericalCap.html

36. NTNU, Department of Biotechnology and Food Science. Labratorieoppgaver i mikrobiologi 2023 [lab compendium]. Trondheim; 2023. [Accessed: 15.02.2024]

37. Nagakubo D, Kaibori Y. Oral Microbiota: The Influences and Interations of Saliva, IgA, and Dietary Factors in Health and Disease. Microorganisms. 2023;11(9):2307.

38. Central Dental Associates. How Many Bacteria Are Secretly Living Inside Your Mouth? [Internet]. Norwood; Central Dental Associates: 13.03.2021 [Cited 20.05.2024]. Available from: https://www.centraldentalnorwood.com/blog/2021/03/13/corrosive-oral-bacteria/

39. Siliezar J. Microbes are around and within us but there's much we don't know about them. The Harvard Gazette. 02.02.2021:1.

40. Scalzo Maintenace. Could Your Shoes Be Making You Sick? [Internet]. Middlesex: Scalzo Maintenance [Cited 20.05.2024]. Available from: https://scalzoclean.com/shoe-bacteria/

41. Kaiser G. 17.2: Factors that Influence Bacterial Growth [Internet]. California: Libretext [Cited 20.05.2021]. Available from: https://bio.libretexts.org/Bookshelves/Microbiology/Microbiology_(Kaiser)/Unit_7%3A_Microbial_Genetics_and_Microbial_Metabolism/17%3A_Bacterial_Growth_and_Energy_Production/17.2%3A_Factors_that_Influence_Bacterial_Growth

42. Fox J. Don't force your regression through zero just because you know the true intercept has to be zero [Internet]. Calgary: Dynamic Ecology; 13.04.2017 [Cited 20.05.2024]. Available

from: https://dynamicecology.wordpress.com/2017/04/13/dont-force-your-regression-through-zero-just-because-you-know-the-true-intercept-has-to-be-zero/

43. Tyowua AT, Targema M, Ubuo EE et al. Progress in Adhesion and Adhesieves. Beverly: Scrivener Publishing; 2020.

44. O'toole DK. Effect of incubation conditions at 55 C on moisture loss from agar plates. Appl Microbiol. 1975;30(4):692-693.

45. Cleveland Clinic. Can You Still Use an Expired COVID-19 Test? [Internet]. Cleveland: Cleveland Clinic; 20.03.2023 [Cited 20.05.2024]. Available from: https://health.clevelandclinic.org/expired-covid-test

46. KEMI (Swedish Chemicals Agency). Phasing out biocidal products when the authorization has expired or changed. [Internet]. Esplanaden 3A, Sundbyberg, Stockholm. 16.6.2023 [Cited:20.05.2024] Available from: https://www.kemi.se/en/pesticides-and-biocides/biocidal-products/rules-for-biocidal-products/phasing-out-biocidal-products-when-the-authorisation-has-expired-or-changed

47. CS Medical. Do expiration dates really matter? [Internet]. East Lyon Station Road: CS Medical; 25.10.2021 [Cited:20.05.2024] Available from: https://csmedicalllc.com/news/do-expiration-dates-really-matter

Appendix

A1 All four flow curves for the mist sprayer

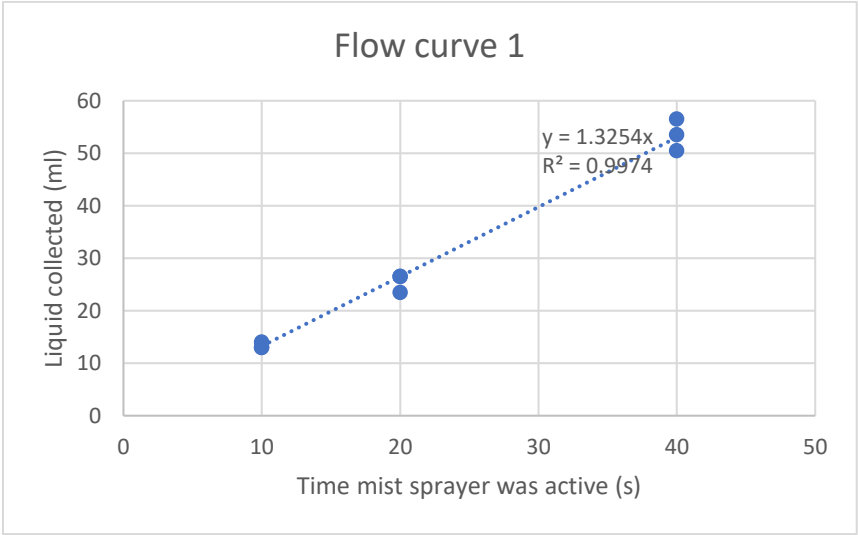


Figure A1: Flow curve labelled CW1. This curve is a linear regression fit through origin of the flow tests taken on the day the turf 1 was disinfected.

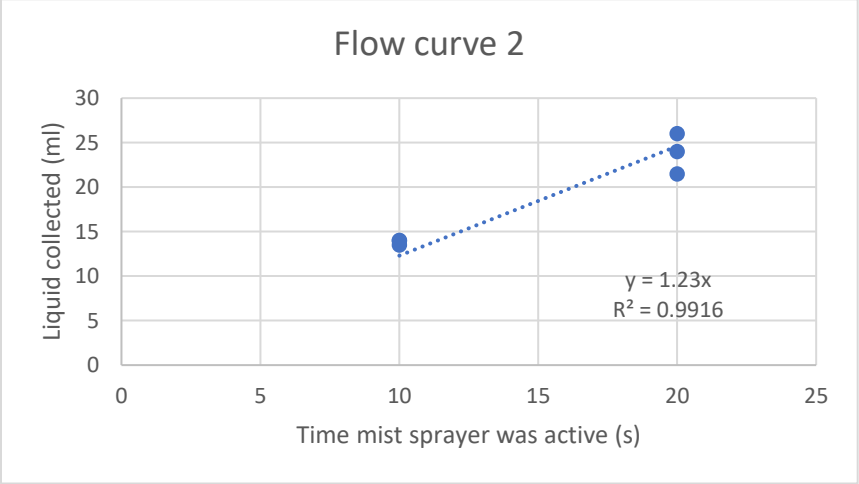


Figure A2: Flow curve labelled CW2. This curve is a linear regression fit through origin of the flow tests taken on the day the turfs 2 and 3 were disinfected.

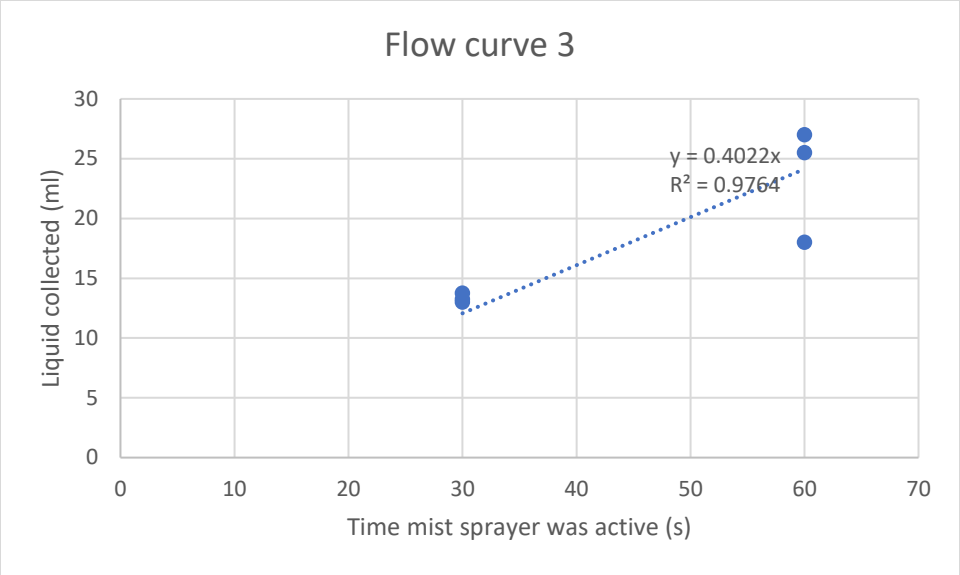


Figure A3: Flow curve labelled CW3. This curve is a linear regression fit through origin of the flow tests taken on the day the turfs 4, 5 and 6 were disinfected.

