Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Civil and Environmental Engineering

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Investigation of Particle and Heavy Metal Removal and Detergent Degradation in Sedimented Tunnel Wash Water

Master's thesis in Civil and Environmental Engineering
Supervisor: Thomas Meyn

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Abstract

Norway has many road tunnels in need of regularly washing due to traffic safety and maintenance. The wash water contains a high number of particles and a wide spectrum of pollutants such as heavy metals, PAH, detergents, and microplastics. The water is proven to have ecotoxicological effects and there are national recommendations for treatment before releasing it to recipients. For newer tunnels in Norway, this has commonly been implemented as closed sedimentation basins as a first treatment step. The water is stored in these basins for approximately 30 days, mainly to achieve detergent degradation and particle removal. However, there is little knowledge about the treatment performance during this time; such as to what extent detergents degrade in the dark and cold conditions; and the fate of dissolved pollutants in the system.

In this study, tunnel wash water was collected from three tunnels in Oslo, Norway, and stored in sedimentation columns in a cooled environment for 35 days. During that time the following parameters were monitored: total solids (TS), total suspended solids (TSS), turbidity, particle size distribution, pH, conductivity, detergent content (by dissolved organic carbon and size-exclusion chromatography), metal concentrations, and dissolved oxygen.

Sedimentation reduced TSS with 88-91% and turbidity with 80-95%. The pH stayed stable at around 8. A total solid concentration of 1.16-2.34 g/L was measured after the sedimentation, most probably originating from road salt. Dissolved oxygen concentration decreased down to anaerobic condition in some cases, and a small reduction in dissolved organic carbon was observed, which may indicate some detergent degradation. The particle size distribution showed many small particles with a diameter <10 µm. The >1.2 µm fraction of the analysed metals got significantly reduced, while no clear removal of the smaller fractions was seen.

The effluent TSS concentration was lower than the commonly used limit of 100 mg/L. The effluent total concentration of copper and zink were within EQS class 2 or 4, depending on the type of recipient (fresh water or sea water). Due to the high effluent metal concentrations, combined with uncertainties about detergent degradation, a second treatment step after sedimentation is recommended.

Samandrag

Noreg har mange vegtunnelar, som treng jamleg vasking på grunn av trafikktryggleik og vedlikehald. Vaskevatnet inneheld mykje partiklar, og er ureina av tungmetall, PAH, vaskemiddel og mikroplast. Det er vist at vatnet har økotoksiologiske effektar, og det er anbefalingar om reinsing før det blir slept til resipient. I nyare tunnelar i Noreg har dette vanlegvis blitt implementert som eit innandørs sedimentasjonsbasseng som første reinsesteg. Vatnet vert oppbevart her i omlag 30 dagar, hovudsakleg for å bryte ned vaskemidla og for å fjerne partiklar. Det er lite kunnskap om reinseeffekten av dette; slik som kor bra vaskemidla vert nedbrotne i dei mørke og kalde omgivnadene, og kva som skjer med dei oppløyste ureiningane.

I denne studien vart tunnelvaskevatn henta frå tre tunnelar i Oslo og lagra kjølig i 35 dagar. I løpet av den tida vart dei følgande parametrane overvaka: totalt tørrstoff (TS) , totalt suspendert stoff (TSS), turbiditet, partikkelstorleiksfordeling, pH, konduktivitet, innhald av vaskemiddel (ved å sjå på oppløyst organisk karbon og eksklusjonskromatografi), metallkonsentrasjonar og oppløyst oksygen.

Resultata viser ein tydeleg reduksjon av TSS (88-91%) og turbiditet (80-95%) . Målt pH heldt seg stabil rundt 8. Ein konsentrasjon av TS på 1.16-2.34 g/L vart målt etter sedimentering, som truleg kjem frå vegsalt. Konsentrasjonen av oppløyst oksygen vart i nokre tilfelle redusert til anaerobe forhold og ein liten nedgang i oppløyst organisk karbon vart observert, som kan indikere nedbryting av vaskemidla. Dette burde imidlertidig undersøkast vidare. Partikkelstorleiksfordelinga viste mange små partiklar <10 µm. Metallfraksjonane > 1.2 µm vart tydeleg redusert, medan dei mindre fraksjonane såg ikkje ut til å bli fjerna.

Etter sedimentering var TSS konsentrasjonen i vatnet under den mykje brukte grensa på 100 mg/L. Totalkonsentrasjonen av kobber og sink enda opp i EQS klasse 2 eller 4, avhengig av type resipient (ferskvatn eller sjøvatn). På grunn av dei høge metallkonsentrasjonane, kombinert med usikkerheiter rundt nedbryting av vaskemidla, burde eit andre reinsesteg verte vurdert.

Preface

This master thesis was carried out as a part of the master's degree in Civil and Environmental Engineering at Norwegian University of Technology and Science, between January to July 2020.

The laboratory part of the thesis, which was planned to be carried out in the timespan February to the middle of April 2020, was affected by the Covid-19 breakout. Temporarily closing of the labs from 12th March, combined with time limitations for the master thesis and certain limitations for tunnel wash water sampling*, influenced the work. Many analyses planned to be carried out were limited by lab restrictions. The method part of this thesis describes how the lab part was actually carried out, which makes the analysis frequency seem rather random. The original lab plan with more structure is attached in Appendix B. Additionally, due to time limitations some of the planned parameters could not be analysed for all the samples.

The first tunnel used for tunnel wash water sampling was *Smestadtunnelen*. Early in the process it was discussed whether the results from this sample should be included or not, as it was many possible sources of errors. The results also showed different values than for the two other tunnels, making it questionable how representative they were. However, since this was the sedimentation process with most datapoints, it was decided to include it.

This thesis could not have been done without the help from several people. First, I would like to thank Associate Professor Thomas Meyn, for not only supervising me through the thesis work, but also helping me with the water collections in Oslo and the lab analyses after 12th March.

Furthermore, I would like to thank:

-Nina Mari Jørgensen, Statens Vegvesen, for answering my questions about tunnel wash water, as well as helping us to plan the water collections

-Trine Margrete Håberg Næss, Department of Civil and Environmental Engineering, NTNU, for all guidance and help in the lab

-Thuat Trinh, Yinghong Gao, and Blanca Magdalena Gonzales Silva, Department of Civil and Environmental Engineering, NTNU, for teaching me how to use some of the lab instruments

-Tone Merethe Muthanna, Department of Civil and Environmental Engineering, NTNU, for advices about scientific writing

**Washing of Norwegian road tunnels is scheduled by The Norwegian Public Road Administration. Whole or half washes were carried out every 1-3 month for the tunnels that were suitable for water sampling in this study.*

Ågot Bjotveit

Kinsarvik, 18th June 2020

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Translations

A list of some specific Norwegian technical words and expressions, translated to English:

Årsdøgnstrafikk (ÅDT) - Annual Average Daily Traffic (a measure of the average traffic on a road or a tunnel through the year)

Statens vegvesen- Norwegian Public Road Administration

Heilvask – Whole-wash (tunnel washing which includes washing of all surfaces and technical equipment)*

Halvvask - Half-wash (tunnel washing which includes washing of technical equipment, the road surface and walls) *

Teknisk vask - Technical wash (tunnel washing of technical equipment, such as signs and lights)*

**Information about the types of washes is from Torp and Meland (2013)*

Abbreviations

AADT – Annual Average Daily Traffic

TWW- Tunnel Tash Tater

NPRA - Norwegian Public Road Administrations

EQS- Environmental Quality Standards

BT - Bjørnegårdstunnelen

ST - Smestadtunnelen

TT - Tåsentunnelen

PAH - Polycyclic Aromatic Hydrocarbons

LAS – Linear Alkylbenzene Sulfonate

SLES – Sodium Lauryl Ether sulfate

TSS – Total Suspended Solids

TS- Total Solids

DO – Dissolved Oxygen

DOC – Dissolved Organic Carbon

PSD- Particle Size Distribution

OPA- Optical Particle Analysis

1. Introduction

Norway has over 1100 road tunnels due to a challenging topography. The tunnels are washed 1-12 times a year due to traffic safety and maintenance, the frequency depending on the annual average daily traffic (AADT) (Torp and Meland, 2013). The reported water volume varies from 60-140 L/m tunnel for so-called whole- and half-washes, while washing of only technical equipment requires much less water (Vogelsang *et al.*, 2019). The most frequent procedure is half-washes, meaning all surfaces except the ceiling is washed (Meland *et al.*, 2010a). The washing procedure generates large volumes of polluted tunnel wash water (TWW). In most cases the TWW is released untreated to the recipient, except removal of the coarsest material by sweeping machines and gully pots (Torp and Meland, 2013).

TWW contains a mix of pollutants originating from car parts and the road surface. The dominant pollutants are a high sediment load, PAHs (Polycyclic aromatic hydrocarbons) and heavy metals such as copper (Cu), zink (Zn) aluminium (Al), and lead (Pb) (Paruch and Roseth, 2008a.b; Meland 2010, Meland and Rødland 2018). These pollutants are also well documented as typical constituents in road runoff, among others by Brown and Peake (2006); Hallberg, Renman and Lundbom (2007). TWW mainly differs from road runoff by having higher pollutant concentrations (Meland, Ranneklev and Hertel-Aas, 2016). Additionally, detergents are typically applied during the washing for an easier removal of dirt, resulting in detergent concentrations of 0.5-1.0 % in the outflow water (Meland *et al.*, 2010a). Lately microplastics in road dust originating from car tires, road markings and asphalt have gained increased awareness, making this a concern for TWW (Vogelsang *et al.*, 2019). This cocktail of pollutants has severe negative effects on the aquatic life, and can cause pollution in the recipients (Meland *et al.*, 2010b; Meland and Rødland, 2018).

Most tunnels have no water treatment solution, but it is recommended for new installations (Meland and Rødland, 2018). This recommendation is included in the current national guidelines given by the Norwegian Public Road Administration (NPRA), stating that TWW should be treated if it can be harmful for the environment (Statens Vegvesen, 2020). Open-air sedimentation ponds have been tried as a treatment solution, but experience has shown that there is little possibility of controlling the retention time. There has also been reported negative effects on the aquatic life in these ponds. (Garshol *et al.*, 2016; Meland, 2012). Hence, according to the current guidelines, treatment of TWW should be done in closed solutions, and minimum include sedimentation of particles, separation of oil and degrading of detergents (Statens Vegvesen, 2020). A further specification of the treatment process is not provided by the NPRA. At the time being there is a lack of a so-called Best Available Technology (BAT) for treatment of TWW (Garshol *et al.*, 2016). However, sedimentation with a hydraulic retention time of 4-5 weeks has been recommended as a treatment method (Rathnaweera *et al.*, 2019). This is the practice currently used for the tunnels investigated in this study.

Except some lab scale studies, there is little knowledge about how these closed sedimentations basin perform given typical TWW properties. Garshol *et al.* (2016) investigated sedimentation among other treatment processes and combinations for TWW, with a focus on Zn- and Cu- removal. Total concentrations of these metals were reported after 7 and 37 days. The state of the metals does affect their bioavailability, the dissolved compounds generally being of a greater concern (Meland, 2010). Particle bound pollution in road runoff should be easily removable by sedimentation (Paruch and Roseth, 2008b; 2008a), while the dissolved ones are more questionable.

Detergents are a concern in TWW. Their main constituent is surfactants (Yu, Zhao and Bayly, 2008), which are widely discussed substances (Porter, 1991). They are documented to have toxic effects on aquatic life when certain concentrations are exceeded, among others by Caracciolo *et al.* (2017); Ying (2006); Corneliussen *et al.* (2007). According to EU-regulations detergents should degrade 60% within 28 days (EUR-lex, 2004). It has been questioned if this requirement is met for detergents in TWW, considered the typical dark and cold conditions in the closed sedimentation basins. By investigating a few tunnel wash detergents, Roseth and Søvik (2006) found that degradation happened slowly under the above-mentioned conditions. However, a different detergent is used for tunnel washing now, according to the NPRA. As detergents have complex formulas consisting of surfactants, solvents, complexing and alkaline substances (Yu, Zhao and Bayly, 2008), the new detergent with an updated formula might behave differently. Detergents and the metal states are also connected, as it has been found that detergents might remobilize Cu and Zn and TWW (Aasum, 2013)

Norwegian laws and regulations do not specify allowed effluent concentrations of different pollutants from TWW. The common practice is that the released water should not worsen the water quality in the recipient, which is defined by the use of so-called Environmental Quality Standards (EQS). Untreated tunnel wash water will in most cases exceed these standards (Meland and Rødland, 2018).

The European Water Framework Directive (WFD), which is implemented in the Norwegian Water Regulation (Vannforskriften, 2006), has the aim of ensuring a good ecological and chemical water quality (Meland *et al.*, 2010a). In the light of WDF it is important to find a suitable treatment for TWW. As sedimentation basins currently are the common practice for TWW, it is of interest to obtain more knowledge about their performance. As several of the components are expected to be in the dissolved state, an additional treatment step should be considered, especially for highly trafficked tunnels (Meland, 2012). More knowledge about the effluent water quality will give a better basis for determining the need for additional treatment. Further it can assist in the choice of a secondary treatment process.

By monitoring the sedimentation process in TWW for 35 days, this study aims to describe how this affects the water quality over time. There will be a focus on the following questions:

-How is the sedimentation process affecting the analysed water parameters, both the particle related and dissolved ones?

- How does the currently used tunnel wash detergent degrading in typical sedimentation basin conditions?

-How are the variations in the water quality, both for the different tunnels studied, and compared to previous studies on this topic?

2. Method

2.1 Field Site and Sampling

TWW was collected from three tunnels in the Oslo area between February and March 2020. The tunnels *Smestadtunnelen* (ST), *Bjørnegårdtunnelen* (BT), and *Tåsentunnelen* (TT) were chosen mainly based on the following criteria: (1) they all have closed sedimentation basins, (2) their equality in AADT, and (3) time limitations due to the washing schedule suggested by the NPRA. An overview of the tunnels and washing information can be seen in *Table 2.1*. As tunnel washing for practical reasons happens during the night, the collections were done early in the morning after the washing.

According to the NPRA, these sedimentation basins have a maximum water depth of 2.2-2.9 meters. The depth is specific for each tunnel and also varies due to slightly inclined floors. The basins are dimensioned for whole-washes, additionally to some sludge- and safety volume. As the collections in this study were done after half-washes, the basins were not filled up. The exact water depths at the sampling times were not known but did probably not exceed 2 meters.

The sampling was done directly from the sedimentation basins. A submersible pump (*Metabo Skittenvannspumpe, PS 18000 SN*) was used for transferring the TWW into containers made of high-density polyethylene. When collecting TWW in ST, the pump broke. Due to little time available, the TWW was collected with buckets instead, and a smaller volume than planned was collected. The sample from ST was approximately 150 L, and the samples from BT and TT were 300 L. All the samples were transported to the Norwegian University of Technology and Science (NTNU) in Trondheim where the analyses were carried out. The first sample from ST was transported a 1000 L tank. During the transport time some sedimentation probably already happened, and the large tank made it hard to resuspend these sediments. For the two next samples 20 L containers were used for the transportation.

Table 2.1*:The tunnels where the TWW was collected. AADT is estimated from Torp and Meland (2013) and information from the road map of NPRA (Vegkart, n.d.). The water depth written here is at the deepest point of the inclined floor.*

Tunnel name	AADT	Date for water collection	Sedimentation basin	Other information
Smestadtunnelen (ST)	48648	03.02.2020	Max water depth: 2.75 m. Water retained for 21 days*	Two tunnel tubes, both washed 02.02. Half washing. Pump broke, buckets were used for collecting most of the water. Around 150 L of sample collected close to the water surface.
Bjørnegårdtunnelen (BT)	29964**	03.03.2020	Max water depth: 2,9 m. Water retained for 35 days*	Two tunnel tubes, one washed 02.03. Half washing and brushing. Water collected around 1 m under the surface.
Tåsentunnelen (TT)	49850	12.03.2020	Max water depth: 3 m. Water retained for 21 days*	Two tunnel tubes, both washed 11.03. Half washing. Water collected close to the surface.

**According to the NPRA, the hydraulic retention time for the TWW mainly depends on the AADT and washing frequency. ST and TT are washed more frequent than BT, making it necessary to empty the basins more often.*

***AADT for BT was found from the road map of NPRA (Vegkart, n.d.). As the road map stated two different numbers for the south-going tube in the tunnel, the average was used for estimating a total AADT.*

2.2 Lab Setup

The lab setup aimed to imitate typical conditions in the sedimentation basins by storing the TWW in two columns inside a dark and temperature-controlled room at around 6° C. Each column had a height of 2 m, and a diameter of 30 cm, resulting in a volume of 141 L. The top had an open water surface like the sedimentation basins. The maximum sedimentation basin depth of around 3 meters was not possible to recreate in the lab due to space limitations. This limited the column height to 2 m. The columns were equipped with taps made of stainless steel every 25 cm, making it possible to collect water from different depths. In the present study the upper, middle and lower tap were used for sampling, named tap 1, 2 and 3 respectively. To observe the sedimentation process visually, the columns were made of poly methyl methacrylate (known as plexiglass). The necessary column diameter was estimated from having enough water available from the upper tap for all the analyses.

After the sampling and transportation to Trondheim, the TWW was transferred to the columns immediately. The transferring was done by pouring the water into a bucket, followed by using the submersible pump to fill up the columns (see *Figure 2, Appendix A*). For minimizing possible errors due to sedimentation during the transport, the water was mixed before the transferring. As mentioned above, this mixing was limited for the TWW from ST due to the large tank. TWW was stored in two parallel columns for 35 days, while water samples were collected and analysed regularly.

For TWW from BT and TT the two columns, named column 1 and 2, were considered as parallels. The TWW collected in ST was only enough for one column.

Figure 2.1*: A picture of the columns used in the lab setup. Tap 1, 2 and 3 were used in the present experiments. Each column had a height of 2 meters and a diameter of 30 cm. Tap 1 was initially 25 cm under the water surface. Tap 3 was 1 cm above the bottom.*

2.3 Analysed Water Parameters

Several parameters were analysed during the 35 days, to obtain knowledge about the overall performance of the basins. *Table 2.2* presents an overview of the parameters and the respective methods and standards. For parameters expected to be affected by the sedimentation process or the water depth, samples were taken and analysed from different taps. This includes total solids (TS), total suspended solids (TSS), particle size distribution (PSD), turbidity, and dissolved oxygen (DO). For the parameters related to dissolved components, the sampling was done from one tap. When possible, the analyses were carrying out immediately after sampling from the columns. If not possible due to practical considerations, the samples were conserved as described in the respective standard until analysing. *Table 2.3* lists the analysis frequency, which was established based on how rapid changes that were expected due to sedimentation. The methods in need for further description, e.g. those not following a standard, are further explained in the following sections.

To minimize possible errors from sediments in the taps, some water was discarded prior to each sampling. Rinsing of instruments was always done with de-ionized water, additionally to some TWW from the current sample before the analyses were carried out.

Table 2.2*: An overview of the analysed parameters for determining the water quality before, during and after sedimentation.*

Parameter	Method/standard	Taps for sampling	Comment
pH	ISO 10523:2008	1,2, 3	Heated to 25°C in a water bath before measured.
Conductivity	NS-ISO 7888:1985	2	Heated to 25°C in a water bath before measured.
Total solids (TS)	NS 4764:1980 (*DIN EN 872:2005-04 1.4.2005)	1, 3 (after 12th march: only tap 1)	All weighting of the samples was done using a four-decimal scale.
Total suspended solids (TSS)	NS 4733:1983 (*ISO 11923:1997)	1, 3 (after 12th march: only tap 1)	All weighting of the filters was done using a four-decimal scale The filtration was done with a glass microfiber filter, pore size 1.2 µm.
Turbidity	ISO 7027-1:2016	1, 2, 3	Analysed each sample twice for eliminating errors from possible condense etc.
Particle size distribution (PSD)	1) Optical particle analyses (OPA), with PN3000 XPT detector 2) Laser diffraction with Beckman Coulter LS 230	1, 2, 3	Method 1) is also measuring the particle amount Method 2) was included from the start of analyses of the BT sample.
Dissolved oxygen (DO)	ISO 5814:2012	1 (upper part of the column), 3	Expected to be affected by distance to the water surface. The upper value measured directly in the column
Dissolved organic carbon (DOC)	ISO 8245:1999	2	Indication of detergent degrading
Carbon fractioning	Size-exclusion chromatography (SEC) with LC-OCD-OND	2	Indication for detergent degrading
Metal concentrations	IPC-MS	1	Analyses done in a parallel study by Kowollik (2020).

** NS standards are Norwegian standards (Norsk Standard, 2019). If the analysis procedure followed was described in Norwegian, the standard within the brackets is the closest corresponding international standard.*

***Table 2.3**: The analysis frequency for each of the TWW samples. Due to the lab closing and restrictions from 12th March the frequency are different for each of the TWW samples.*

	Tunnel		
Parameter	ST [days]	BT [days]	TT [days]
pH	0, 1, 2, 10, 15, 21, 35	0, 1, 2, 6, 11, 25, 44	0, 2, 4, 16, 35
Conductivity	0, 35	0	-
TS	0, 15	0, 44	0, 35
TSS	0, 15	0, 44	0, 35
Turbidity	0, 1, 2, 3, 7, 11, 15, 22, 25, 35	0, 1, 2, 6, 11, 16, 25, 44	0, 2, 4, 16, 35
PSD – optical particle measurement	0,1,2,3, 7, 10, 15, 21, 25, 35	0, 1, 2, 6, 11, 16, 25, 44	0, 2, 4, 16, 35
PSD- laser diffraction	-	0, 3	-
DO	-	0, 1, 2, 3, 7, 11, 44	0, 2, 35
DOC	0, 7, 15	Day 0, 13, 25, 44	0, 16, 35
Carbon fractioning	0, 7, 15, 21, 35	0, 6, 13, 25, 44	0, 16, 35
Metal concentrations	0, 11, 21, 36	0, 25, 44	0, 16, 35

2.3.1 Particle Size Distribution

The PSD analyses were carried out with the instrument PN3000 XPT detector, which combines optical particle sizing with image analysis to determine the size, amount and distribution of particles (Postnova, n.d.). The settings for the PN3000 XPT were adjusted to the TWW, which mostly contained small and spherical particles (see pictures in *Appendix C.5*). The instrument was set to 100 pictures per analysis, and a maximum diameter of detection of 50 µm. During the analyses, the sample was aggregated with a magnetic stirrer.

PSD can be represented by a number-weighted distribution or a volume-weighted distribution, which affects the calculation basis for the PSD (Horiba Instruments, 2017). The optical particle analyses (OPA) by the PN3000 detector gives number-weighted PSDs. The software also provides a conversion to a volume-weighted PSD, which was done for the samples from ST. This was not further prioritized after the lab closing.

In order to complement the OPA, which considered particles between 0 and 50 µm, laser diffraction analyses were carried out. The instrument LS 230 Beckman coulter was used for this, which can measure particles in the size range of 0.04-2000 µm, from laser diffraction due to particles and information from the PIDS-model (polarization intensity differential scattering) for the particles <0.4 µm (Beckman Coulter, 2011). It provides a volume-weighted PSD. Approximately 5 ml of sample was used for each of the PSD analyses, until a PIDS between 45-55% was obtained. De-ionized water was used for rinsing the instrument 3 times between each analysis. The average PSDs from 3 runs per sample were used. The software also provided conversion to number-weighted PSDs. These conversions should however be handled carefully, as they are only valid for symmetrical distributions, and errors can occur when converting volume-weighted calculations to number-weighted calculations (Horiba Instruments, 2017).

The PSD measurements by laser diffraction were planned to be carried out for the TWW from BT and TT. Due to the lab closing, only a few measurements from BT were done.

2.3.2 Dissolved Oxygen

Dissolved Oxygen (DO) was analysed according to ISO 5814:2012, by using a WTW Oxi 3315 portable meter. This was only done in the TWW from BT and TT. Since DO was expected to be affected by the distance to the water surface, analyses were done for TWW from different water depths. The first measurements (day 0, 1 and 3 for BT) from the upper part were done by analysing TWW tapped from tap 1. To minimize interference from air bubbles, all the following analyses after this were done by inserting the probe directly in the column. With the equipment available, it was not possible to do the analyses directly in the column for the lower part. These analyses were carried out immediately after carefully tapping the samples from tap 3.

Road salt was probably present in the samples, which could be seen from a conductivity of 4.17 mS/cm in the BT sample, and many unremoved solids after sedimentation (see chapter 3.2). However, as the influence on the DO was assumed to be minor, the measurements were not corrected for salinity.

2.3.3 Detergent Degradation

Since the datasheet for the present detergent, *Purify Infravask* (see *Appendix D*), only provided information about the surfactants, it was not focused further on other detergent constituents.

The analyses on detergents in this study were done by method LC-OND-OCD (Liquid Chromatography-Organic Carbon Detection- Organic Nitrogen Detection), and measurements of dissolved organic carbon (DOC).

LC-OCD-OND

The method for LC-OCD-OND (Liquid Chromatography- Organic Carbon Detection- Organic Nitrogen Detection) is described by Huber *et al.* (2011). It is a size-exclusion chromatographic (SEC) method, which divides the sample into fractions of biopolymers, humic substances (HS), building blocks (often HS with low molecular weight (LMW)), LMW-acids, LMW- neutrals (e.g. Alcohols, sugars, amino acids etc) and hydrophobic organic carbon.

Water was collected and filtered through 0.45 µm polymer filters. The filters were rinsed with de-ionized water prior to sampling. By studying the peaks in the chromatograms, possible development of the organic substances in the detergent could be observed. The chromatogram of the detergent alone was also studied, for comparison and exclude peaks that belong to other constituents in the water. The detergent was diluted x500 to obtain a signal within the same size range as the TWW samples.

Dissolved Organic Carbon (DOC)

The instrument TOC Apollo 9000 was used for determination of DOC. The analyses were carried out according to recommendations in the instrument user manual and the standard ISO 8245:1999. As detergents consists of organic materials dissolved in the water, changes in DOC can indicate degrading (Roseth and Søvik, 2006). This method will only give an indication, not a direct measurement of detergent degrading.

After sampling the water was filtered through a 0.45 µm polymer filter. The filter was rinsed with de-ionized water prior to filtering to minimize possible organic material originating from the polymer. The analyses were carried out as soon as possible, meanwhile the samples were conserved as described in the standard, by adding acid (H_3PO_4) and storing it cold. The determination of CO_2 was done with a NDRI (Non-dispersive Infrared) detector. The samples were diluted with 6 times before analysing. before analysing. On the last measurements date for the BT and TT sample, 2 parallels for each column were analysed.

2.3.4 Metal Concentrations

The fate of the metals Aluminium (Al), Arsenic (As), Calcium (Ca), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Sodium (Na), Nickel (Ni), Phosphorus (P), Lead (Pb), Silicon (Si), Tin (Sn) and Zink (Zn) were investigated in a parallel study by Kowollik (2020). The concentration of the fractions >1.2 µm, 1.2-0.45 µm, 0.45 µm-3 kDa, and <3 kDa were determined by using IPC-MS (Inductively coupled plasma mass spectrometry). Explanation of the fraction determination and method in general is further described by Kowollik (2020).

3. Results and Discussion

3.1 pH and Conductivity

Figure 3.1 represent the average pH for each day, showing neutral values between 7.3- 8.1.

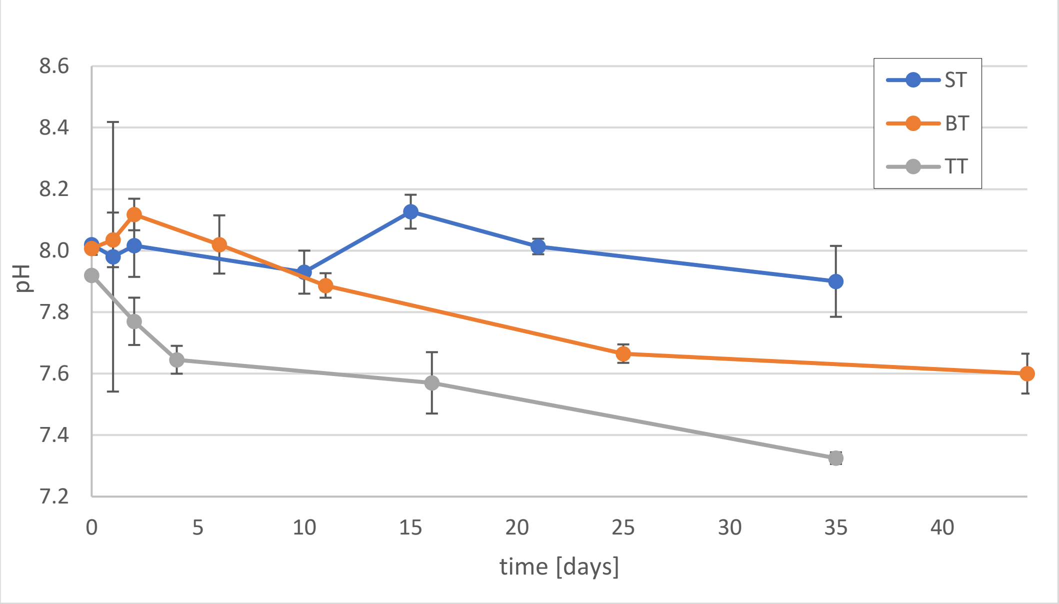

Figure 3.1*: Measured pH for ST, BT, and TT, the data points representing the average from the three taps each day.*

Figure 3.1 shows a slowly decreasing pH for BT and TT, while the results for ST fluctuated more. Some variations between the taps occurred, but no clear trend related to the water depth was found. The fluctuations for ST can be explained by a lack of consistent water temperature when the analyses were carried out.

Similar values for pH in TWW have been reported by Garshol *et al.* (2016) and Aasum (2013). Roseth and Søvik (2006) found that pH-values of 9-10 could slow down the biodegradation of detergents. This is however not a concern for this case, as the present pH-levels did not exceed pH values of 8.1.

Due to instrument errors, the first conductivity measurements from ST had to be discarded. The last measured values for ST and the initial for BT were both within the range of 4.17 ±0.9 mS/cm. After the lab closing conductivity was not a prioritized parameter.

Varying values for conductivity in TWW have previously been reported, among those 4.5 mS/cm by Roseth and Søvik (2006) and values up to 9.5 mS/cm by Meland (2010). Meland and Rødland (2018) found an average conductivity of 1.4 mS/cm from several tunnels. These variations are probably mostly influenced by road salt, which is further discussed in Chapter *3.4.2*.

3.2 TS and TSS

Figure 3.2 displays the results for TS and TSS for tap 1. Due to time limitations samples from tap 3 were not analysed after 12th March. The middle measurements were done on day 15, while the end measurements were done on day 35 for ST and TT, and 44 for TT.

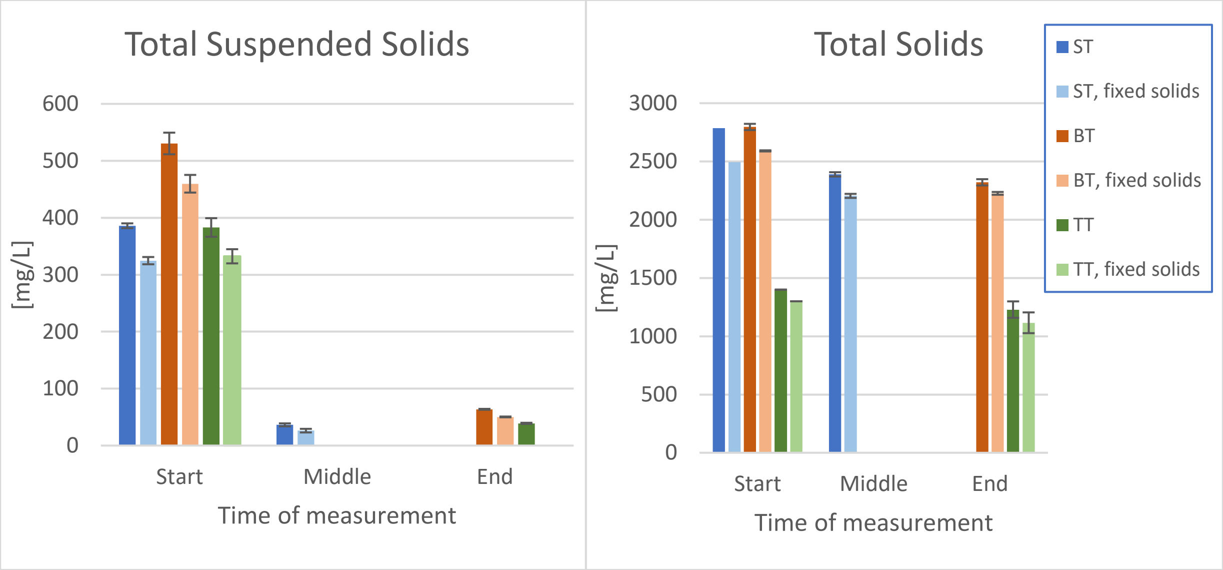

Figure 3.2: *TS and TSS, sampled from tap 1. The middle measurements are after 15 days, and the end measurements are after 35 for TT, while 44 days for BT. The values from ST is from one column, while from BT and TT the values represent the average from the average from the two columns.*

The TSS had a reduction of 88-91% in all the TWW samples, both for the dried weight and the fixed solids. The TS showed a small reduction of 11-17 % removal during the sedimentation time. Even if the percentage removal of TS and TSS are different, the absolute removal for each sample had similar values (see Appendix C.2-C.3). This shows that the particles >1.2 µm were well removed by sedimentation.