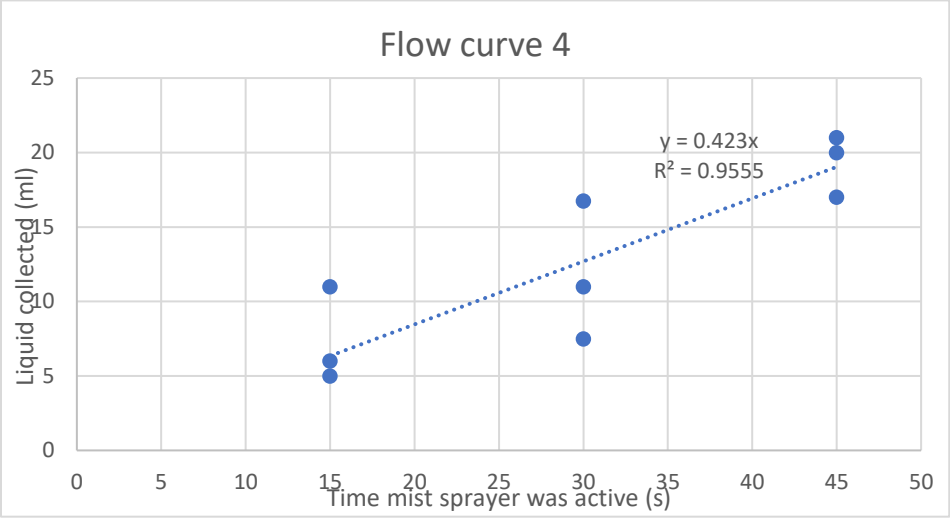


Figure A4: Flow curve labelled CW4. This curve is a linear regression fit through origin of the flow tests taken on the day the turfs 7, 8, 9 and 10 were disinfected.

A2 The tray and turf placement relative to the nozzle for all flow curves

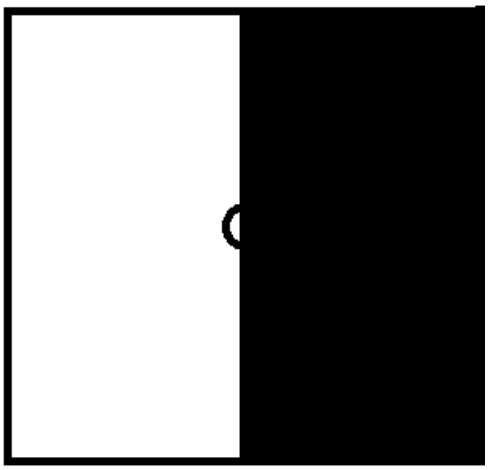


Figure A5: Illustration of the area covered by the turf and collection tray for CW1 and CW2. The black rectangle is the covered area and the circle is the location of the nozzle. The top is toward the back of the fume hood and the bottom is toward the opening of the fume hood. The square is 20 cm by 20 cm.

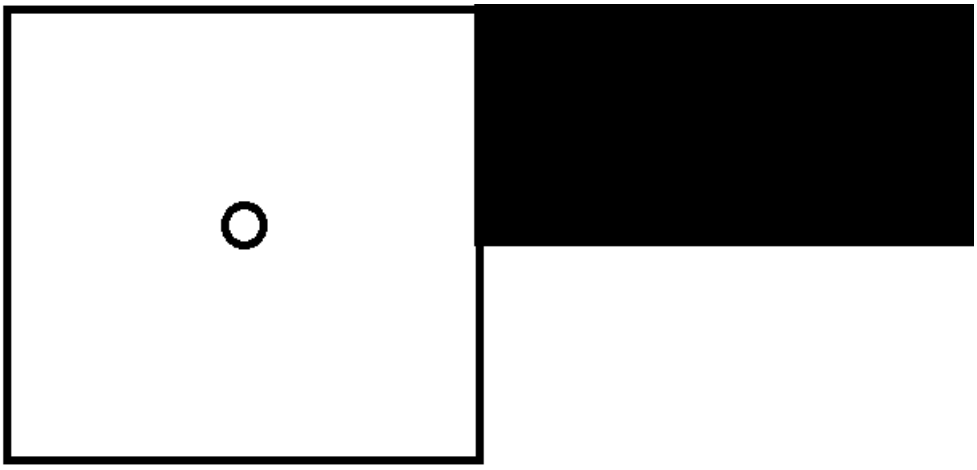


Figure A6: Illustration of the area covered by the turf and collection tray for CW3. The black rectangle is the covered area and the circle is the location of the nozzle. The top is toward the back of the fume hood and the bottom is toward the opening of the fume hood. The square is 20 cm by 20 cm.

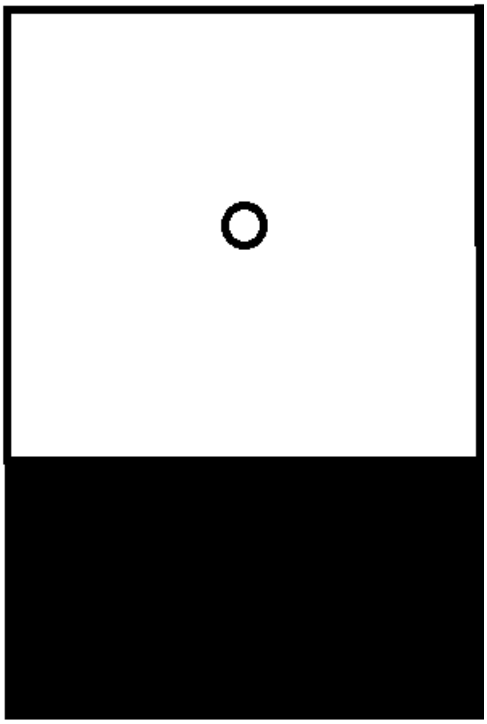


Figure A7: Illustration of the area covered by the turf and collection tray for CW4. The black rectangle is the covered area and the circle is the location of the nozzle. The top is toward the back of the fume hood and the bottom is toward the opening of the fume hood. The square is 20 cm by 20 cm.

Attachments

Disinfection of synthetic turf

Bjørn Aas
2023-06-23

COWI

Presentation for Sandmaster – Dr.Nüsken

Background

KG2021 – a project on future synthetic turf systems 2018-2023

4 years of research on microorganisms in turf

- Occurrence in different turf systems
- Identification
- Disinfection products
- Equipment development

COWI

Status June 2023

KG2021 completed

Tested disinfection products

- Citric acid
- Hydrogenperoxide
- UV
- Chlorine
- Nuescocept Pro

COWI

EFOG concept

Developed by Elergy/Are Pedersen and Björn Aas

- Tested in indoor environment for 6 months
- Validated by student's thesis 2023
- Industrial prototype ready for market June 2023
  - Integrated on regular grooming equipment
  - Powered from vehicle or battery

COWI

EFOG concept

Unique features:

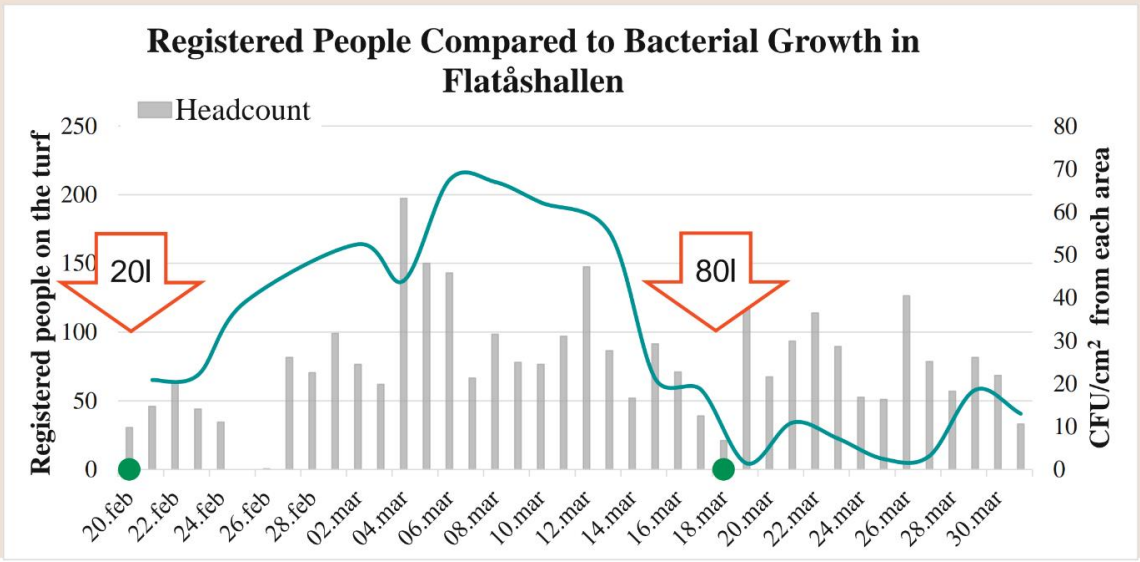
- Fully automatic operation
- Remotely controlled by driver
- Very low flow rates
- Liquid mixed on site
- Nozzle design allow for surface coverage at very small flows

COWI

EFOG test results

Test run 1	Liquid	50	l	17,86	ml/m²
	Water	49,75	l	17,77	ml/m²
	Nüscocept	0,25	l	0,09	ml/m²
Test run 2	Liquid	80	l	28,57	ml/m²
	Water	79,6	l	28,43	ml/m²
	Nüscocept	0,4	l	0,14	ml/m²

COWI



COWI

EFOG findings

Liquid
- 0.5% dilution works well
- Around 50 l in each batch

Demand trigged by usage

Dosage interval 20-30 days
- Following grooming interval (2x/month)

COWI

Questions

- What do we see here?
  - Aerosol formation in indoor environment
    - HSE questions
    - Operator's safety
    - Impact on surfaces
      - Corrosion, other impact?
  - Retention/reaction time
  - Evaporation/dissosiation in room air?

Next step

- EFOG has proven good results
- Product is ready for market
  - Synthetic turf
  - Playgrounds (handheld device)
  - Pool facilities
  - Kinder garden outdoor

Is this a concept for Sandmaster – Dr. Nüsken to work with?

NORDIC TEST CERTIFICATE

VALID FOR SWEDEN, NORWAY, DENMARK, ICELAND, FEROE ISLANDS, FINLAND

FLATÅSEN - 7ER - TRONDHEIM

All tests hereafter are based on EN- Standards also used by FIFA
Etterfølgende tester er basert på EN-Standarder også benyttet av FIFA

Turf system producer Kunstgressprodusent	**FieldTurf**	
Turf product (brand name) Kunstgressets navn (varemerke)	**Purefield Ultra HD 30-17 Alveo 3001-12**	
Turf product (code) Kunstgressets typebetegnelse	*Purefield Ultra HD 30-17 Alveo 3001-12 med sand*	
Test applicant (address, phone, e-mail) Søkers navn, adresse, telefon mm.	FieldTurf Tarkett Unit 2, Swanston Steadings 109 Swanston Road Edinburgh, EH10 7DS UK	Phone: +44 (0) 131 629 0437 (www.tarkett-sports.com

TURF COMPOSITION
KUNSTGRESSETS OPPBYGGING

Product / System declaration of the turf manufacturer, refer to pages 3 to 5
Kunstgressprodusentens deklarasjon av kunstgress-systemet (jf. side 3-5).

Tuft A Tuft A	**Pile fibre 1** Fiber nr. 1	**Stretched pile fibre length** Strukket fiberlengde	**Number of strands** Antall fiber i tuften	12.000 DTEX 100 % PE	30 mm	- Strands
	Pile fibre 2 Fiber nr. 2			8.000 DTEX 100 % PE	30 mm	- Strands
Tuft B Tuft B	**Pile fibre 3** Fiber nr. 3				mm	Strands
	Pile fibre 4 Fiber nr. 4				mm	Strands
Number of tufts per m^2 and total fibre weight Antall sting og tot. fibervekt pr. m2				17.848 per m^2		2.526 gr./ m^2
Stabilisation infill Stabiliserende ifyllingsmateriale (f.eks. sand)				Sand	10 mm	13 kg / m^2
Shock absorbing infill Støtdempende ifyllingsmateriale (f.eks. gummi)						Not in use
Height of fibres above infill Fiberhøyde over fyllmaterialet					20 mm	
Total height and weight of the turf product Total høyde og vekt av kunstgresset					32 mm	3.931 kg / m^2
Elastic pad / shock absorbing layer Elastisk pad/ støtdempende underlag				Alveo 3001	12 mm	

PRODUCT-SYSTEM DECLARATION BY THE TURF SYSTEM PRODUCER

KUNSTGRESSPRODUSENTENS PRODUKT- DEKLARASJON

Turf Tufting Kunstgress tufting		
Turf tufting manufacturer/ teppeprodusent		FieldTurf
Turf Fibre (main fibre) Kunstgress hoved-fibere		
Fibre manufacturer/ Produsent kunstgressfibrene		Morton GmbH
Material identification (brand name)/ (varemerke)		Classic HD
Material identification (code or description) Material betegnelse (typebetegn. el. Beskrivelse)		Classic HD
Colour, green (compulsory)/ Farge: grønn (krav)	**Test method** Test metode	**Test results** Test resultat
Total length of stretched fibre/ Samlet lengde av utstrakt gressfiber		31 mm
Fibre weight / Fibervekt		11.958 dtex
Pile weight per unit area/ Fibervekt pr. Arealenhet		1.464 gr / m²
Tuft per unit area/ Antall tufter pr. arealenhet		17.735 / m²
Tuft pattern/ Mønster for tufting (på rekke el. sikksakk)	straight / zig zag	Straight
Tufting construction /Metode for festing av gressfiber	Gauge	3/8 "
Thickness of pile fibre/ Tykkelse av gressfiber		130 micron
Complementary Turf Fibre (if applicable) Supplerende fibere (hvis benyttet)		
Fibre manufacturer/ Produsent av gressfibere		Morton GmbH
Material identification (brand name)/ (varemerke)		ULS
Material identification (code or description) Material betegnelse (typebetegn. el. beskrivelse)		ULS
Colour/ Farge: grønn (krav)	green, compulsory	
Total length of stretched fibre/ Samlet lengde av utstrakt gressfiber		31 mm
Fibre weight/ Fibervekt		7.591 Dtex
Pile weight per unit area/ Fibervekt pr. Arealenhet		905 Gr./ m²
Tuft per unit area / Fibervekt pr. arealenhet		17.735 m²
Tuft pattern/ Mønster for tufting (på rekke el. sikksakk)	straight / zig zag	Straight
Tufting construction /Metode for festing av gressfiber	Gauge	3/8 "
Thickness of pile fibre / Tykkelse av gressfiber		320 Micron
Turf Backing Teppets backing		
Manufacturer / Produsent		Carpet Backing
Material identification (brand name) / (varemerke)		R3
Material identification (code or description) Material betegnelse (typebetegn. el. beskrivelse)		R3
Type of primary backing / Primær backing		Wowen PP + fleece / glass reinforcement
Type of secondary backing / Sekundær backing		
Type of induction / Induksjonsmetode		Latex
Total weight of backing and induction Samlet vekt av backing- og induksjon		1.405 gr./ m²