The last measurement for the TSS- fixed solids for the TT sample was not plotted in the figure, as it weighted 2.045 mg/L, which is under the detection limit of 5 mg/L (Norsk Standard, 1983).

After the ignition, each of the TS samples had lost 4.1-10.5 % of the dried weight, indicating mostly inorganic solids. For TSS the most samples lost 13.3-27.9 % of the dried weight. The exception was the last measurement for TT, which lost 94.8% of the weight. This deviation was not investigated further.

3.3 Turbidity

The measured turbidity for the TWW can be seen in *Figure 3.3*.

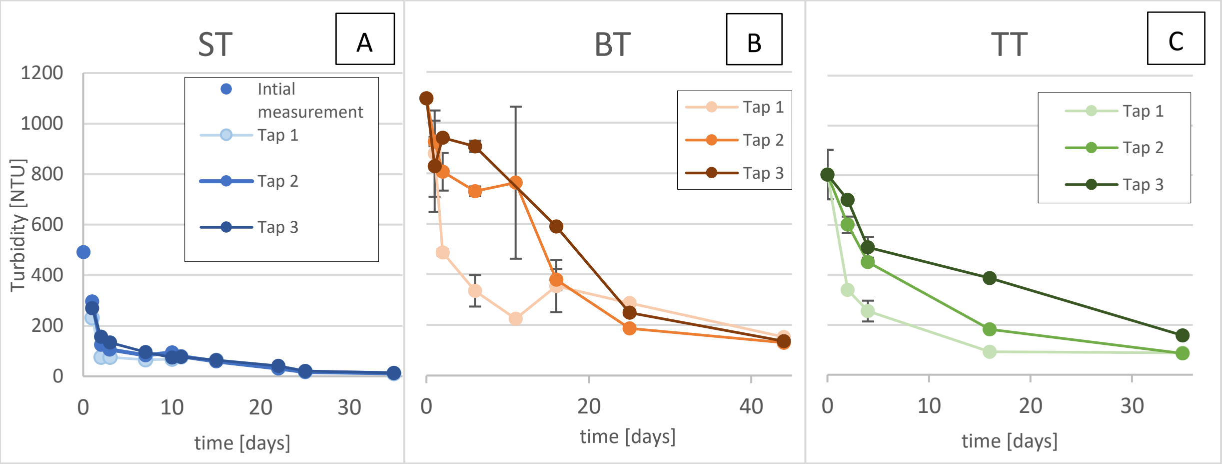

Figure 3.3*: Turbidity for the TWW samples from ST, BT and TT.* ***B****) Turbidity in the BT sample, the datapoints represent the average from column 1 and 2. Mostly these results were similar, with a few exceptions reflected by high standard deviations.* ***C****) The datapoints represent the average of the two columns for TT. The development between day 5 to 25 is not properly represented here due to few measurements.*

The turbidity got significantly (80-95%) reduced over time for all the tunnels. ST had the lowest values, starting at 492 NTU, which is much lower than the initial 1097 NTU and 803 NTU for BT and TT, respectively. ST also had the lowest end value of 12± 2 NTU after 35 days, while the TT sample ended at a turbidity of 122 ±36 NTU, and the BT sample at 141 ±12 NTU. With more measurement points for TT, the graphs would probably have a development more similar to the ST and BT graphs.

Some of the results, especially from BT, deviated strongly from the trend. At day 6 one turbidity measured was at 3000 NTU in column 1, which differed strongly from the other results that it was not included in *Figure 3.3.B*. Some days the results from the two columns were different, which is reflected in the standard deviations. Possible explanations for these deviations are air bubbles, sediments in the taps or lack of properly mixing.

Other reported initial turbidity values for TWW are around 400-1000 NTU (Garshol *et al.*, 2016; Aasum, 2013).

3.4 Particle Size Distribution

3.4.1 Particle amount

The particle amount measured by the PN3000 XPT Detector can be seen in *Figure 3.4*. These graphs represent a relative particle number, as the exact water volume in each PSD analysis was not known.

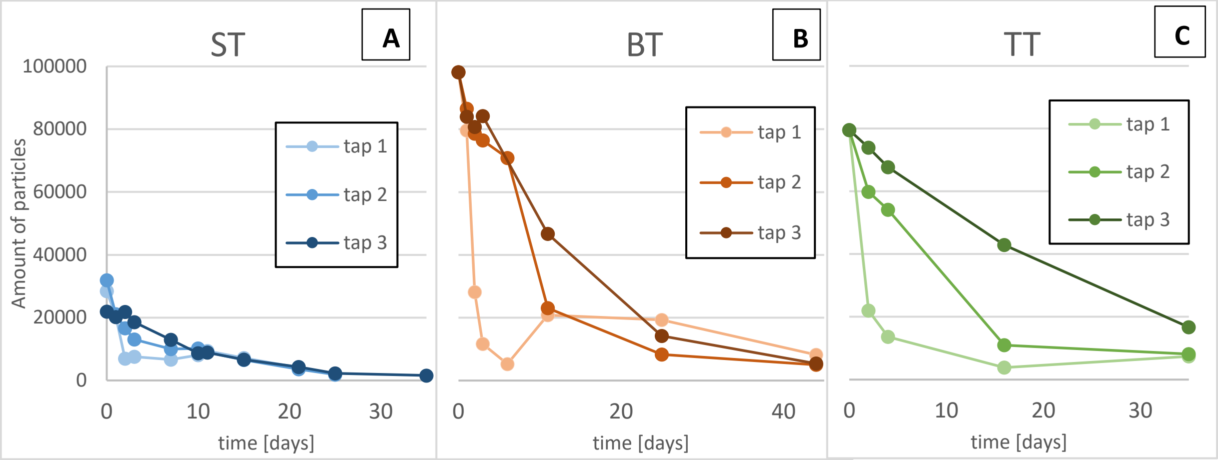

Figure 3.4*: Particle amount measured by PN3000 XPT. The graphs represent relative numbers, as the water volume used by the instrument in each analysis was not known.* ***C****) With more measurement points for TT, the particle amounts would probably even out faster than represented by the graphs here.*

As the results represent relative values, the trends are more interesting than the numbers themselves. The measured particle amounts clearly had the same trends as the turbidity. The days where the turbidity had deviating values, was also reflected in the particle amount. On day 6 BT had a particle amount of 199850, which was a so strongly deviating from the other numbers that it was not included in *Figure 3.4*.

3.4.2 PSD by Optical Particle Analysis (OPA)

The PSD measured by OPA with the PN3000 XPT detector showed small particles, with a weighted diameter average of 3-5 µm in all the TWW samples. *Figure 3.5* show the PSD from start, middle and end time of sedimentation, as well as from sludge collected from the TT sample.

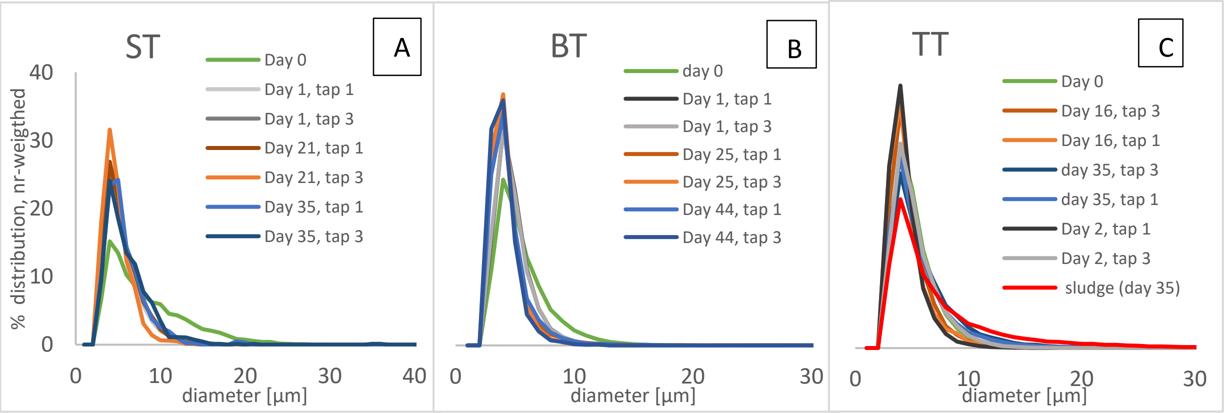

Figure 3.5*: PSD from the OPA, number-weighted.* ***A)*** *The initial measurement was taken from the bucked used for transferring the TWW to the column, and probably contained more sediments than the rest of the water.* ***B)*** *The average PSD for the two BT columns.* ***C)*** *The average PSD for the two TT columns.*

In *Figure 3.5,* a change from day 0 to 1 in the PSD could be seen for the ST and BT sample, indicating fast sedimentation of the larger particles. For the TT sample, this change was not seen. The analysed sludge sample from day 35 did still indicate some larger particles here as well. No trend related to the water depth was seen for any of the samples.

The measurements might have been more accurate with a larger diameter range, as larger particles around 100 µm was detected by the laser diffraction.

3.4.3 Volume-weighted PSD- conversion from the OPA

Figure 3.6 shows the conversion from the OPA to volume-weighted PSD the ST sample.

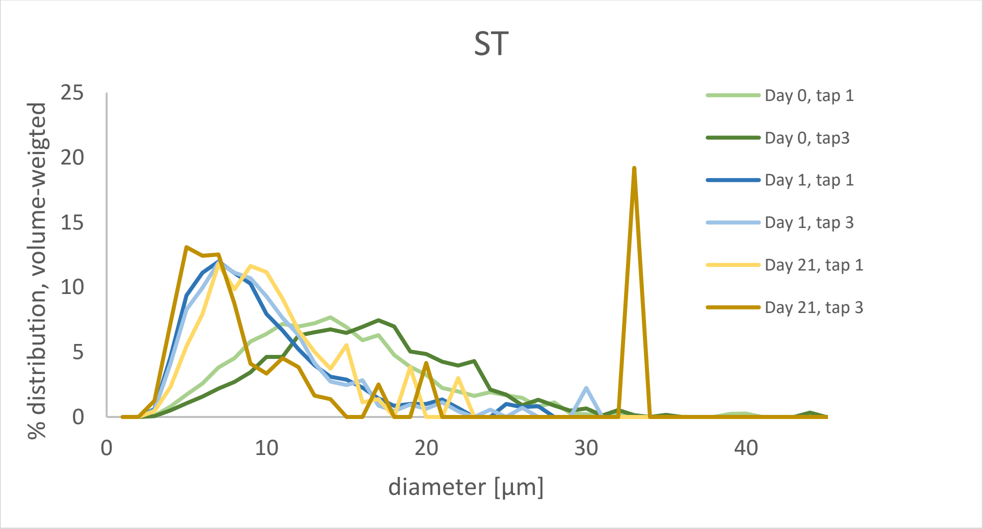

***Figure 3.6**: Volume-weighted PSD for ST, from tap 1 and 3. This distribution is converted from the original number-weighted PSD.*

The volume-weighted PSD gives more weighting to the larger particles than the number-weighted ones (Horiba Instruments, 2017). This can be seen in the diameter range of 10-35 µm, where the graphs in *Figure 3.6* indicate particles that can hardly be seen on the number-weighted graphs in *Figure 3.5*.

The difference in PSD from day 0 to 1 in the ST samples was also reflected in *Figure 3.6*.

3.4.4 PSD by Laser Diffraction

Figure 3.7 shows the PSD measured by laser diffraction, the graphs representing the average of 3 measurements per sample.

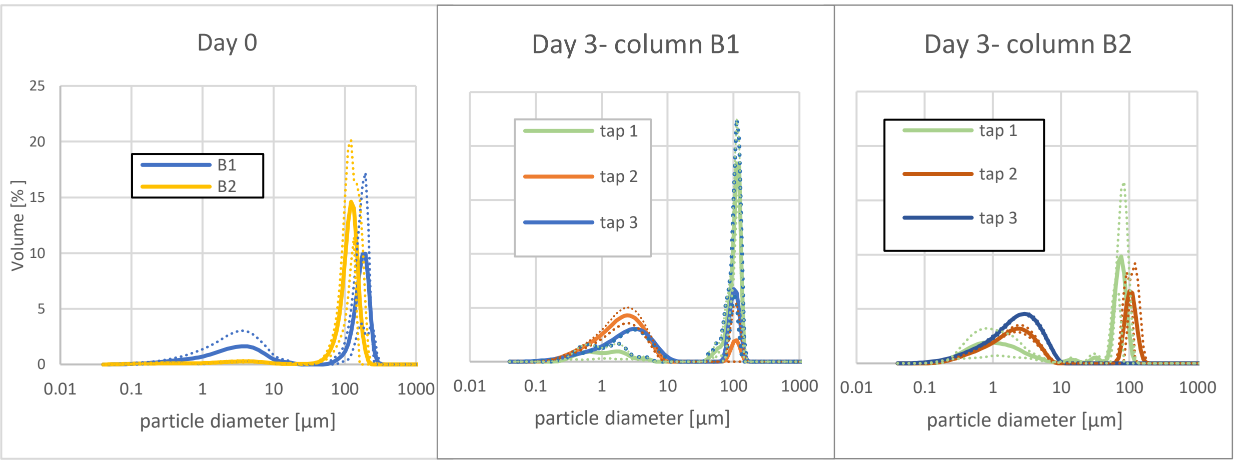

Figure 3.7: *Volume-weighted PSD from the laser diffraction, for BT on day 0 and day 3*

Figure 3.7 shows some PSD variations, but roughly the same peaks between 1-10 µm and around 100 µm were seen in nearly all measurements. The smallest peak also indicated many particles with a diameter <1 µm. As these PSDs are volume-weighted, the peak around 100 µm represent a few large particles, while the peak around 1-10 µm represent many small particles. The peak around 1-10 µm is less sharp day 0, which might indicate more large particles at the start time.

The distributions in Figure 3.7 are not symmetrical, which means the conversions to number- weighted distributions should be handled carefully (Horiba Instruments, 2017). These conversions are attached in *Appendix C.6*.

The two characteristic peaks around 1-10 µm and 100 µm was also found in road runoff by Charters, Cochrane and O'Sullivan (2015). In the study by Garshol *et al.* (2016), the PSD changed significantly the 24 hours. Their further measurements found some variations, but the same peak between 1-10 µm was also observed there.

3.5 Discussion of TS, TSS, Turbidity, and PSD

Some trends for particle amount and turbidity were seen for all the tunnels: (1) A significant reduction of the parameters over time, (2) a more rapid reduction the first days, and (3) the parameters were faster reduced for the upper part of the column in the beginning. After approximately 15-25 days, varying from tunnel to tunnel, the samples from the different taps had a nearly similar concentration of solids. Since turbidity is a measure of the undissolved matter present in water (Norsk Standard, 2016), TSS would probably have showed the same trends with more measurement points. It seemed like a sludge zone established below tap 3.

Sedimentation happened at a slow pace, and for BT and TT columns particles were still present at the end of the sedimentation time, detected by a turbidity of >100 NTU. The settling velocity of a particle under laminar conditions depends on the particle diameter, water viscosity and density of particle and water (Crittenden *et al.*, 2012). The small particle diameter observed in the PSD results, combined with the low temperature affecting the viscosity, can slow down the settling. The BT sample seemed to have the slowest sedimentation, which can be cause by the columns standing closest to the cooling aggregate. So-called Brownian motion might also have influenced the sedimentation. This phenomenon, which occur for small particles, means that gravity settling is hindered by random particle motion and collision with water molecules (Crittenden *et al.*, 2012).

Even if OPA and laser diffraction represent the PSD differently, they both showed many small particles <10 µm. From the laser diffraction many small particles <1 µm were detected, as well as some larger ones around 100 µm. Larger particles were also observed at pictures at end of the sedimentation time (see *Appendix C.5*). As these were not sedimented, a possible origination is from sediments stuck in the taps. Another reason might be a low particle density, hindering settling. A general source of error to consider, is that many larger/heavier particles might already have sedimented at the time of the water collection. Additionally, many larger particles are being removed by sweeping cars and gully pots. This is not a concern for the treatment process, as the larger particles should be easily removable by sedimentation. It should still be considered when comparing to road runoff, where the whole particle spectre is represented.

TS had a smaller reduction than expected. This might partly be caused by the small particles in the TWW but can also indicate the presence of dissolved solids. The TWW was collected during the winter season, meaning road salt probably was present. The high concentrations of sodium (Na), which was not removed by sedimentation (see chapter 3.4), supports this theory. Even if sedimentation will not reduce the salt concentrations, being aware of the presence of it and how it affects the water quality can be useful.

The particle related parameters in TWW are strongly seasonal dependent, due to the use of studded tyres. Previously values of TSS between 8 mg/L to 31 000 mg/L have been reported (Meland and Rødland, 2018). The TWW investigated in the present study was collected in the winter season, meaning the concentration generally can be considered to be in the upper range. BT had the highest concentrations. An explanation for this can be the type of wash, as it included brushing according to the washing plan. The ST sample had lower concentrations that the two others, which can be related to the problems during the water collection and transportation.

The Norwegian legislation do not specify max release concentrations of particulate matter from TWW. However, for newer tunnels a typical requirement of maximum 100 mg TSS /L is often set (Meland and Rødland, 2018). After the long-term sedimentation, the TWW investigated in this study met this requirement.

Micro plastics were not investigated in this study, but according to Vogelsang *et al.* (2019), TSS might be a good surrogate parameter for thread wear particles (TWP), which are micro plastics originating from typically tyres. If this is assumed, good removal of TSS can indicate removal of also TWP.

3.6 Dissolved Oxygen

DO was clearly reduced for all columns, with a larger and more rapid reduction by tap 3 (*Figure 3.8).*

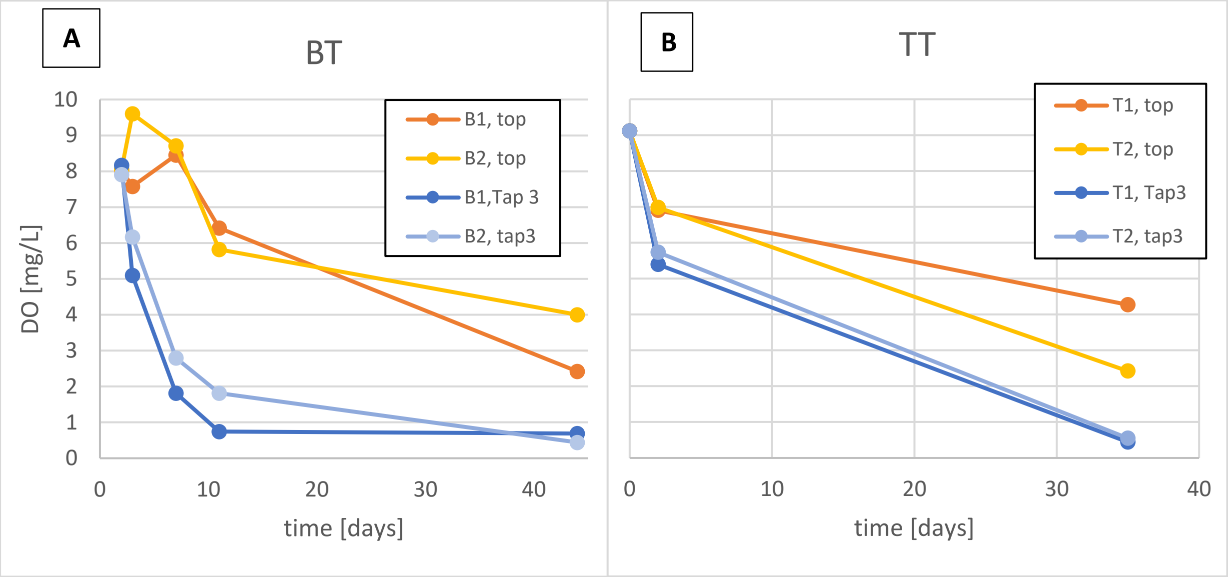

Figure 3.8*: DO for the BT and TT samples.* ***A)*** *The BT sample had some fluctuating values, probably caused by air bubbles.* ***B)*** *The actual development for TT between day 5-25 is not properly represented here due to few measurements.*

The TWW had initial DO values of 8-9 mg/L, which is lower than the roughly expected 12 mg/L in freshwater at 5 °C (Ødegaard, 2014). The samples from tap 3 had significant reductions in DO, reaching oxygen levels < 1 mg/L for all the columns. This low oxygen concentrations have also been observed in real TWW sedimentation basins, especially by the smell of sulphide.

The first measurements for BT had to be discarded due to a clear interference from air bubbles. For the analyses done on samples collected from the taps, additional air bubbles must be considered as a general source of error.

Oxygen reduction can be caused by biodegradation of organic matter, such as detergents and surfactants (Ødegaard, 2014; Akyüz and Roberts, 2002). However, anaerobe conditions can cause fish death (Ødegaard, 2014), making large volumes of water with low oxygen concentration a concern.

3.7 Detergent degradation

3.7.1 DOC

The initial DOC concentration was varying from tunnel to tunnel, starting at 29 mg/L for BT, 24.5 mg/L for TT and 10.2 mg/L for ST (see *Figure 3.9*). The lower concentrations in ST might be caused by a lower amount of detergent used. At the end of the sedimentation period, a DOC of 21 mg/L, 21.5 mg/l and 8.8 mg/L was measured, respectively. These slightly decreasing concentrations might indicate some detergent degradation. It should be taken into consideration that oil and tar originating from traffic also can influence the DOC (Roseth and Søvik, 2006).

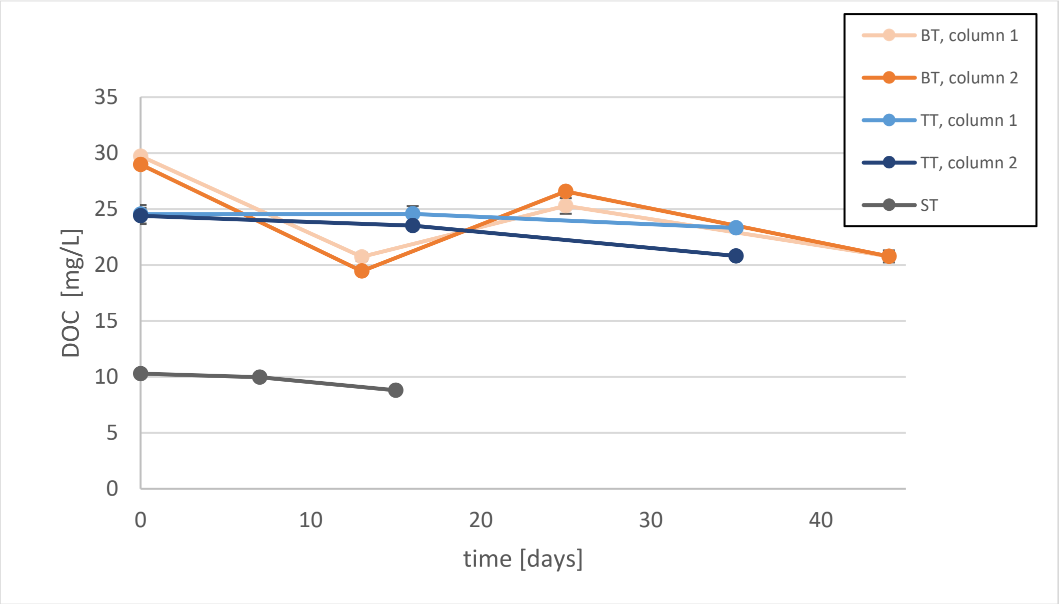

Figure 3.9: DOC from the three TWW samples. The last datapoint for BT and TT represent the result from the 2 parallels which had the lowest standard deviation.

The slow reduction of organic carbon was also found by Roseth and Søvik (2006), measured as total organic carbon (TOC). They reported higher initial values, starting at approximately 275 mg TOC /L. The difference between DOC and TOC should be considered, as possible particulate carbon is not included in the DOC numbers. Aasum (2013) did however find significantly higher DOC concentration than measured in this study, even without detergents present. It should be marked that the water in those studies was sampled from the tunnels *Nordbytunnelen* and *Smihagentunnelen*, which both have outdoor sedimentation ponds (Torp and Meland, 2013). This means that organic material from the ponds might contribute to the DOC/TOC content. The detergent used now (*Purify Infravask*), generally contains less surfactants than the detergents investigated by (Roseth and Søvik, 2006), which also might influence the DOC concentration.

During the analysis procedure foam appeared in the samples. This was not unexpected, as the detergent contains the surfactant sodium lauryl ether sulfate (SLES), which is known to be an effective foaming agent (Im and Ryoo, 2009; Caracciolo *et al.*, 2017). As this might influence the results, they should be handled with care. The low DOC concentration on day 13 for BT can be cause by the foam, or a dilution error. On the last analysis day, the measurements with the lowest standard deviation of the two parallels were included in *Figure 3.9*.

3.7.2 Carbon Fractioning

SEC- analyses were done to further characterise the DOC content in the TWW. While the SEC-analysis is based on the LC-OCD-OND methodology introduced by Huber *et al.* (2011), only the chromatograms are considered in this thesis, using them as an organic carbon fingerprint. Due to relatively small changes over time, some chromatograms were not included in *Figure 3.10*. All the chromatograms can be seen in *Appendix C.8*. The detergent chromatograph represents the detergent diluted with a factor of 500.

Figure 3.10: *Chromatograms for the BT, ST and TT samples, showing the OCD-graphs. The detergent represented here was diluted with a factor of 500.*

Figure 3.10 show two detergent peaks, one minor after 45 minutes (peak A) which may be placed in the building block-fraction, and a major peak after 75 minutes (peak B), that corresponds to the LMW-fraction (Huber *et al.*, 2011). It was not known which peak(s) belonged to the surfactants in the detergent. Peak A was seen in all the TWW samples. In the TWW from TT and ST peak B was clearly detected, while it was absent in the BT samples. Since the fractionation method was originally developed for analysis of surface waters, care needs to be taken when dividing the organic carbon into fractions as described by Huber *et al.* (2011).

Some development in the chromatograms were seen, e.g. by a minor reduction in peak B for ST ant TT. It was generally seen a slight decrease of the LMW fractions (from 47 to 42% in ST, from 65.5±3.5 to 56±1% in TT, from 48 to 32±1% in BT), and a slight increase in the biopolymer fractions (from 4 to 6% in ST, from 1.5±0.5 to 3% in TT, and from 4 to 8% in BT). This increase in the biopolymer fraction might indicate some biological activity.

The DOC concentrations found by the SEC analysis were around 50% of the concentrations found by the DOC-analyses. This might be explained from the different oxidation methods in the analysis. The DOC analyser had a greater ability to oxidize the organic carbon to CO_2, than the thin-film UV reactor in the SEC setup. Another reason may be the application of a SEC column, which may retain some part of the DOC.

3.7.3 Discussion of Detergent Degradation

Degradation of surfactants happens in two steps; the primary, which means that the surfactant properties are lost, then total degradation to CO_2, CH_4, water, mineral salts and biomass (Scott and Jones, 2000). The slowly decreasing DOC concentration can indicate some total degradation. DOC gives no information about possibly primary degradation (Roseth and Søvik, 2006).

As SEC separates molecules based on their size, identifying changes in the structure should be possible to detect from chromatograms. As mention above, it is not known which peaks that belonged to the surfactants in this case. The small increase of the biopolymer fraction might indicate some detergent degradation from biological activity. However, the changes in the chromatograms for the TWW samples were quite vague, making it hard to draw any clear conclusion.

Biological degradation is one aspect of detergents removal, but also sedimentation with particles has previously been discussed. Surfactants adhere to particles, and are often found present in sediments (Ying, 2006). The high particle reduction combined with the slow DOC reduction indicate that this was no strong removal mechanism here. A reason can be that anionic surfactants, which are used in *Purify Infravask*, have lower sorption to sludge than cationic and non-ionic surfactants (Ying, 2006).

According to the datasheet *Purify* contains <5% anionic surfactants, which generally are considered less toxic than cationic surfactants, but more toxic than non-ionic ones (Singh *et al.*, 2002). The surfactants in *Purify* are within the groups of linear alkylbenzene sulfonate (LAS) and SLES, which are widely used and discussed substances. LAS is considered ecotoxicological (Ødegaard, 2014). It is biodegradable under aerobe conditions, while anaerobic conditions strongly limit degradation (Ying, 2006). The biodegradability to SLES was reviewed by Caracciolo *et al.* (2017). They described the research on this surfactant as rather limited, but from the studies available, they concluded that SLES mostly seemed biodegradable in aerobic conditions. However, the CAS-number 9004-82-4, which is found in *Purify*, is mentioned specifically. According to Appendix III on the ECHA website, this surfactant might be persistent in the environment (European Chemical Agency, n.y.)

Generally, the results might indicate a slight detergent degradation, but the extent is not known. From the literature the surfactants in *Purify Infravask* seem biodegradable. According to the datasheet the requirement of 60% degradation within 28 days is met. However, the anaerobic conditions found in the water can limit this degradation. Previously, Roseth (2013) and Aasum (2013) have reported degradation of anionic surfactants in TWW, but no clear degradation trend was found there either.

More information should be obtained about surfactant degradation in TWW. A possible approach is the official method for determination of total concentration of anionic surfactants, which is based on a reaction between the anions and the cationic substance methylene blue. One disadvantage of this method is a production of toxic solvents (Caracciolo et al., 2017). Other possible surfactants analyses are chromotographic methods, such as gas chromatography (GC) or high-performance liquid chromatography (HPCL) (EUR-lex, 2004). It can also be of interest to investigate the other constituents, not just surfactants, in detergents further.

3.8 Metals

This section represents some of the metal results found by Kowollik (2020), among those the Cu and Zn concentrations (see *Figure 3.11-3.12*). Na fractions are also represented in *Figure 3.14* due to the relevance for road salt content.

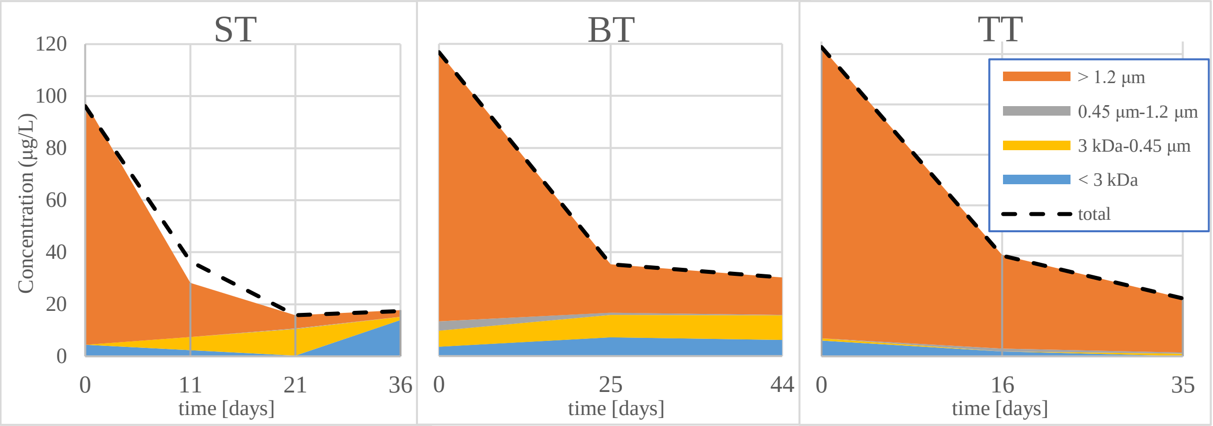

***Figure 3.11**: Concentrations of the different Cu fractions. (Figure: Kowollik (2020)).*

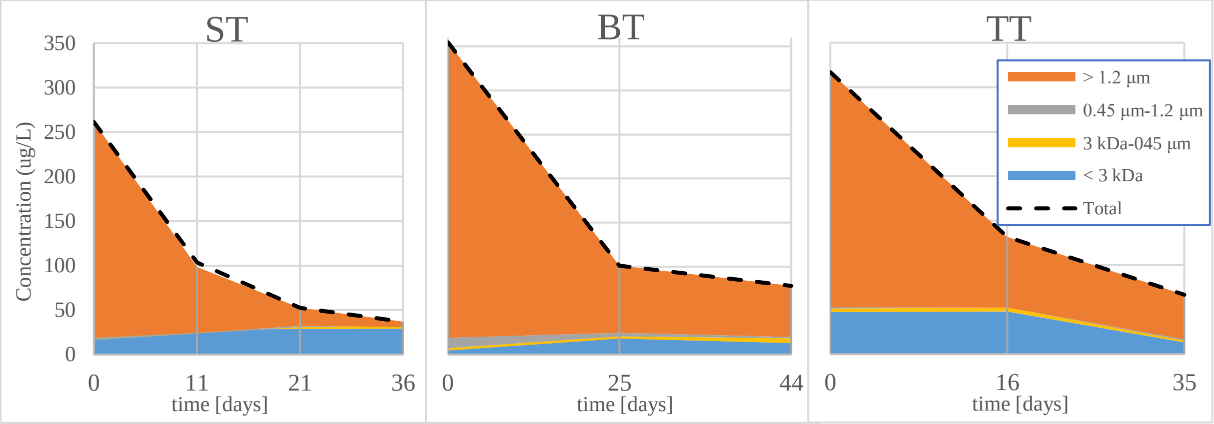

***Figure 3.12**: Concentrations of the different Zn fractions. (Figure: Kowollik (2020)).*

The total concentrations of both Cu and Zn were clearly reduced, ending at <31 µg/L and <78 µg/L, respectively. As *Figure 3.11 and 3.12* shows, the concentration of the different size fractions varied for the tunnels. The >1.2 µm fraction was the largest but got significantly reduced by sedimentation. A clear correlation between the Zn and Cu total concentrations and turbidity was also found, see F*igure 3.13*. The smaller fractions were still present after sedimentation.