Sewn or Velcro attached Turf Joints (if applicable) Sydde skjøter (hvis benyttet)		
Thread or Velcro manufacturer Trådprodusent og firma-/handelsnavn		
Type of tread or Velcro / Trådtype		
Glue manufacturer / brand name Limprodusent / varemerke		
Glue / Limtype og produktnavn		gr./ per m
Glued Turf Joints (if applicable) Limte skjøter (hvis benyttet)		
Backing manufacturer / brand name Produsent backing, varemerke	King Sports	M136
Total weight of backing / Samlet vekt av backing		156 gr/ m^2
Width of joint backing tape / Bredde av tape under skjøter		30 cm
Glue manufacturer / brand name Limprodusent, varemerke	HB Fuller Stauf	TEC149 IBOLA R202
Glue / Limtype og mengde		600 gr/rm

Stabilisation Infill (if applicable) Stabiliserende fyllmateriale, bunnlag (hvis benyttet)		
Manufacturer / Produsent		Diverse
Brand name / Betegnelse/varemerke		Filøtersand 0408
Material identification (code or description) Materialbetegnelse (typebetegn. el. beskrivelse)		Dryed washed filtersand
Colour / farge		Beige
Weight per unit area / Vekt pr. Arealenhet		13 kg / m^2
Infill thickness / Fyllmateriale, tykkelse		10 mm
Particle size w/range / Kornstørrelse og –fordeling		0,4 – 0,8 mm
Particle shape / Kornform		80 % rounded
Particulate Infill (if applicable) Støtdempende fyllmateriale, topplag (hvis benyttet)		
Manufacturer / Produsent		Not in use
Brand name / Betegnelse (varemerke)		
Material identification (code or description) Material betegnelse (typebetegn. el. beskrivelse)		
Colour / Farge		
Weight per unit area / Vekt pr. Arealenhet		
Infill thickness / Fyllmateriale, tykkelse		
Particle size w/range / Kornstørrelse og –fordeling		
Particle shape / Kornform		
Shock pad (if applicable) Støtdempende pad/matte (hvis benyttet)		
Manufacturer / Produsent		Alveo
Brand name / Betegnelse (varemerke)		3001 - 12
Material identification (code or description) Material betegnelse (typebetegn. el. beskrivelse)		Closed cell PE foam
Force reduction / Støtdemping		-
Cross tensile strength / Bruddstyrke		0,15 N/mm²
Weight per unit area / Vekt pr. Arealenhet		0,5 kg/m²
Thickness / Tykkelse		12 mm

TEST RESULTS - LABORATORY TESTS
GRASSROOT SYSTEMS

SPORTSFUNKSJONELLE EGENSKAPER: LABORATORIUM TESTRESULTATER.

Footballistic Characteristics Sportsfunksjonelle egenskaber			Required Values Krav / Grenseverdi	Test conditions Test forhold	Test Results Test resultater	Nordic Compliance Overenstemmelse med Nordiske krav
Force reduction Støtdemping	Mean Value 2nd/3rd impact Snitt 2. & 3. støt	**EN 14808**	**55 - 70 %**	dry/ tørr	**56**	**Pass**
Vertical deformation Deformasjon	Mean Value 2nd/3rd impact Snitt 2. & 3. støt	**EN 14809**	**4 - 9 mm**	dry/ tørr	**6,0**	**Pass**
Rotational resistance Vridefriksjon/ traction		**EN 15301-1**	**25 – 50 Nm**	dry/ tørr	**32**	**Pass**
Ball rebound Ballsprett		**EN 12334**	**0,6 – 1,0 m**	dry/ tørr	**0,74**	**Pass**
Ball roll Ballrulle		**EN 12335**	**4 – 10 m**	dry/ tørr	**7,6**	**Pass**
Permeability Vanngj.slippelighet		**EN 12228**	**Min 180mm/h**		**1.229 mm/hour**	**Pass**

APPROVED TEST LABORATORY AND TEST VALIDITY

Laboratorium-registrering, gyldighet.

Name Navn	**KIWA ISA-SPORT NORDIC** Based on Lab-report signed Stijn Rambour Project nr: 18-0310-03	***The laboratory tests complies with the NORDIC FA requirements*** Det testede kunstgressystem er i overensstemmelse med Nordiske krav.	
Number and date Nr. og dato	**91180035 – 15.06.2018**	***Grassroot***	
Signature	**Morten Gabrielsen** Morten Gabrielsen	***Pass***	

FIELD TEST REPORT
HAS TO INCLUDE PAGE 1 TO 4 – LABORATORY VALUES
Felttest rapport må også inneholde side 1 til 4 – laboratorie verdier

FIELD TEST REGISTRATION
Felttest-registrering

Country Land	Norge
District / city Kommune / by	Trondheim
Name of the field Banens navn	Flatåshallen / Bonitashallen
Name og club Klubbnavn	Flatås IL
Playing area Spilleflate	60 m x 40 m
Total size Total gressflate	64 m x 44 m
Installation date Installert dato	September/oktober 2018

INFRASTRUCTURE AND GRASS SYSTEM CHARACTERISTICS
Baneoppbygningens og gressystemets karakteristika.

Soil heating, yes / no Undervarme, ja / nei	Ikke oppgitt	
Water irrigation system, yes / no Vanningssystem, ja / nei	Ikke oppgitt	
Maintenance equipment on site *Registrert vedlikeholdsutstyr*	Børste-harv-oppsamler og traktor	
Pile density *Stråtetthett*	Rader / m:	100
	Sting / m:	182
	Sting / m²:	18.200
Pile length *Strålengde*	30 mm	
Particle size rubber and sand *Kornstørrelse for gummi og sand i mm*	Gummi: Not in use	Sand: 0,315 – 0,8
Draining holes/ m² in grass *Drenshull / m² i gresset*	102	

TEST RESULTS - FIELD TESTS

Kunstgressets sportsfunksjonelle og tekniske egenskaper: Felttest.

Footballistic characteristics		Required values Krav	Test position Bane A og B						Pitch mean Gj.snitt	Nordic Compliance Overenstem-melse med Nordiske krav
		Kl. 2	1	2	3	4	5	6		
Force reduction Støtdempning g	Mean 2nd/3rd Impact Snitt 2.& 3. støt	**EN 14808 55 – 70 %**	57	61	61	-	-	-	**60**	**Ja**
Vertical deformation Deformasjon	Mean 2nd/3rd Impact Snitt 2.& 3. støt	**EN 14809 4 - 9 mm**	7,3	7,9	7,8	-	-	-	**7,7**	**Ja**
Rotational resistance Vridefriksjon		**EN 15301-1 25 – 50 Nm**	31	29	30	-	-	-	**30**	**Ja**
Ball rebound ballsprett		**EN 12334 60 – 100 cm**	89	87	87	-	-	-	**88**	**Ja**
Ball roll Ball-rulle	Actual ball roll Virkelig rullelengde	**EN 12335 Initial test 4 – 10m Re-tests 4 – 12m**	9,6	9,8	9,7	-	-	-	**9,7**	**Ja**
Permeability Vanngj.slippelighet		**Control of drain holes** Kontroll av drenshull	Average of four corners / m²						**102**	**Ja**
Evenness Jevnhet overflate		**<10mm over 3m**	Ok	Ok	Ok	-	-	-	**Ok**	**Ja**
Total fill height, 7 mesurements across the field for each spot, EN 1969:2000-B Total fyllhøyde, 7 målinger på tvers av banen for hvert punkt, EN 1969:2000-B **Max variation ±10 % of lab. value**			11	11	11	-	-	-	**11**	**Ja**

The pitch mean result is the mean of the three test locations.
Each of the lowest and the highest results at the 3 locations shall meet the NORDIC requirements.
Banens gjennomsnittsresultat er gjennomsnittet av prøver på de 3 prøvestedene.
Alle banens testresultater på de 3 utagningssteder skal overholde Nordiske krav.