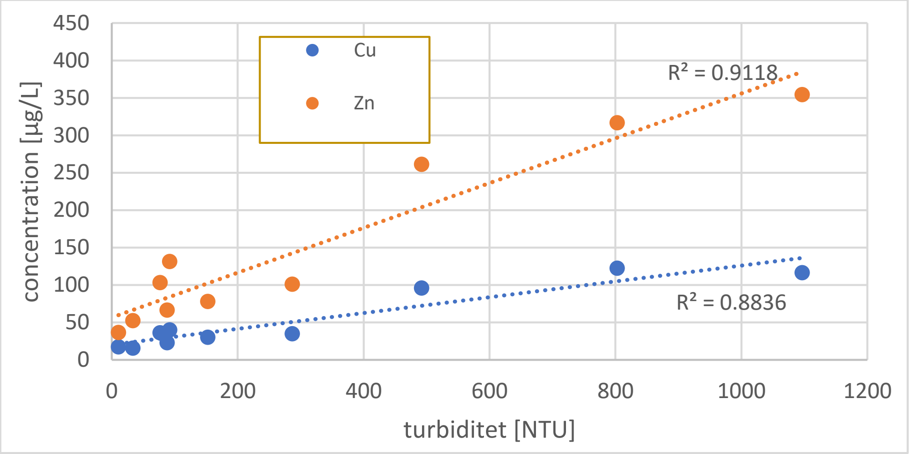

Figure 3.13*: The correlation between the turbidity and total concentrations of Cu and Zn.*

Table 3.1 compares the effluent Cu and Zn concentrations with EQS, found in Miljødirektoratet (2016). The EQS divides the water quality into 5 classes, where class 1 is the best quality. The EQS in *Table 3.1* are multiplied with 10, as this is a commonly used dilution factor when setting maximum release concentrations (Meland and Rødland, 2018). All Cu and Zn concentrations found were within class 2 for freshwater, while for sea water both Cu and Zn concentration in the BT sample was in class 4. The Zn concentration in the TT sample also ends up in class 4. Hence, the TWW exceeded the accepted concentrations in many recipients also after sedimentation. Different treatment methods for Cu and Zn in TWW removal was investigated by Garshol et al. (2016). Many options were possible, but sedimentation followed by coagulation/flocculation or filtration had a good removal effect.

Table 3.1*: Total concentrations of metal in the TWW at the end of the sedimentation time, compared to EQS. The EQS here are multiplied with a factor of 10, as this is a commonly applied dilution factor (Meland and Rødland, 2018). The EQS were found in Table 2.1* and 2.2 *in Miljødirektoratet (2016).*

Metal	Total effluent concentration in the TWW [µg/L]			EQS *10 – Freshwater [µg/L]				EQS*10 – sea water [µg/L]			
	ST	BT	TT	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4
Cu	17.4	30.2	23.0	3	78	78	156	3	26	26	52
Zn	36.9	78.1	66.8	15	110	110	600	15	34	60	600

High concentrations of metals such as Al and Fe were found, nearly everything in the > 1.2 µm fraction. The highest total concentrations were found for BT, with Al and Fe starting on 41545 µg/L and 24378 µg/L, respectively. After sedimentation these were reduced to 4047 µg/L and 3038 µg/L. Further discussion of these and the other metals can be found in Kowollik (2020).

As Sodium Chloride (NaCl) is used for road salting in Norway (Statens Vegvesen, 2018a), the high concentrations seen in *Figure 3.15* support the discussion about road salt. Na was found in high concentrations, around 750 mg/L in ST and BT, and 350 mg/L in TT. Nearly everything was in the < 3kDa fraction and was not reduced from sedimentation. The TS concentrations (chapter 3.2) also show a significant lower value for TT. If assuming that the Na concentrations originate from road salt, a reason for the lower concentration in TT might be that this sample was collected later in the winter season, when the road salting had declined.

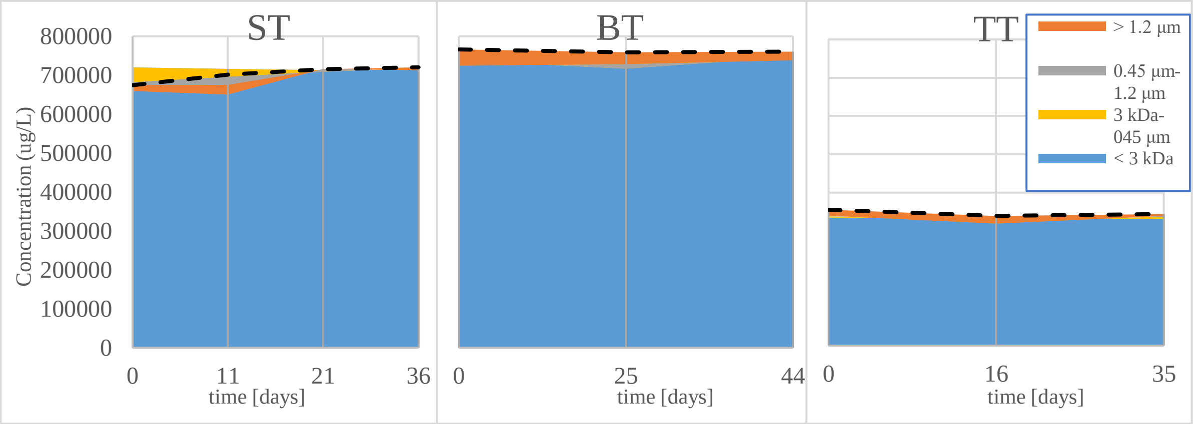

***Figure 3.14**: Concentration of the different Na fractions. (Figure: Kowollik (2020)).*

4. Conclusion

After the long term-sedimentation the three TWW samples had lower TSS concentrations than the commonly used limit of 100 mg/L, and the turbidity was reduced with 80 to 95%. Despite the high solid reduction, turbidity values higher than 100 NTU were still found in the BT and TT sample at the end of the experiments. The slow sedimentation might be caused by a low particle density, or the presence of many small particles. From the PSD-analyses small particles were detected, most of them with a particle diameter <10 µm, and some <1 µm. TS was still present in high concentration, which may be cause by both the small particles and road salt.

A well removal of the Cu and Zn fractions >1.2 µm was observed, while the <1.2 µm fractions were not clearly reduced. The total concentrations of Cu and Zn in the effluent water were within EQS class 2 for freshwater, while some of the samples were within class 4 for sea water. This means that the effluent TWW from the sedimentation basins will exceed the accepted metal concentrations for many recipients.

A clear conclusion about the degradation of the detergents could not be drawn. The reduction of DOC, combined with the slightly increasing biopolymer-fraction in the chromatography results, might indicate some biodegradation of the detergents. The detergent used for the washes contained the surfactants LAS and SLES, which should be biodegradable in aerobic conditions. DO was clearly reduced, in the lower part of the column to nearly anaerobic condition. This can indicate biological activity, but the oxygen-free conditions can also limit the degradation of the present surfactants. Detergent and surfactant degradation in TWW should be investigated further. Analyses on this can be carried out with methods such as methylene blue and HPCL or GC.

The parameters measured in the TWW from BT and TT were mostly within the same size range, while the ST sample had a lower particle content and DOC concentration. The pH, conductivity, and initial concentrations of TSS and turbidity was within the same range as previously reported values for TWW. It should be taken into consideration that the TWW in this study was collected in the winter season, from tunnels with an AADT roughly between 30 000 to 50 000. This means that generally high pollutant loads can be expected.

The TWW investigated in this study still had a high turbidity and contained high concentrations of Cu and Zn after sedimentation. Combined with the uncertainties about the effluent detergent content, further treatment should be applied before releasing it to recipients. Two treatment steps are required for road runoff from roads with an AADT > 30 000 (Statens Vegvesen, 2018b), making it applicable for TWW as well.

There are several options for a second treatment step after sedimentation. Previously filtration or coagulation/flocculation has been suggested as a second treatment step in TWW, as they removed Cu and Zn well. For the possible choice of a filtration method it should be considered that most of the constituents to be removed after sedimentation are dissolved. Generally, further information about detergent degradation, as well as practical considerations about operation and maintenance should be taken into account when choosing a second treatment step.

5. References

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6. Appendices

Appendix A- Pictures

Figure 1: *The sedimentation basin and pilot setup in Bjørnegårdstunnelen (BT). The second water collection was done here, in the basin on the left side*

Figure 2*: The water from Smestadtunnelen (ST) was transferred to the columns by pouring the water into the bucket, then using a submersible pump to pump the water into the columns. For the other tunnels smaller containers were used for the transportation. These* were shaken before also using the bucket and the submersible pump to transfer the water into the columns.

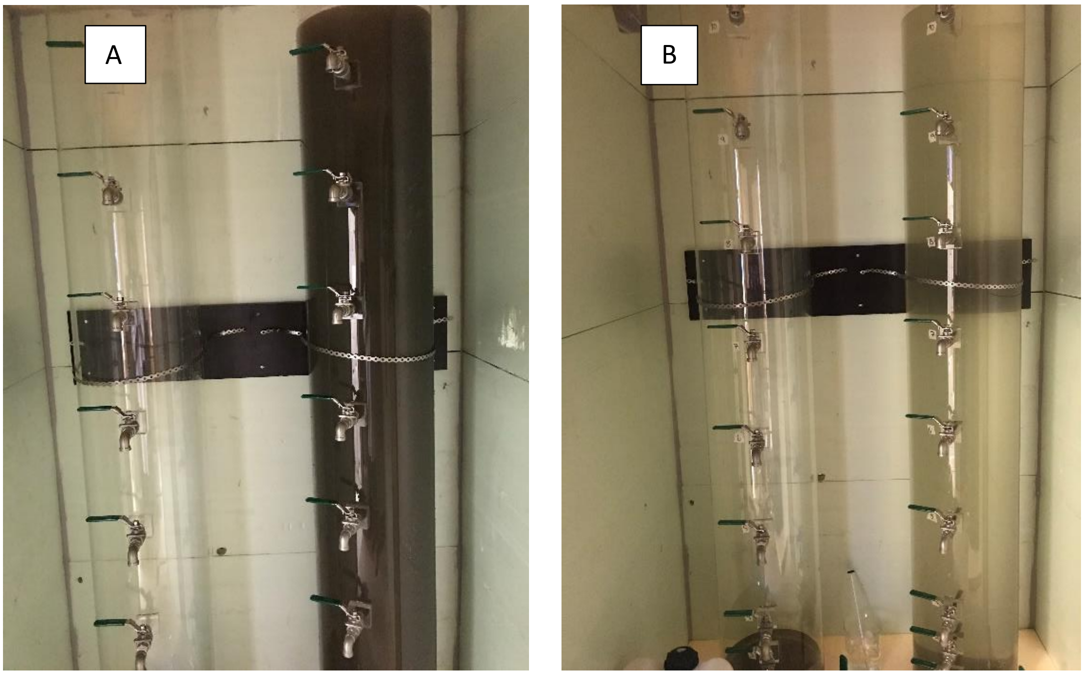


__Figure 3:__ The TWW from ST where it was enough water for only 1 column. __A__) day 0 (03.02.2020). (Photo: Ågot Bjotveit), __B__) day 31 (05.03.2020). (Photo: Ågot Bjotveit)

__Figure 4:__ The TWW from BT.__A)__ Day 0 (03.03.2020). (Photo: Ågot Bjotveit) __B)__ Day 44 (16.04.2020). Sedimentation has happened, but particles are clearly still present. (Photo: Thomas Meyn)

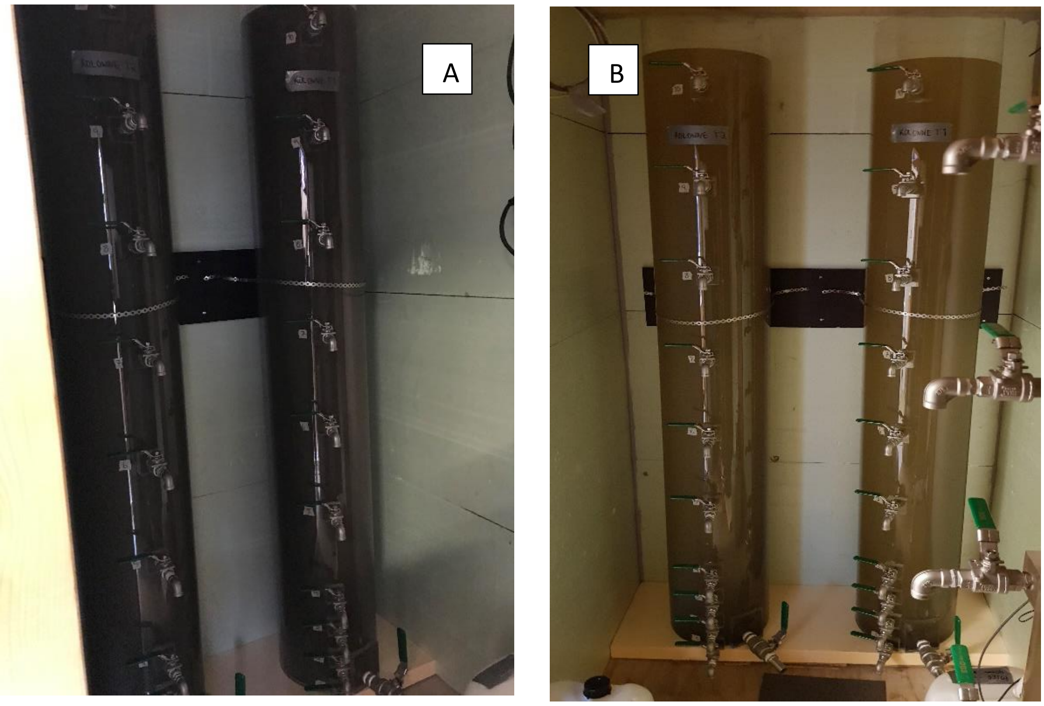
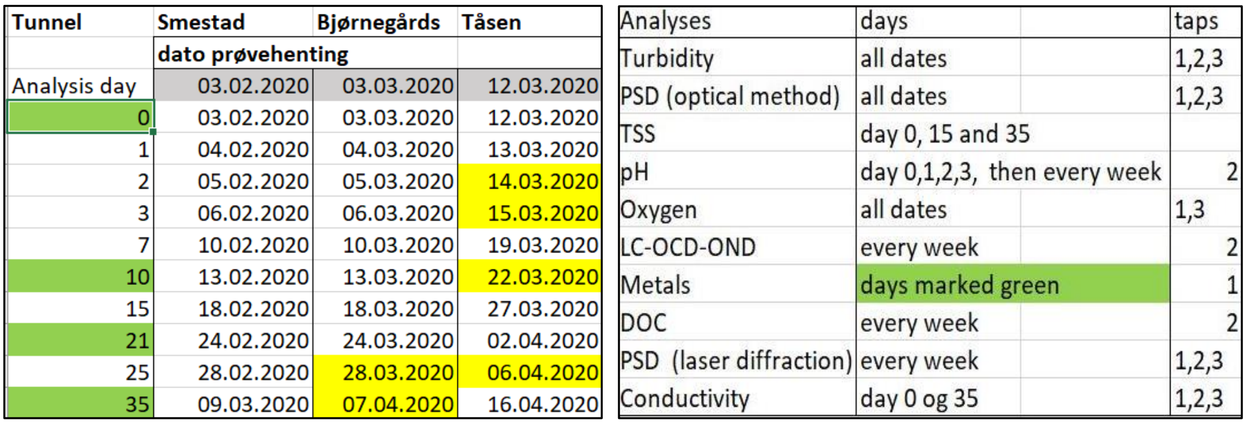


Figure 5: *TWW from Tåsentunnelen (TT).* ***A)*** *Day 0 (12.03.2020). (Photo: Ågot Bjotveit).* ***B)*** *Day 35 (16.04.2020). (Photo: Thomas Meyn).*

Appendix B – original analysis plan

*Table 1: The same analysis frequency was planned for all the tunnels. **A)** Some of the dates (marked in yellow) were planned to be changed to avoid weekends and public holidays. The last measurements from BT was for example planned to be done after the Easter break, 16th April. **B**) Not all analyses were planned to be carried out all the dates.*



A

Tunnel	Smestad	Bjørnegårds	Tåsen
	dato prøvehenting		
Analysis day	03.02.2020	03.03.2020	12.03.2020
0	03.02.2020	03.03.2020	12.03.2020
1	04.02.2020	04.03.2020	13.03.2020
2	05.02.2020	05.03.2020	14.03.2020
3	06.02.2020	06.03.2020	15.03.2020
7	10.02.2020	10.03.2020	19.03.2020
10	13.02.2020	13.03.2020	22.03.2020
15	18.02.2020	18.03.2020	27.03.2020
21	24.02.2020	24.03.2020	02.04.2020
25	28.02.2020	28.03.2020	06.04.2020
35	09.03.2020	07.04.2020	16.04.2020

B

Analyses	days	taps
Turbidity	all dates	1,2,3
PSD (optical method)	all dates	1,2,3
TSS	day 0, 15 and 35	
pH	day 0,1,2,3, then every week	2
Oxygen	all dates	1,3
LC-OCD-OND	every week	2
Metals	days marked green	1
DOC	every week	2
PSD (laser diffraction)	every week	1,2,3
Conductivity	day 0 og 35	1,2,3

Table 2: Overview over the original analysis plan for how should be carried out. Method 2) for PSD and DO analyses were included for the BT and TT sample. The lab closing limited both the frequency, and how many parameters that could be analysed.

Parameter	Frequency	Method/standard *	Taps for sampling	Comment
Routine water quality parameters				
pH	Every week	ISO 10523:2008	1,2, 3	Heated to 25°C in a water bath before measured.
Conductivity	Day 0 and day 35	NS-ISO 7888:1985	2	Heated to 25°C in a water bath before measured. Affected mostly by road salt and assumed to stay stable, hence measured only twice.
Particle bound parameters				
Total solids	Day 0, day 15, day 35	NS 4764:1980	1, 3	All weighting of the samples was done using a four-decimal scale.
Total suspended solids	Day 0, day 15, day 35	NS 4733:1983 (**ISO 11923:1997)	1, 3	All weighting of the filters was done using a four-decimal scale The filtration was done with a glass microfiber filter, pore size 1.2 µm.
Turbidity	Day 0,1,2,3, 7, 10, 15, 21, 25, 35	ISO 7027-1:2016	1, 2, 3	Measured twice each sample for eliminating errors from possible condense etc.

Particle size distribution	Day 0,1,2,3, 7, 10, 15, 21, 25, 35	1) Optical particle analyses (OPA) PN3000 XPT detector 2) Laser diffraction with Beckman Coulter LS 230	1, 2, 3	Method 1) is also measuring the particle amount Method 2) was included from the start of analyses for the water from BT
Dissolved parameters				
Dissolved oxygen	Day 0,1,2,3, 7, 10, 15, 21, 25, 35	ISO 5814:2012	1,(the top of the column), 3	Expected to be affected by distance to the water surface. The upper value measured directly in the column
Dissolved organic carbon	Every week	ISO 8245:1999	2	Indication of detergent degrading
Carbon fractioning	Every week	Size-exclusion chromatography with LC-OCD-OND	2	Indication for detergent degrading
Metal concentrations	Day 0, 10, 21 and 35	2) IPC-MS	1	Analyses done in a parallel study (Kowollik (2020))

Appendix C – Raw data

C.1 pH

***Table 3**: All pH measurements.*

ST							
Date	Column 1			Column 2			Average
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3	
03/02	8.02	8.02	8.02	-	-	-	8.02
04/02	7.67	-	8.29	-	-	-	7.98
05/02	7.9	8.06	8.09	-	-	-	8.02
13.02	7.93	8.00	7.86	-	-	-	7.93
18.02	8.18	8.07	8.13	-	-	-	8.13
24.02	8.04	8.01	7.99	-	-	-	8.01
09.03	7.84	7.89	8.06	-	-	-	7.93
BT							
Date	Column 1			Column 2			Average
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3	
03.03	8.01	8.01	8.01	8.00	8.00	8.00	8.01
04.03	-	-	8.05	-	-	8.02	8.04
05.03	8.17	8.20	8.10	-	-	8.00	8.12
09.03	7.94	8.09	8.11	7.87	8.07	8.04	8.02
14.03	7.91	7.94	7.84	7.89	7.84	7.90	7.89
28.03	7.64	-	7.1	7.64	-	7.68	7.67
16.04	7.58	-	7.52	7.63	--	7.67	7.60
TT							
Date	Column 1			Column 2			Average
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3	
12.03	7.91	7.91	7.91	7.93	7.93	7.93	7.92
14.03	7.78	7.69	7.78	7.91	7.78	7.74	7.77
16.03	7.63	7.6	7.63	7.66	7.65	7.62	7.65
28.03	7.57	-	7.57	7.68	-	7.44	7.57
16.04	7.35	-	7.35	7.32	-	7.31	7.32

C.2 Total Solids

Table 4: *All TS measurements*

	Column 1				Column 2			
Time of measurement	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]
ST								
Start (Day 0)*	2758.00	2494.00	-	-	-	-	-	-
Middle (Day 16)	2389.33	2204.68	2407.99	2224.48	-	-	-	-
End (day 35)	-	-	-	-	-	-	-	-
BT								
Start (Day 0)	2814.94	2587.35	2797,75	2617.98	2777.01	2594.25	2822.22	2591.11
End (day 44)	2301.96	2217.65	-	-	2340.00	2234.74	-	-
TT								
Start (Day 0)	1400	1300	1400	1300	1400	1300	1600	1500
End (day 35)	1258.88	1160.71			1188.30	1070.67		

Table 5*: Average values and standard deviations for TS and fixed solids (FS) from the different taps, calculated from the results in Table 4. Where it was enough data, the relative and absolute removal were also calculated.*

Time of measurement	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]
ST								
	Values from column 1				Standard deviation			
Start (Day 0)*	2758	2494	-	-	-	-	-	-
Middle (Day 16)	2389.33	2204.68	2407.99	2224.48	-	-	-	-
End (Day 35)	-	-	-	-	-	-	-	-
Relative removal [%] day 16	*14.2*	*11.6*						
Absolute removal [mg/L]	*395.7*							
BT								
	Average values column 1 and 2				Standard deviation			
Start (Day 0)	2795.98	2590.80	2809.99	2604.54	26.82	4.88	17.3	19.0
End (Day 44)	2320.98	2226.19	-	-	26.90	12.80	-	-
Relative removal [%]	*16.99*	*14.07*						
Absolute removal [mg/L]	*475.00*	*364.61*						
TT								
	Average values, column 1 and 2				Standard deviation			

Start (Day 0)	1400	1300	1500	1400	0	0	141.4	141.4
End (Day 35)	1228.59	1115.69	-	-	70.58	89.12	-	-
Relative removal [%]	*12.2*	*14.2*						
Absolute removal [mg/L]	*171.4*	*184.3*						

C.3 Total Suspended solids

Table 6*: All TSS measurements*

	Column 1				Column 2			
Time of measurement	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]
ST								
Start (Day 0)*	386	324.7	386	324.7	-	-	-	-
Middle (Day 16)	47.9	32.7	36.4	26.2	-	-	-	-
End (day 35)	-	-	-	-	-	-	-	-
BT								
Start (Day 0)	543.90	470.73	584.51	507.04	517.07	448.78	547.44	476.92
End (day 44)	64.3	50.8	-	-	63.1	49.8	-	-
TT								
Start (Day 0)	371.4	323.6	354.3	308.8	394.5	341.2	358.5	399.2
End (day 35)**	39.78	2.115			39.25	1.975		

**The measured values from day 0 in ST were not taken from the column, but from the bucket used for transferring it into the column.*

***The numbers marked in red were under the limit of detection described in the standard*

Table 7*: Average values and standard deviations for TSS and the fixed solids (FS), calculated from* ***Table 6****. Where it was enough data, the relative and absolute removal were also calculated.*

Time of measurement	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]	Tap 1 [mg/L]	Tap 1, FS [mg/L]	Tap 3 [mg/L]	Tap 3, FS [mg/L]
ST								
	Column 1				Standard deviation			
Start (Day 0)*	386	324.7	386	324.7	-	-	-	-
Middle (Day 16)	47.9	32.7	36.4	26.2	-	-	-	-
End (day 35)					-	-	-	-
Relative removal [%]	*90.58*	*91.92*						

Absolute removal [mg/L]	*249.61*	*298.48*						
BT								
	Average column 1 and 2				Standard deviation			
Start (Day 0)	530.49	459.76	565.97	491.98	18.97	15.52	26.21	21.30
End (day 44)	63.68	50.30	-	-	0.80	0.71	-	-
Relative removal [%]	*88.0*	*89.06*						
Absolute removal [mg/L]	*466.81*	*409.46*						
TT								
	Average column 1 and 2				Standard deviation			
Start (Day 0)	383.0	332.4	406.4	332.4	16.35	12.43	73.71	63.89
End (day 35)	39.015	2.045			1.035	0.298	-	-
Relative removal [%]	*89.8*	*99.4*						
Absolute removal [mg/L]	*343.9*	*330.3*						

**The measured values from day 0 in ST were not taken from the column, but from the bucket used for transferring it into the column.*

***Figure 6**: Pictures from some of the TS and TSS measurements.*

C.4 Turbidity

Table 8: All turbidity measurements

ST						
Date	Column 1 [NTU]			Column 2 [NTU]		
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3
03.02	492			-	-	-
04.02	231		270	-	-	-
05.02	130		153	-	-	-
06.02	76	125	157	-	-	-
10.02	76	106	134	-	-	-
13.02	66	83	96	-	-	-
14.02	68	95	75	-	-	-
18.03	63	59	64	-	-	-
24.02	34	31	42	-	-	-
28.02	18	17	22	-	-	-
09.03	11	12	12	-	-	-
BT						
Date	Column 1 [NTU]			Column 2 [NTU]		
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3
03.03	1100	1100	1100	1093	1093	1093
04.03	998	912	700	757	938	955
05.03	495	753	943	478	858	936
06.03	379	715	922	291	742	890
09.03	219	550	3038	230	975	868
14.03	281	409	581	427	350	498
28.03	287	186	249	287	186	249
16.04	146	128	136	159	132	136
TT						
Date	Column 1 [NTU]			Column 2 [NTU]		
	Tap 1	Tap 2	Tap 3	Tap 1	Tap 2	Tap 3
12.03	733	733	733	873	873	873
14.03	344	579	728	336	625	675
16.03	226	449	491	285	454	532
28.03		185	374	92	179	402
16.04	86	85	180	90	86	135

C.5 Particle size distribution from the optical particle analysis (OPA)

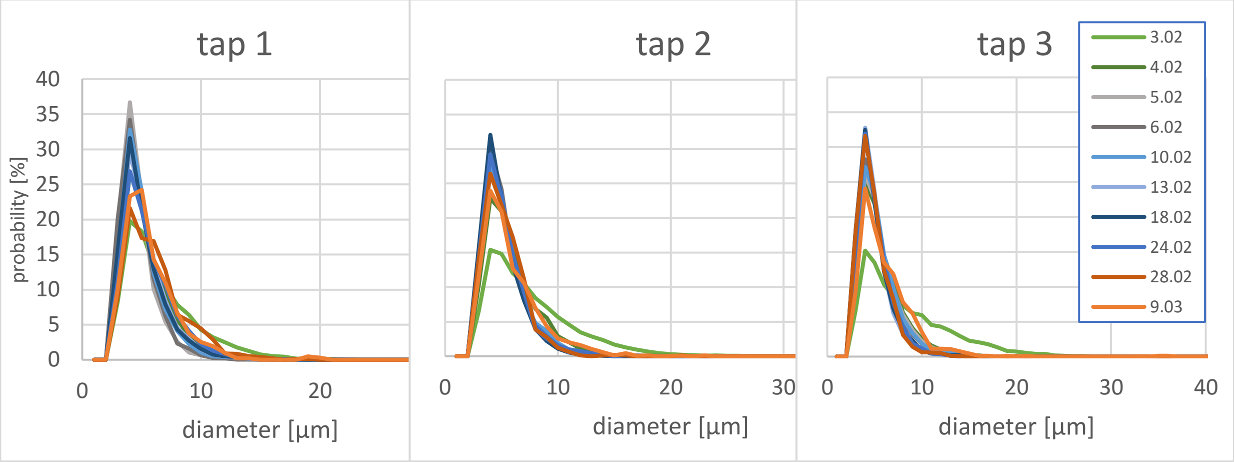


***Figure 7**: All measurements for ST. There is a clear difference between day 0 (03.02) and the rest of the measurements. At day 0 the water was taken from the bucket used for transferring into the columns.*

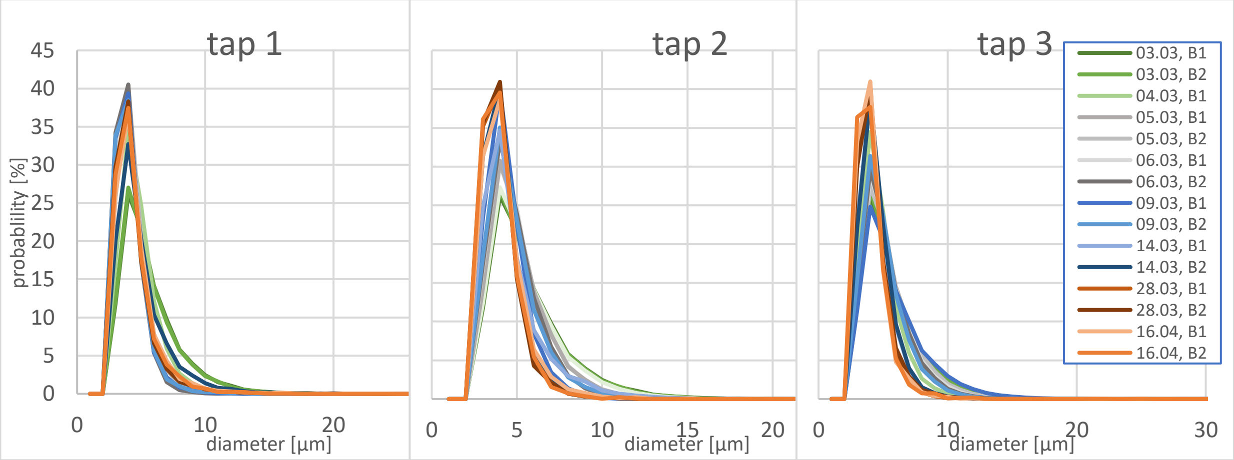


***Figure 8**: All PSD measurements for BT. Day 0 (03.03) had a less sharp peak, indicating some larger particles. Some variations were seen the other days as well, but no clear trends were found.*

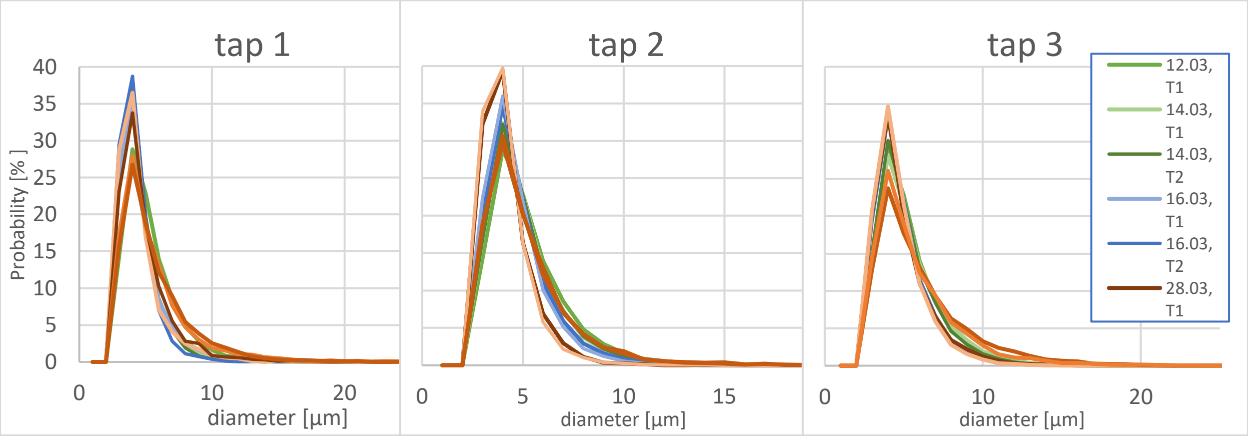


***Figure 9**: All PSD measurements for TT. There were some variations from day to day, but generally small changes.*

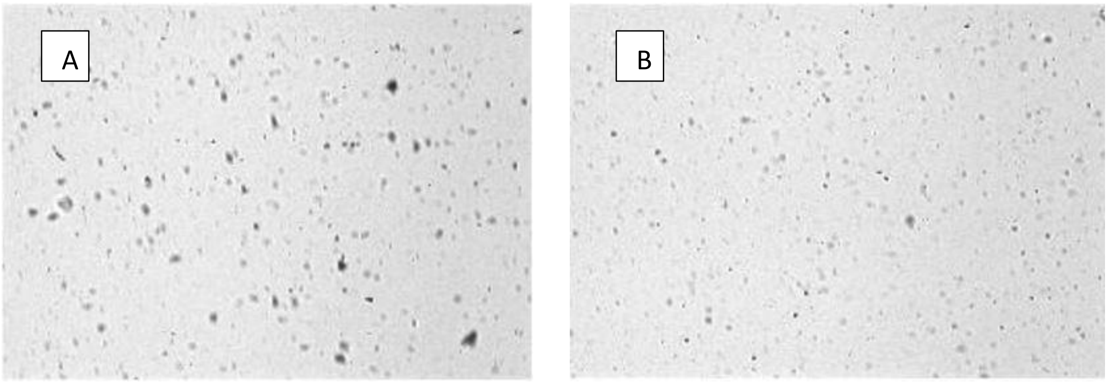


***Figure 10**: Pictures used from the optical particle analysis (OPA), for ST. **A**) TWW from day 0, water collected from the bucket. More large particles can be seen here. **B)** TWW from day 1, collected from the column.*