Conditioning of tests areas by using a studded roller if the pitch is less than 4 weeks old (cross to show if conditioning is used or not) Avkrysning for utført bearbeidn./tromling av test arealet.	Yes	No X	
Air temperature during test programme luft temperatur under testen	9 °C		
Surface temperature during test programme Overflatetemperatur under testen	9 °C		
Humidity during test programme Luftfuktighet under testen	76 % RH		
Test surfaces / Overflatens tilstand	Dry/ tørr X	Moist/ fuktig	Wet/ våt
Wind speed Vindhastighet under ballrulle-testen	Ball roll/ ballrulle	0 m / s	

Additional comments from the test laboratory / manufacturer Supplerende bemerkninger fra test laboratorium / leverandør.

FIELD TEST VALIDITY
Felttest, gyldighet.

Approved Test laboratory Godkjent testlaboratorium .	**Kiwa ISA Sport Nordic**			***The tested field complies with the NORDIC FA requirements*** Den testede banen er i overensstemmelse med Nordiske krav.	
				Grassroot, Passed or Failed	
				Passed	
Field test **Felttest**	**Date** Dato	**Number** Nummer	**Signature** Underskrift	**Kommentarer**	
Initial test Første felttest	7.1.2019	91180149-B	Kjell Terjesen	Banen underkjennes pga for lav vridemotstand	
1st renewal 1. fornyet test	26.2.2019	91180149-B	Kjell Terjesen	Banen er etterfylt med sand, vridemotstand er innenfor kravet og banen godkjennes	
2nd renewal 2. fornyet test					

Felttest for breddefotball skal utføres senest 10 måneder efter legging. For baner brukt mindre enn 4 uker skal utvalgte områder tromles før testing.

PRODUCT-SYSTEM-DECLARATION Produkt-System-Deklaration	DATE AND SIGNATURE Dato og underskrift	
Turf System Producer Kunstgressprodusent	26.11.2018	ScanTurf, ved Frode Norheim
Report made by, rapport utarbeidet av: **Kiwa ISA Sport Nordic**	11.3.2019	Morten Gabrielsen

The product identification declaration can, when required, be cross-checked with the registered turf sample.
Produkt-deklarasjon kan, om ønskelig, kontrolleres mot den registrerte kunstgressprøven.

(Contd. of page 6)

· **STOT-repeated exposure** Based on available data, the classification criteria are not met.
· **Aspiration hazard** Based on available data, the classification criteria are not met.

SECTION 12: Ecological information

· **12.1 Toxicity**

· **Aquatic toxicity:**	
68424-85-1 quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides	
LC50/96 h	0.085 mg/l (Regenbogenforelle) (OECD 203)
EC50/48 h	0.016 mg/l (daphnia)
EC50/72 h (dynamic)	0.02 mg/l (sc) (OECD 201)
7173-51-5 didecyldimethylammonium chloride	
LC50/96 h	1 mg/l (fish) (OECD 203 (Oncorhynchus mykiss))
EC50/48 h	0.06 mg/l (daphnia)
EC50/96 h	0.12 mg/l (algae) ((Selenastrum capricornutum))
67-63-0 propan-2-ol	
LC50/96 h	9,640 mg/l (fish) (Fish, Acute Toxicity test)
EC50/48 h	9,714 mg/l (daphnia magna) (Daphnia sp. Acute Immobilisation Test)
EC50/72 h	>100 mg/l (algae)
EC50	>1,000 mg/l (bacteria)

· **12.2 Persistence and degradability**
The surfactant(s) contained in this preparation complies(comply) with the biodegradability criteria as laid down in Regulation (EC) No.648/2004 on detergents. Data to support this assertion are held at the disposal of the competent authorities of the Member States and will be made available to them, at their direct request or at the request of a detergent manufacturer.
· **12.3 Bioaccumulative potential** No further relevant information available.
· **12.4 Mobility in soil** No further relevant information available.
· **Ecotoxical effects:**
· **Behaviour in sewage processing plants:**

· **Type of test**	**Effective concentration**	**Method**	**Assessment**
7173-51-5 didecyldimethylammonium chloride			
EC0	2 mg/l (bacteria) ((Belebtschlamm))		
67-63-0 propan-2-ol			
EC10	5,175 mg/l (bacteria)		

· **Additional ecological information:**
· **AOX-indication:**
The mixture does not contain substances, which can affect the AOX value of waste water.
· **12.5 Results of PBT and vPvB assessment**
· **PBT:** Not applicable.
· **vPvB:** Not applicable.
· **12.6 Other adverse effects** No further relevant information available.

SECTION 13: Disposal considerations

· **13.1 Waste treatment methods**
· **Recommendation**
Product residues should be disposed of in compliance with the Waste Directive 2008/98/EG, as well as national and regional regulations

· **European waste catalogue**	
07 00 00	WASTES FROM ORGANIC CHEMICAL PROCESSES

(Contd. on page 8)

(Contd. of page 1)

H411 Toxic to aquatic life with long lasting effects.

· **Precautionary statements**

P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P301+P330+P331	IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303+P361+P353	IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310	Immediately call a POISON CENTER/doctor.
P501	Dispose of contents/container in accordance with local/regional/national/international regulations.

· **2.3 Other hazards**

· **Results of PBT and vPvB assessment**

· **PBT:** Not applicable.

· **vPvB:** Not applicable.

SECTION 3: Composition/information on ingredients

· **3.2 Chemical characterisation: Mixtures**

· **Description:** Mixture of the substances listed below with harmless additions.

· **Dangerous components:**

CAS: 68424-85-1 Reg.nr.: 01-2119970550-39	quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides Met. Corr.1, H290; Skin Corr. 1B, H314; Eye Dam. 1, H318; Aquatic Acute 1, H400; Aquatic Chronic 1, H410; Acute Tox. 4, H302	≥5-<25%
CAS: 7173-51-5 Index number: 612-131-00-6	didecyldimethylammonium chloride Flam. Liq. 3, H226; Met. Corr.1, H290; Skin Corr. 1B, H314; Eye Dam. 1, H318; Aquatic Acute 1, H400; Aquatic Chronic 2, H411; Acute Tox. 4, H302; STOT SE 3, H336	≥5-<20%
CAS: 67-63-0 Index number: 603-117-00-0 Reg.nr.: 01-2119457558-25-XXX	propan-2-ol Flam. Liq. 2, H225; Eye Irrit. 2, H319; STOT SE 3, H336	<5%
CAS: 110615-47-9 Reg.nr.: 01-2119489418-23	D-Glucopyranose, Oligomer, C10-16 Alkylglycosid Eye Dam. 1, H318; Skin Irrit. 2, H315	≥1-<3%
CAS: 1310-73-2 Index number: 011-002-00-6 Reg.nr.: 01-2119457892-27	sodium hydroxide Met. Corr.1, H290; Skin Corr. 1A, H314; Eye Dam. 1, H318	<0.5%

· **Regulation (EC) No 648/2004 on detergents / Labelling for contents**

<5% nonionic surfactants, complexing agents, solvents

· **Additional information** For the wording of the listed hazard phrases refer to section 16.

SECTION 4: First aid measures

· **4.1 Description of first aid measures**

· **General information**

Instantly remove any clothing soiled by the product.

Take affected persons out of danger area and instruct to lie down.

If symptoms persist, call a physician.

(Contd. on page 3)

(Contd. of page 2)

· **After inhalation**
In case of unconsciousness bring patient into stable side position for transport.
Seek medical treatment in case of complaints.
Supply fresh air.
· **After skin contact**
Instantly rinse with water.
If skin irritation continues, consult a doctor.
· **After eye contact** Rinse opened eye for several minutes under running water. Then consult doctor.
· **After swallowing**
Immediately rinses the mouth.
Drink plenty of water (200 - 300 mL) in small swallows (dilution effect). Avoid vomiting.
No neutralization attempts.
· **4.2 Most important symptoms and effects, both acute and delayed**
No further relevant information available.
· **4.3 Indication of any immediate medical attention and special treatment needed**
No further relevant information available.