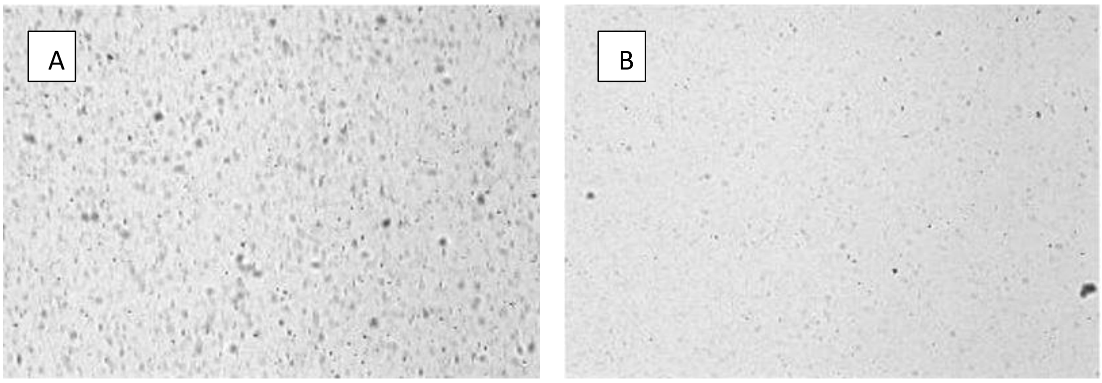


***Figure 11**: Pictures from the OPA, for BT. **A)** TWW from day 0. Many particles are present. **B)** The TWW after 44 days of sedimentation, containing fewer and smaller particles. Every now and then some larger particles were observed, as the one seen to the right on the picture.*

C.6 Number-based from LS 230

The number-weighted conversions from the laser diffraction are displayed in *Figure 12-14.*

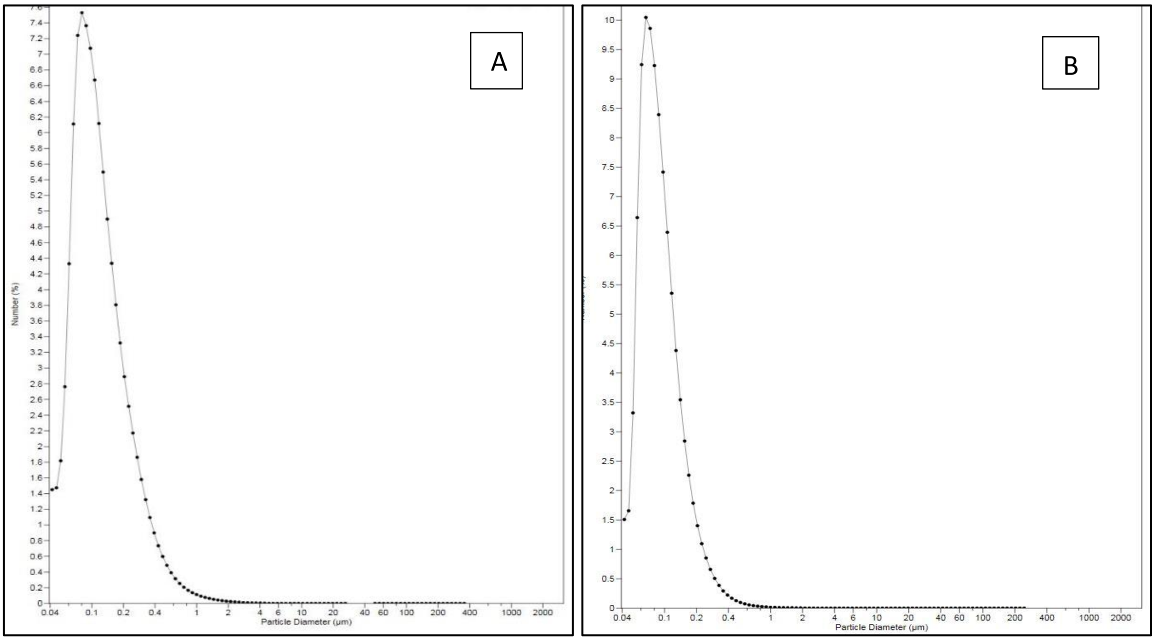


Figure 12: *Number-based measurements from day 0 (03.03) in TWW from BT.* ***A)*** *column B1,* ***B)*** *column B2*

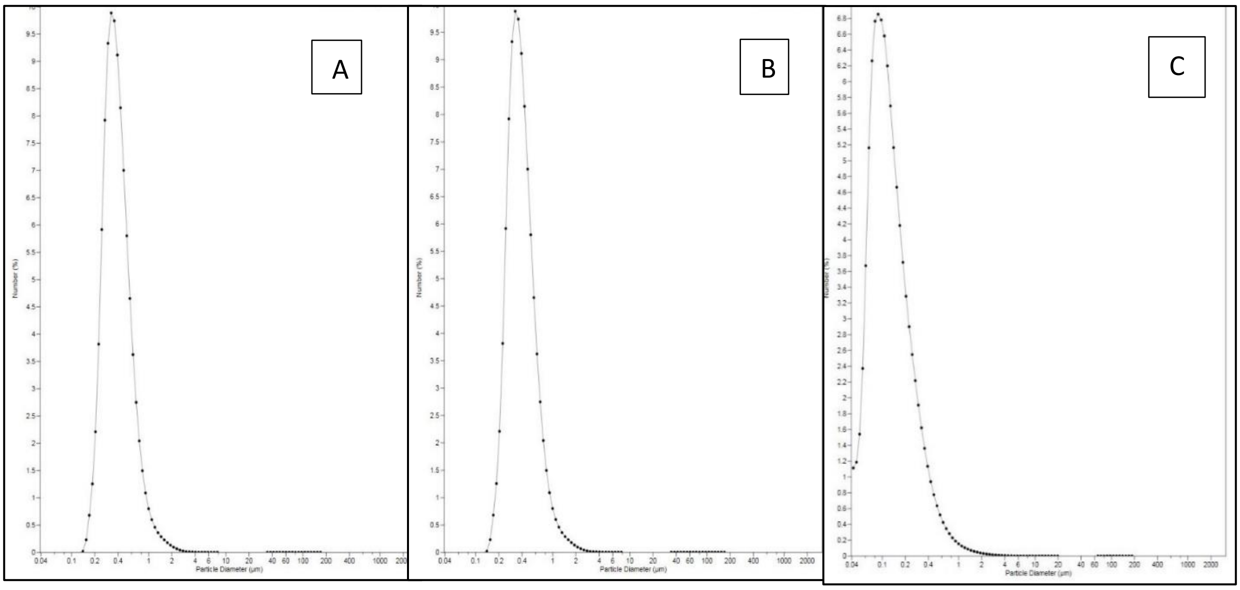


Figure 13: *Number-based measurements from day 3 (06.03) for BT, column 1.* ***A)*** *tap 1,* ***B)*** *tap 2,* ***C)*** *tap 3.*

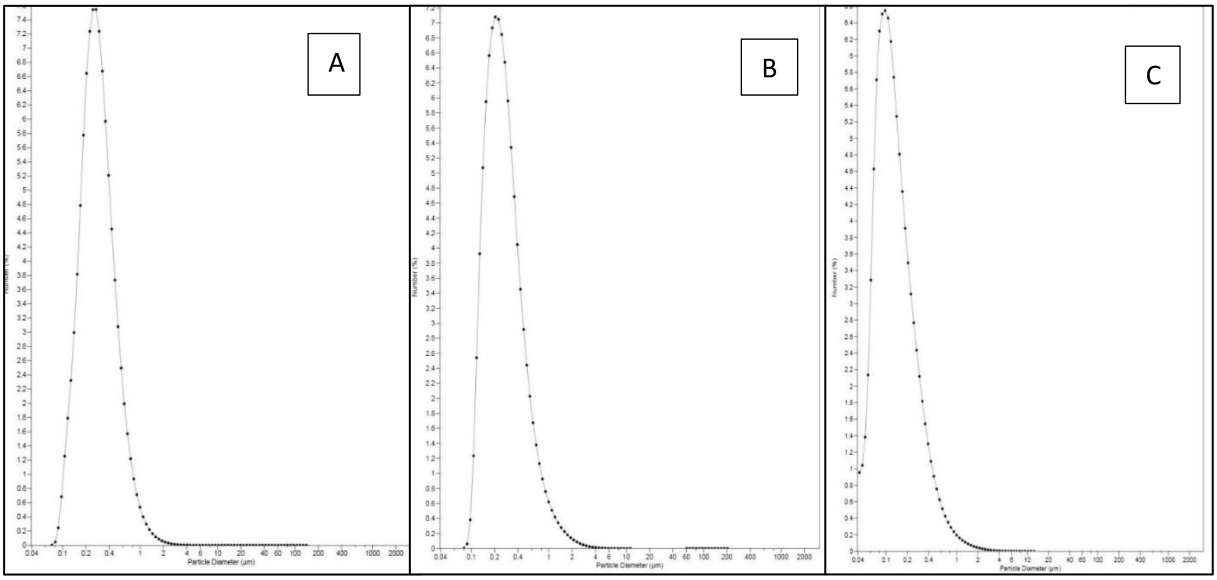


Figure 14: *Number-based measurements from day 3 (06.03) for column B2.* ***A)*** *tap 1,* ***B****) tap 2,* ***C)*** *tap 3.*

C.7 DOC

Table 9*: DOC from ST, BT and TT, measured by DOC-analyses. The samples were diluted with a factor of 6 prior the analyses. The values in the table are multiplied to the original concentrations. For BT and TT two parallels for each column were analysed on day 44 and 35.*

Day (date)	Column 1 [mg/L]	Standard deviation 1	Column 2 [mg/L]	Standard deviation 2
ST				
0 (03.02)	10.2918	0.2406	-	-
7 (10.02)	9.9792	0.2088	-	-
15 (18.02)	8.8050	0.2016	-	-
35 (09.03)	-	-	-	-
BT				
0 (03.03)	29.7282	0.1356	28.9824	0.3636
13 (16.03)	20.7288	0.3702	19.4514	0.2268
25 (28.03)	25.2732	0.6912	26.5854	0.0978
44 (16.04)	20.763	0.3216	20.763	0.536
44 (16.04)	20.4600	0.3966	22.5894	0.8322
TT				
0 (12.03)	24.5352	0.8328	24.3924	0.7260
16 (28.03)	24.5622	0.6996	23.5260	0.2694
35 (16.04)	23.3094	0.1482	20.8068	0.1386
35 (16.04)	21.5460	0.3588	20.9376	0.1620

C.8 LC-OCD-OND

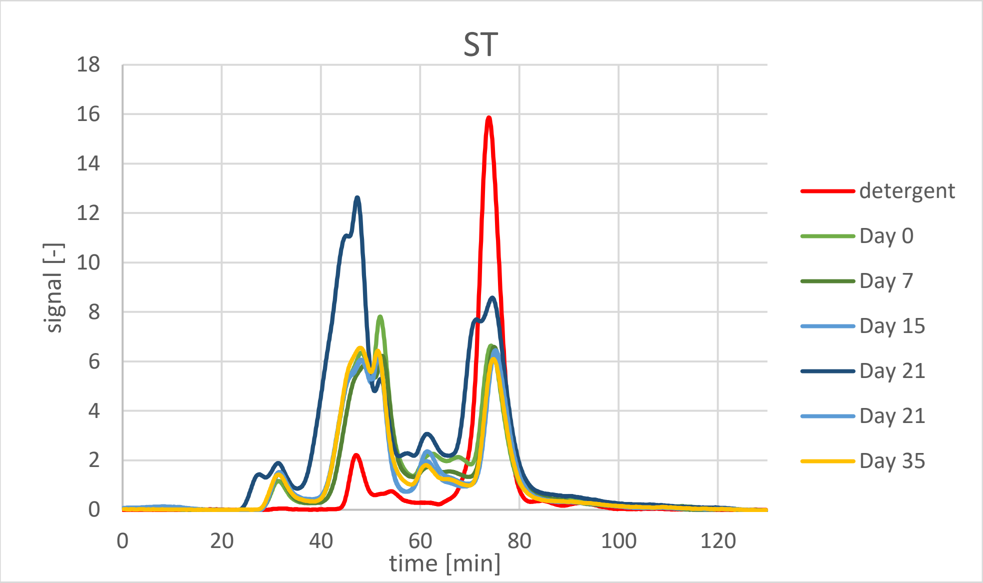


Figure 15: *All ODC-chromatograms from ST. The deviation on day 21 was probably caused by a dilution error.*