SECTION 5: Firefighting measures

· **5.1 Extinguishing media**
· **Suitable extinguishing agents** Use fire fighting measures that suit the environment.
· **For safety reasons unsuitable extinguishing agents** Water with a full water jet.
· **5.2 Special hazards arising from the substance or mixture**
Nitrogen oxides (NOx)
Under certain fire conditions, traces of other toxic gases cannot be excluded, e.g.: carbon monoxide, carbon dioxide
Chlorine compounds.
· **5.3 Advice for firefighters**
· **Protective equipment:** Do not inhale explosion gases or combustion gases.
· **Additional information** Collect contaminated fire fighting water separately. It must not enter drains.

SECTION 6: Accidental release measures

· **6.1 Personal precautions, protective equipment and emergency procedures**
Put on breathing apparatus.
Wear protective equipment. Keep unprotected persons away.
· **6.2 Environmental precautions:** Do not allow to enter drainage system, surface or ground water.
· **6.3 Methods and material for containment and cleaning up:**
Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders).
Dispose of contaminated material as waste according to item 13.
Ensure adequate ventilation.
· **6.4 Reference to other sections**
See Section 7 for information on safe handling
See Section 8 for information on personal protection equipment.
See Section 13 for information on disposal.

SECTION 7: Handling and storage

· **7.1 Precautions for safe handling**
Ensure good ventilation/exhaustion at the workplace.
Prevent formation of aerosols.
minimum standard of operational safety should be followed
· **Information about protection against explosions and fires:** The product is not flammable

(Contd. on page 4)

(Contd. of page 3)

· **7.2 Conditions for safe storage, including any incompatibilities**
· **Storage**
· **Requirements to be met by storerooms and containers:**
Store in cool location.
Store in a well-ventilated place.
· **Information about storage in one common storage facility:**
Store away from foodstuffs.
Store away from oxidising agents.
· **Further information about storage conditions:** Keep container tightly sealed.
· **7.3 Specific end use(s)** No further relevant information available.

SECTION 8: Exposure controls/personal protection

· **Additional information about design of technical systems:** No further data; see item 7.

· **8.1 Control parameters**

· **Components with critical values that require monitoring at the workplace:**	
67-63-0 propan-2-ol	
WEL	Short-term value: 1250 mg/m³, 500 ppm Long-term value: 999 mg/m³, 400 ppm

· **DNELs**		
67-63-0 propan-2-ol		
Oral	DNEL (chronisch)	26 mg/kg/day (Consumer)
Dermal	DNEL (chronisch)	888 mg/kg/day (Worker)
		319 mg/kg/day (Consumer)
Inhalative	DNEL (chronisch)	500 mg/m³ (Worker)
		89 mg/m³ (Consumer)

· **PNECs**	
67-63-0 propan-2-ol	
PNEC	140.9 mg/l (sweet water)
	140.9 mg/l (seawater)
PNEC	28 mg/kg (soil)

· **Additional information:** The lists that were valid during the compilation were used as basis.

· **8.2 Exposure controls**
· **Personal protective equipment**
· **General protective and hygienic measures**
Keep away from foodstuffs, beverages and food.
Instantly remove any soiled and impregnated garments.
Wash hands during breaks and at the end of the work.
Avoid contact with the eyes and skin.
Do not eat or drink while working.
· **Breathing equipment:**
In case of insufficient ventilation wear suitable respiratory equipment (gas filter type A) (EN 14387).
· **Protection of hands:**

Protective gloves.

Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation
· **Material of gloves**
Butyl rubber, BR

(Contd. on page 5)

(Contd. of page 4)

Fluorocarbon rubber (Viton)
Nitrile rubber, NBR
Chloroprene rubber, CR
The selection of the suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer.

· **Penetration time of glove material**
The exact break trough time has to be found out by the manufacturer of the protective gloves and has to be observed.

· **For the permanent contact gloves made of the following materials are suitable:**
Protective gloves of nitrile rubber
Dr. Nüsken Article: 50143-xx

· **As protection from splashes gloves made of the following materials are suitable:**
Protective gloves of nitrile rubber
Dr. Nüsken Article: 50164-xx

· **Eye protection:**

Tightly sealed safety glasses.

· **Body protection:**
If while handling the product or its diluted solution the danger of the body contact (e.g. Fill over, a spraying) exists, then is carrying a suitable and steady protection protective clothing (e.g. Plastic apron) during this time recommendable.

SECTION 9: Physical and chemical properties

· **9.1 Information on basic physical and chemical properties**	
· **General Information**	
· **Appearance:**	
Form:	Fluid
Colour:	colorless
· **Smell:**	Recognisable
· **Odour threshold:**	Not determined.
· **pH-value:**	9
· **Change in condition**	
Melting point/freezing point:	Not determined
Initial boiling point and boiling range:	100 °C
· **Flash point:**	Not applicable
· **Inflammability (solid, gaseous)**	Not applicable.
· **Decomposition temperature:**	Not determined.
· **Self-inflammability:**	Product is not selfigniting.
· **Explosive properties:**	Product is not explosive.
· **Critical values for explosion:**	
Lower:	Not applicable
Upper:	Not applicable
· **Steam pressure at 20 °C:**	<0.1 hPa Calculated from the ingredients
· **Density at 20 °C**	1.01 g/cm³
· **Relative density**	Not determined.
· **Vapour density**	Not determined.

(Contd. on page 6)

(Contd. of page 5)

· **Evaporation rate**	Not determined.
· **Solubility in / Miscibility with Water:**	Fully miscible
· **Partition coefficient: n-octanol/water:**	Not determined.
· **Viscosity:**	
dynamic:	Not determined.
kinematic:	Not determined.
· **Solvent content:**	
Organic solvents:	<5 %
Solids content:	<0.5 %
· **9.2 Other information**	No further relevant information available.

SECTION 10: Stability and reactivity

· **10.1 Reactivity** No further relevant information available.
· **10.2 Chemical stability**
· **Thermal decomposition / conditions to be avoided:**
No decomposition if used according to specifications.
· **10.3 Possibility of hazardous reactions** Reactions with oxidizing agents.
· **10.4 Conditions to avoid** No further relevant information available.
· **10.5 Incompatible materials:** oxidant
· **10.6 Hazardous decomposition products:**
Carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen oxides (NO_x), chlorine compounds

SECTION 11: Toxicological information

· **11.1 Information on toxicological effects**
· **Acute toxicity** Based on available data, the classification criteria are not met.

· **LD/LC50 values that are relevant for classification:**		
68424-85-1 quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides		
Oral	LD50	795 mg/kg (rat)
7173-51-5 didecyldimethylammonium chloride		
Oral	LD50	645 mg/kg (rat)
Dermal	LD50	>2,000 mg/kg (rat)
67-63-0 propan-2-ol		
Oral	LD50	5,840 mg/kg (rat) (Acute Oral Toxicity)
Dermal	LD50	13,900 mg/kg (rab) (Acute Dermal Toxicity)
Inhalative	LC50/4 h	>25 mg/l (rat) (Acute Inhalation Toxicity)

· **Primary irritant effect:**
· **Skin corrosion/irritation**
Causes severe skin burns and eye damage.
· **Serious eye damage/irritation**
Causes serious eye damage.
· **Respiratory or skin sensitisation** Based on available data, the classification criteria are not met.
· **CMR effects (carcinogenity, mutagenicity and toxicity for reproduction)**
· **Germ cell mutagenicity** Based on available data, the classification criteria are not met.
· **Carcinogenicity** Based on available data, the classification criteria are not met.
· **Reproductive toxicity** Based on available data, the classification criteria are not met.
· **STOT-single exposure** Based on available data, the classification criteria are not met.

(Contd. on page 7)

(Contd. of page 7)

07 06 00	wastes from the MFSU of fats, grease, soaps, detergents, disinfectants and cosmetics
07 06 99	wastes not otherwise specified

· **Uncleaned packagings:**
· **Recommendation:**
Packaging can be reused or recycled after cleaning.
Packagings that cannot be cleaned are to be disposed of in the same manner as the product.
Our packages are generally reusable containers. You are taken back and reused. You must totally empty, sealed and optionally labeled as hazardous material (only remove stickers when packing was rinsed) be.
· **Recommended cleaning agent:** Water, if necessary with cleaning agent.

SECTION 14: Transport information

· **14.1 UN-Number**
· **ADR, IMDG, IATA** UN1903

· **14.2 UN proper shipping name**
· **ADR** 1903 DISINFECTANT, LIQUID, CORROSIVE, N.O.S. (didecyldimethylammonium chloride, quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides), ENVIRONMENTALLY HAZARDOUS
· **IMDG** DISINFECTANT, LIQUID, CORROSIVE, N.O.S. (didecyldimethylammonium chloride, quaternary ammonium compounds, benzylalkyl(C=12-16) dimethyl, chlorides), MARINE POLLUTANT
· **IATA** DISINFECTANT, LIQUID, CORROSIVE, N.O.S. (didecyldimethylammonium chloride, quaternary ammonium compounds, benzylalkyl(C=12-16) dimethyl, chlorides)

· **14.3 Transport hazard class(es)**

· **ADR**

· **Class** 8 (C9) Corrosive substances.
· **Label** 8

· **IMDG**

· **Class** 8 Corrosive substances.
· **Label** 8

· **IATA**

· **Class** 8 Corrosive substances.
· **Label** 8

(Contd. on page 9)

(Contd. of page 8)

· **14.4 Packing group**	
· **ADR, IMDG, IATA**	III
· **14.5 Environmental hazards:**	Product contains environmentally hazardous substances: quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides
· **Marine pollutant:**	Symbol (fish and tree)
· **Special marking (ADR):**	Symbol (fish and tree)
· **14.6 Special precautions for user**	Warning: Corrosive substances.
· **Kemler Number:**	80
· **EMS Number:**	F-A,S-B
· **Stowage Category**	B
· **14.7 Transport in bulk according to Annex II of Marpol and the IBC Code**	Not applicable.
· **Transport/Additional information:**	
· **ADR**	
· **Limited quantities (LQ)**	1L
· **Excepted quantities (EQ)**	Code: E2 Maximum net quantity per inner packaging: 30 ml Maximum net quantity per outer packaging: 500 ml
· **Transport category**	2
· **Tunnel restriction code**	E
· **IMDG**	
· **Limited quantities (LQ)**	1L
· **Excepted quantities (EQ)**	Code: E2 Maximum net quantity per inner packaging: 30 ml Maximum net quantity per outer packaging: 500 ml
· **UN "Model Regulation":**	UN 1903 DISINFECTANT, LIQUID, CORROSIVE, N.O.S. (DIDECYLDIMETHYLAMMONIUM CHLORIDE, QUATERNARY AMMONIUM COMPOUNDS, BENZYLALKYL(C=12-16) DIMETHYL, CHLORIDES), 8, III, ENVIRONMENTALLY HAZARDOUS

SECTION 15: Regulatory information

· **15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture**

· **Labelling according to Regulation (EC) No 1272/2008**

The product is classified and labelled according to the CLP regulation.

· **Hazard pictograms** GHS05, GHS09

· **Signal word** Danger

· **Hazard-determining components of labelling:**

quaternary ammonium compounds, benzylalkyl(C=12-16)dimethyl, chlorides

didecyldimethylammonium chloride

· **Hazard statements**

H314 Causes severe skin burns and eye damage.

H400 Very toxic to aquatic life.

H411 Toxic to aquatic life with long lasting effects.

· **Precautionary statements**

P273 Avoid release to the environment.

P280 Wear protective gloves/protective clothing/eye protection/face protection.

(Contd. on page 10)

(Contd. of page 9)

P301+P330+P331 IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER/doctor.
P501 Dispose of contents/container in accordance with local/regional/national/international regulations.

· **Directive 2012/18/EU**
· **Named dangerous substances - ANNEX I** None of the ingredients is listed.
· **Seveso category** E2 Hazardous to the Aquatic Environment
· **Qualifying quantity (tonnes) for the application of lower-tier requirements** 100 t
· **Qualifying quantity (tonnes) for the application of upper-tier requirements** 200 t
· **REGULATION (EC) No 1907/2006 ANNEX XVII** Conditions of restriction: 3

· **Regulation (EU) No 649/2012**

7173-51-5	didecyldimethylammonium chloride	Annex I Part 1

· **National regulations**

· **Information about limitation of use:**
Employment restrictions concerning young persons must be observed.
Employment restrictions concerning pregnant and lactating women must be observed.

· **Technical instructions (air):**

Class	Share in %
NK	<25

· **Water hazard class:** Water hazard class 2 (Self-assessment): hazardous for water.
· **15.2 Chemical safety assessment:** A Chemical Safety Assessment has not been carried out.

SECTION 16: Other information

These data are based on our present knowledge. However, they shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

· **Relevant phrases**
H225 Highly flammable liquid and vapour.
H226 Flammable liquid and vapour.
H290 May be corrosive to metals.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.
H315 Causes skin irritation.
H318 Causes serious eye damage.
H319 Causes serious eye irritation.
H336 May cause drowsiness or dizziness.
H400 Very toxic to aquatic life.
H410 Very toxic to aquatic life with long lasting effects.
H411 Toxic to aquatic life with long lasting effects.

· **Department issuing data specification sheet:** Abteilung Herstellung
· **Contact:**
Dr. Dirk P. Dygutsch Tel. +49 (02307) 705-0
Mario Lebrecht (ADR/RID) Tel. +49 (02307) 705-0
· **Abbreviations and acronyms:**
ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
IMDG: International Maritime Code for Dangerous Goods
IATA: International Air Transport Association
GHS: Globally Harmonised System of Classification and Labelling of Chemicals
EINECS: European Inventory of Existing Commercial Chemical Substances

(Contd. on page 11)

(Contd. of page 10)

ELINCS: European List of Notified Chemical Substances
CAS: Chemical Abstracts Service (division of the American Chemical Society)
DNEL: Derived No-Effect Level (REACH)
PNEC: Predicted No-Effect Concentration (REACH)
LC50: Lethal concentration, 50 percent
LD50: Lethal dose, 50 percent
PBT: Persistent, Bioaccumulative and Toxic
vPvB: very Persistent and very Bioaccumulative
Flam. Liq. 2: Flammable liquids – Category 2
Flam. Liq. 3: Flammable liquids – Category 3
Met. Corr.1: Corrosive to metals – Category 1
Acute Tox. 4: Acute toxicity – Category 4
Skin Corr. 1A: Skin corrosion/irritation – Category 1A
Skin Corr. 1B: Skin corrosion/irritation – Category 1B
Skin Irrit. 2: Skin corrosion/irritation – Category 2
Eye Dam. 1: Serious eye damage/eye irritation – Category 1
Eye Irrit. 2: Serious eye damage/eye irritation – Category 2
STOT SE 3: Specific target organ toxicity (single exposure) – Category 3
Aquatic Acute 1: Hazardous to the aquatic environment - acute aquatic hazard – Category 1
Aquatic Chronic 1: Hazardous to the aquatic environment - long-term aquatic hazard – Category 1
Aquatic Chronic 2: Hazardous to the aquatic environment - long-term aquatic hazard – Category 2

· **Sources**

EU directives 1999/45/EG, 67/548/EG, Regulations (EC) 1907/2006, 648/2004, 1272/2008.

· *** Data compared to the previous version altered.**

DATA SHEET

Created: **24.04.2020**

GM-04 NOZZLE

Type of connection	Catalog no
standard connection 3/8" BSP female	
1/2" BSP female	
1/2" BSPT male	
1/4" BSPT male	
3/8" BSPT male	
long 1/2" BSPP with 60° cone (for high pressure hoses)	

System Type:

m-Mist

Applications:

LOCAL

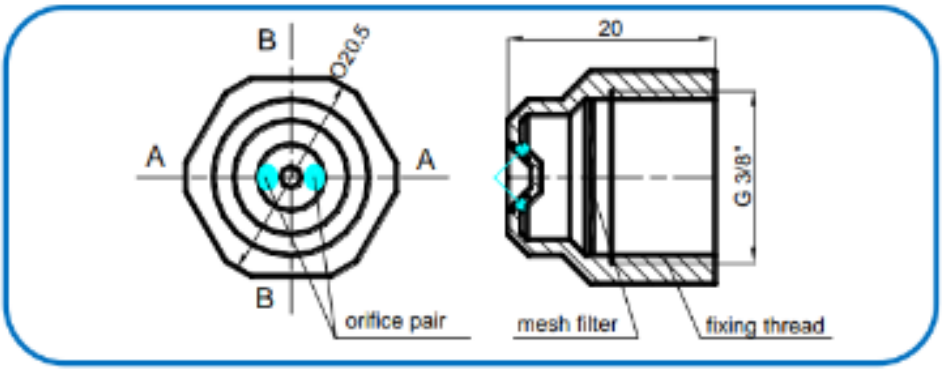
TECHNICAL PARAMETERS		
Material	:	Stainless steel
Total flow surface	:	0,32 mm²
Basic extinguishing media	:	water
Standard connection size	:	3/8" BSP female
Inlet pressure	:	3-10 bar
Number of hole pairs	:	1
Nozzle weight	:	0,01 kg

ELERGY WATER MIST GM-04

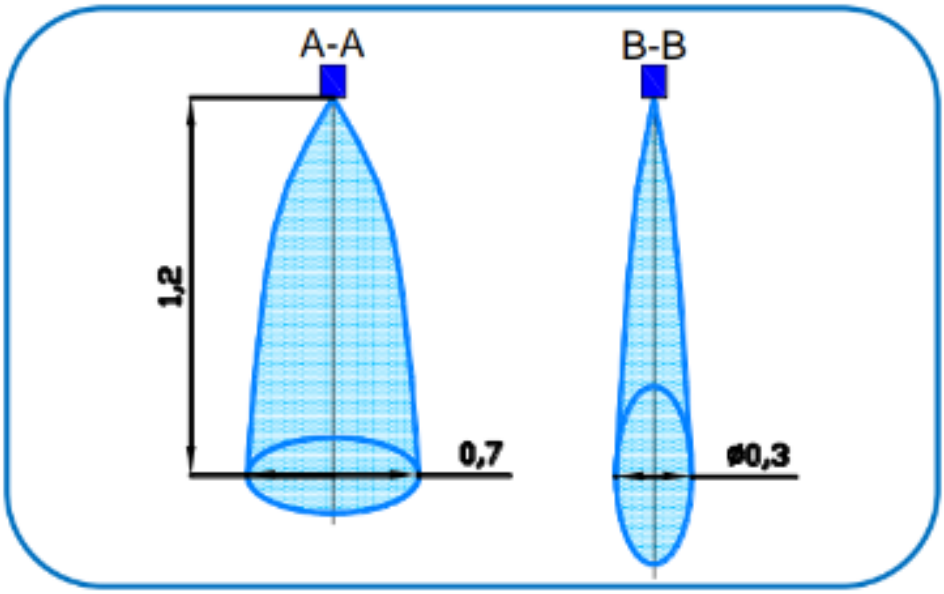
Elergy AS, Haslevollen 3,0579 Oslo, post@elergy.no
Phone: +47 474 54 361
www.elergy.no

TECHNICAL DETAILS

Created: 24.04.2020



MEDIUM PRESSURE SYSTEM - MIST STREAM



MEDIUM PRESSURE SYSTEM - MIST STREAM PARAMETERS					
Working pressure [bar]	:	3	6	8	10
Droplet size D_v [µm]			20 - 80		
Average K flow factor	:		0,15		
Flow rate* [dm³/min]	:	0,28	0,40	0,46	0,52
Effective stream range** [m]	:	0,8	-	1,2	-

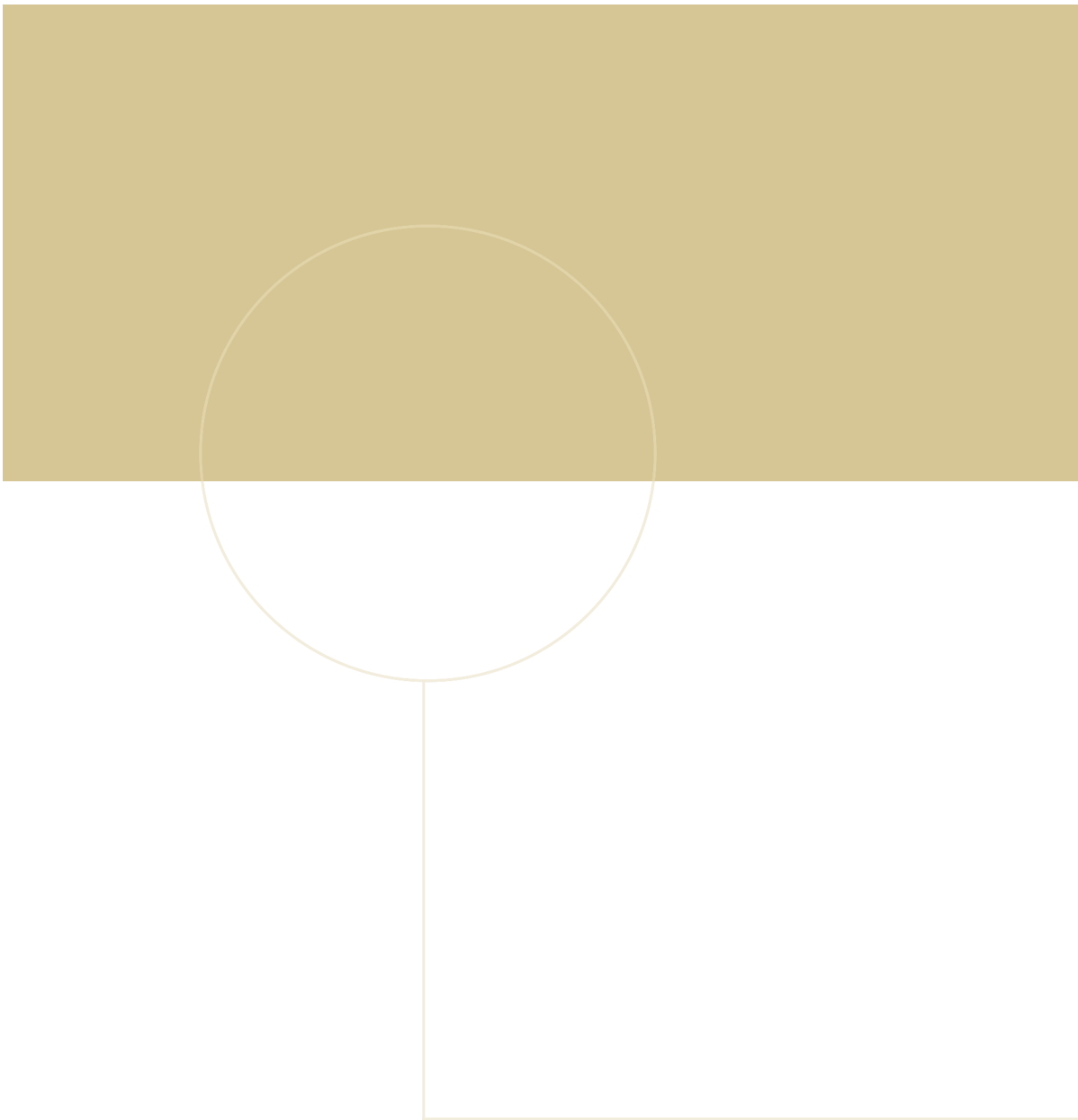
* May vary ± 5%.
** Range of horizontal stream .

Our products are being constantly developed and improved, therefore we reserve the right to change technical specifications without prior notice.

Elergy AS, Haslevollen 3,0579 Oslo, post@elergy.no
Phone: +47 474 54 361
www.elergy.no

GM-04

TELESTO WATER MIST



NTNU

Norwegian University of
Science and Technology