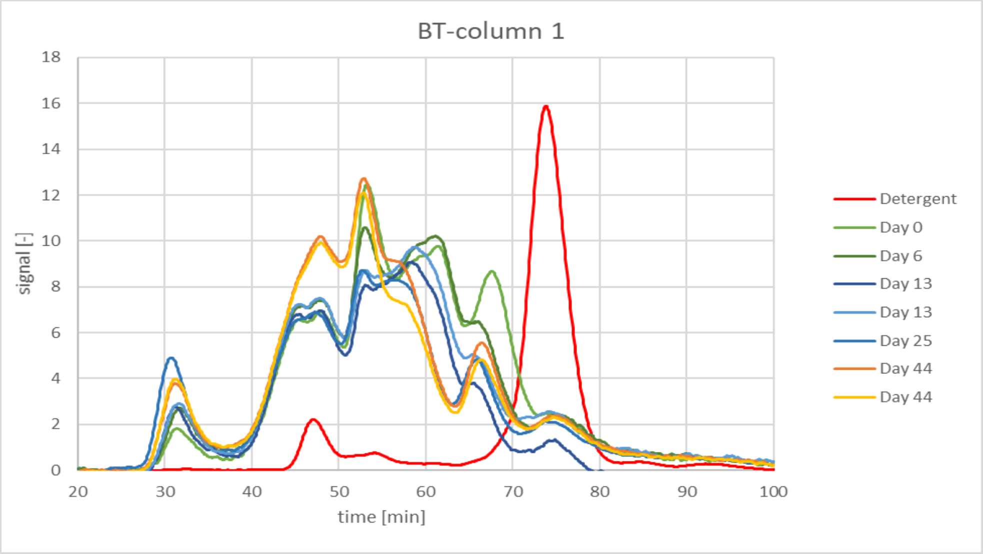


Figure 16: *All OCD-chromatograms from column 1 in BT.*

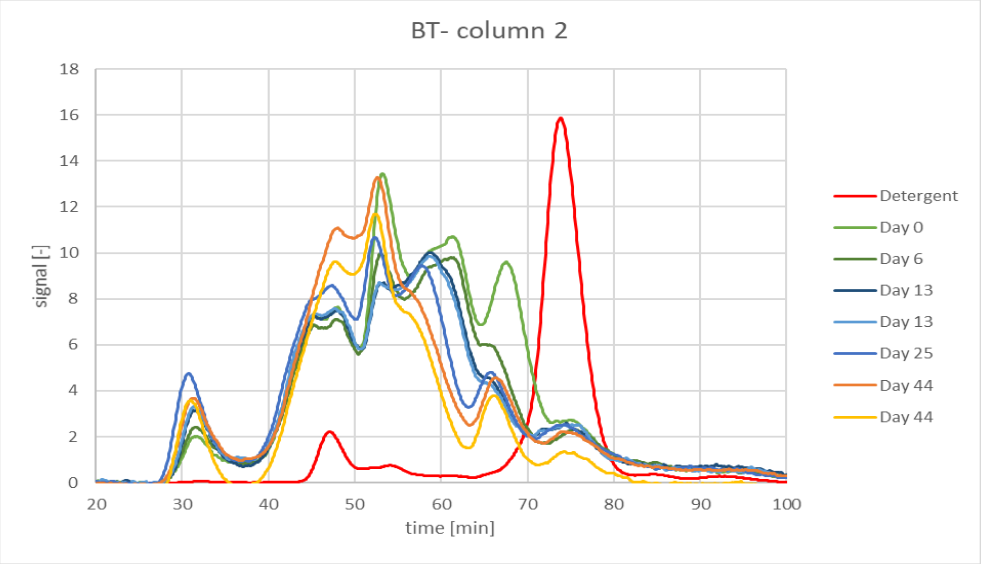


Figure 17*: All ODC- chromatograms from column 2 in BT.*

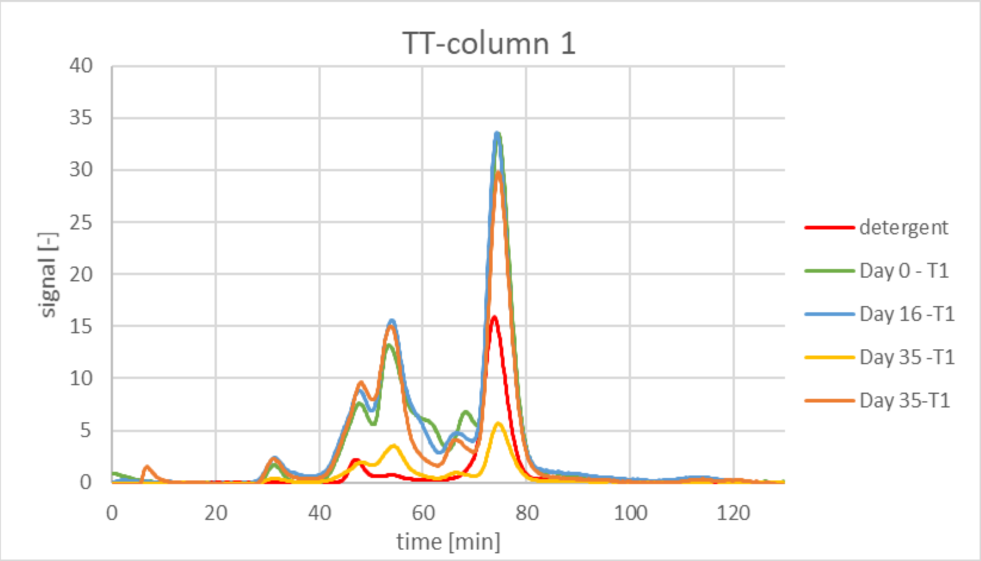


Figure 18*: All OCD- chromatograms for TT-column 1*

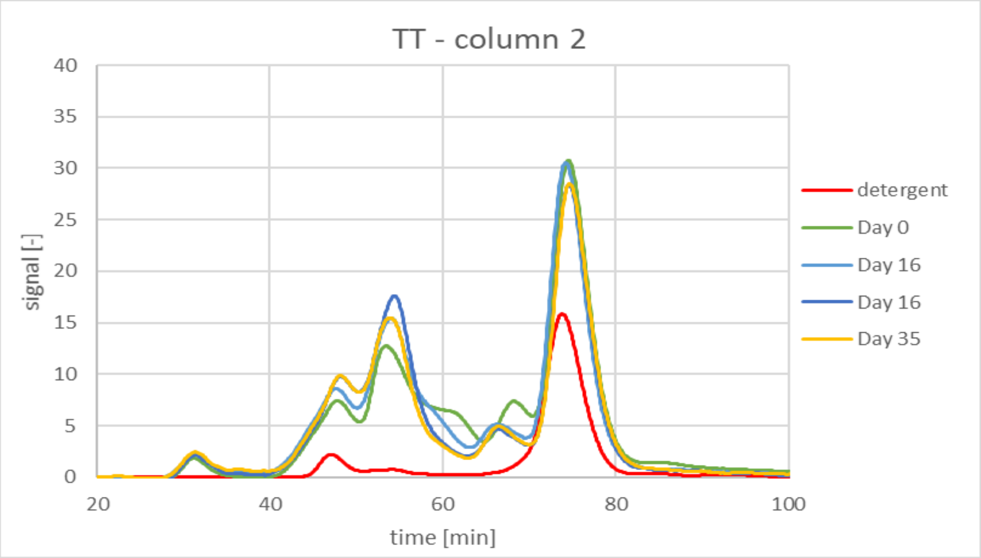


Figure 19: *All OCD-chromatograms from TT-column 2*

Table 10*: DOC, measured from the carbon fractioning (LC-OCD-OND).*

Day (date)	Column 1 [mg/L]	Column 2 [mg/L]
ST		
0 (03.02)	-	-
7 (10.02)	6.563	-
15 (18.02)	6.528	-
35 (09.03)	6.521	-
BT		
0 (03.03)	13.185	-
13 (16.03)	9.417	-
25 (28.03)	10.905	-
44 (16.04)	12.962	-
44 (16.04)	11.965	-
TT		
0 (12.03)	18.191	18.414
16 (28.03)	19.346	18.273
35 (16.04)	16.957	17.277
35 (16.04)	16.373	17.225

Appendix D Datasheet Purify Infravask

On the following 10 pages the datasheet for the detergent *Purify Infravask* is attached.

SIKKERHETSDATABLAD

PG-IV1-X2-1000

Sikkerhetsdatabladet er i samsvar med Kommisjonsforordning (EU) 2015/830 av 28 mai 2015 om endring av europaparlaments- og rådsforordning (EF) nr. 1907/2006 om registrering, vurdering, godkjenning og begrensning av kjemikalier (REACH)

AVSNITT 1: IDENTIFIKASJON AV STOFFET / STOFFBLANDINGEN OG AV SELSKAPET / FORETAKET

Utgitt dato	05.10.2017
Revisjonsdato	03.11.2017

1.1. Produktidentifikator

Kjemikaliets navn	PG-IV1-X2-1000
Synonymer	Infravask

1.2. Relevante identifiserte bruksområder for stoffet eller stoffblandingen og bruk som frarådes

Produktgruppe	Rengjøringsmiddel.
Kjemikaliets bruksområde	Til vask av tunnel, bro, skilt og infrastruktur.

1.3. Opplysninger om leverandøren av sikkerhetsdatabladet

Produsent

Firmanavn	PURIFY AS
Postadresse	Sandvigå 7
Postnr.	4007
Poststed	Stavanger
Land	Norge
Telefon	97 19 49 97
E-post	cm@purify-group.com
Hjemmeside	https://purify-group.com/
Kontaktperson	Claudio Michel

1.4. Nødtelefonnummer

Nødtelefon	Telefon: 22 59 13 00 Beskrivelse: Giftinformasjonen

AVSNITT 2: FAREIDENTIFIKASJON

2.1. Klassifisering av stoffet eller stoffblandingen

Klassifisering i henhold til CLP (EC) No 1272/2008 [CLP / GHS]	Eye Irrit. 2; H319
Stoffets/blandingens farlige egenskaper	Gir alvorlig øyeirritasjon.

2.2. Merkingselementer

Farepiktogrammer (CLP)

Varselord	Advarsel
Faresetninger	H319 Gir alvorlig øyeirritasjon.
Sikkerhetssetninger	P280 Benytt vernebriller/ansiktsskjerm. P305+P351+P338 VED KONTAKT MED ØYNE: Skyll forsiktig med vann i flere minutter. Fjern eventuelle kontaktlinser dersom dette enkelt lar seg gjøre. Fortsett skyllingen. P337+P313 Ved vedvarende øyeirritasjon: Søk legehjelp.
Supplerende faresetninger på etikett	Innhold i henhold til bestemmelser om vaskemidler: <5% anioniske overflateaktive stoffer.

2.3. Andre farer

PBT / vPvB	Blandingen oppfyller ikke gjeldende kriterier for PBT (Persistente, Bioakkumulerbare og Toksiske) eller vPvB (veldig Persistent og veldig Bioakkumulerende).

AVSNITT 3: SAMMENSETNING/OPPLYSNINGER OM BESTANDDELER

3.2. Stoffblandinger

Komponentnavn	Identifikasjon	Klassifisering	Innhold
Benzensulfonsyre, alkylderiv., natriumsalter	CAS-nr.: 68411-30-3 EC-nr.: 270-115-0	Skin Irrit. 2; H315 Eye Dam. 1; H318 Acute tox. 4; H302 Aquatic Chronic 3; H412	< 2 %
Natriumlauryletersulfat	CAS-nr.: 9004-82-4	Skin Irrit. 2; H315 Eye Dam. 1; H318 Aquatic Chronic 3; H412	< 1 %
Innhold i henhold til bestemmelser om vaskemidler:			
Anioniske overflateaktive stoffer			< 5 %
Komponentkommentarer	CAS-nr. 68411-30-3, REACH registreringsnr.:01-2119489428-22. Se avsnitt 16 for forklaring av faresetninger (H).		

AVSNITT 4: FØRSTEHJELPSTILTAK

4.1. Beskrivelse av førstehjelpstiltak

Generelt	Nødtelefon: se avsnitt 1.4. Ved bevisstløshet eller alvorlige tilfeller, ring 113.
Innånding	Frisk luft, ro og varme. Søk legehjelp ved ubehag.
Hudkontakt	Fjern tilsølt tøy. Skyll straks med mye vann. Søk legehjelp ved ubehag.
Øyekontakt	Skyll straks med rikelige mengder vann i opptil 15 minutter. Fjern evt. kontaktlinser og åpne øyet godt opp. Kontakt lege hvis irritasjon vedvarer.
Svelging	Skyll munn med vann. Fremkall ikke brekning. Søk legehjelp ved ubehag.

4.2. De viktigste symptomene og virkningene, både akutte og forsinkede

Akutte symptomer og virkninger	Øyekontakt: Irriterer øynene og kan forårsake rødhet og svie. Svelging: Svelging av kjemikaliet kan forårsake ubehag.

4.3. Angivelse av om umiddelbar legehjelp og spesialbehandling er nødvendig

Annen informasjon	Symptomatisk behandling. Ikke farlig ved riktig bruk.

AVSNITT 5: BRANNSLOKKINGSTILTAK

5.1. Slokkingsmidler

Egnede slokkingsmidler	Velges i forhold til omgivende brann.
Uegnede slokkingsmidler	Ikke bruk vannstråle ved brannslukking da dette vil spre brannen.

5.2. Særlige farer knyttet til stoffet eller stoffblandingen

Brann- og eksplosjonsfarer	Kjemikaliet er ikke brennbart eller eksplosivt.
Farlige forbrenningsprodukter	Kan inkludere, men er ikke begrenset til: Karbondioksid (CO2). Karbonmonoksid (CO). Svovelholdige gasser (SOx). Uspesifiserte organiske forbindelser.

5.3. Råd til brannmannskaper

Personlig verneutstyr	Bruk trykkluftmaske når kjemikaliet er involvert i brann. Ved rømning brukes godkjent rømningsmaske. Se forøvrig avsnitt 8.
Annen informasjon	Beholdere i nærheten av brann flyttes straks eller kjøles med vann.

AVSNITT 6: TILTAK VED UTILSIKTET UTSLIPP

6.1. Personlige forsiktighetsregler, personlig verneutstyr og nødrutiner

Sikkerhetstiltak for å beskytte personell	Benytt personlig verneutstyr som angitt i avsnitt 8. Sørg for tilstrekkelig ventilasjon. Unngå kontakt med øynene. Ved søl: Vær oppmerksom på glatte gulv og overflater.

6.2. Forsiktighetsregler med hensyn til miljø

Sikkerhetstiltak for å beskytte ytre miljø	Forhindre unødvendig utslipp av kjemikaliet i konsentrert form til kloakk, vassdrag og grunn.

6.3. Metoder og materialer for oppsamling og rensing

Opprydding	Skyll tilsølt område med store mengder vann.

6.4. Henvisning til andre avsnitt

Andre anvisninger	Se også avsnitt 8 og 13.

AVSNITT 7: HÅNDTERING OG LAGRING

7.1. Forsiktighetsregler for sikker håndtering

Håndtering	Bruk angitt verneutstyr, se avsnitt 8. Sørg for tilstrekkelig ventilasjon. Unngå kontakt med øynene. Spill gjør gulv og arbeidsredskaper glatte og sleipe.

Beskyttelsestiltak

Råd om generell yrkeshygiene	Det må ikke spises, drikkes eller røykes under arbeidet. Vask hendene etter hvert skift og før spising, røyking eller bruk av toalett. Vask tilsølte klær før de brukes.

7.2. Vilkår for sikker lagring, herunder eventuelle uforenligheter

Oppbevaring	Lagres i tett lukket beholder.

Betingelser for sikker oppbevaring

Råd angående samlagring	Oppbevares adskilt fra næringsmidler.
Lagringstemperatur	Verdi: 1 -90 °C

7.3. Særlig(e) sluttanvendelse(r)

Spesielle bruksområder	Se avsnitt 1.2.

AVSNITT 8: EKSPONERINGSKONTROLL / PERSONLIG VERNEUTSTYR

8.1. Kontrollparametere

Annen informasjon om grenseverdier	Inneholder ingen stoffer med grenseverdi for forurensninger i arbeidsatmosfæren. Referanser (lover/forskrifter): FOR 2011-12-06 nr 1358 Forskrift om tiltaks- og grenseverdier (sist endret gjennom FOR-2016-12-22-1860).

8.2. Eksponeringskontroll

Forholdsregler for å hindre eksponering

Tekniske tiltak for å hindre eksponering	Sørg for tilstrekkelig ventilasjon. Personlig verneutstyr skal være CE-merket og bør velges i samarbeid med leverandøren av slikt utstyr. Det anbefalte verneutstyret og de angitte standardene er veiledende. Standarder skal være av nyeste versjon. Risikovurdering av den aktuelle arbeidsplassen/-operasjonen (faktisk risiko) kan medføre andre vernetiltak. Verneutstyrets egnethet og slitestyrke vil avhenge av bruksområde.

Øye- / ansiktsvern

Øyevernutstyr	Beskrivelse: Bruk tettsittende vernebriller eller ansiktsskjerm. Referanser til relevante standarder: NS-EN 166 (Øyevern - Spesifikasjoner).
Ytterligere øyeverntiltak	Øyedusj skal være på arbeidsplassen. Enten en fast øyedusjenhet koblet til drikkevann (temperert vann ønskelig) eller en bærbar disponibel enhet (øyespyleflaske).

Håndvern

Egnede materialer	Hansker anbefales ved langvarig bruk. Nitril. Vinyl.
Gjennomtrengningstid	Verdi: > 480 minutt(er)
Tykkelsen av hanskemateriale	Verdi: 0,18 mm
Håndvernsutstyr	Beskrivelse: Normalt ikke nødvendig. Bruk hansker ved langvarig eller gjentatt hudkontakt. Hanskenes egenskaper kan variere hos de ulike hanskeprodusentene. Referanser til relevante standarder: NS-EN 374 (Vernehansker mot kjemikalier og mikroorganismer). NS-EN 420 (Vernehansker - Generelle krav og prøvingsmetoder).
Ytterligere håndbeskyttelsestiltak	Skift hansker ved tegn på slitasje.

Hudvern

Anbefalte verneklær	Beskrivelse: Normale arbeidsklær.
Ytterligere hudbeskyttelsestiltak	Nøddusj bør være tilgjengelig på arbeidsplassen.

Åndedrettsvern

Anbefalt åndedrettsvern	Beskrivelse: Normalt ikke nødvendig. Ved utilstrekkelig ventilasjon brukes maske med filter A mot løsemiddeldamper. Referanser til relevante standarder: NS-EN 14387 (Åndedrettsvern - Gassfiltre og kombinerte filtre - Krav, prøving, merking).

Passende miljømessig eksponeringskontroll

Begrensning av miljøeksponering	Forhindre unødvendig utslipp av kjemikaliet i konsentrert form til kloakk, vassdrag og grunn.

AVSNITT 9: FYSISKE OG KJEMISKE EGENSKAPER

9.1. Opplysninger om grunnleggende fysiske og kjemiske egenskaper

Tilstandsform	Væske
Farge	Lysegul
Lukt	Luktfri
Luktgrense	Kommentarer: Ikke relevant.
pH	Verdi: ~ 7

Smeltepunkt / smeltepunktintervall	Kommentarer: Ikke relevant.
Kokepunkt / kokepunktintervall	Verdi: 100 °C
Flammepunkt	Kommentarer: Ikke relevant.
Fordampningshastighet	Kommentarer: Ikke relevant.
Antennelighet (fast stoff, gass)	Ikke relevant.
Eksplosjonsgrense	Kommentarer: Ikke relevant.
Damptrykk	Kommentarer: Ikke relevant.
Damptetthet	Kommentarer: Ikke relevant.
Relativ tetthet	Kommentarer: Ikke relevant.
Løslighet	Medium: Vann Kommentarer: Lett løselig i vann.
Fordelingskoeffisient: n-oktanol/vann	Kommentarer: Ikke relevant for en blanding.
Selvantennelighet	Kommentarer: Ikke selvantennelig.
Dekomponeringstemperatur	Kommentarer: Ikke relevant.
Viskositet	Kommentarer: Som vann.
Eksplosive egenskaper	Ikke eksplosiv.
Oksiderende egenskaper	Ikke oksiderende.

9.2. Andre opplysninger

Andre fysiske og kjemiske egenskaper

Kommentarer	Ingen ytterligere informasjon er tilgjengelig.

AVSNITT 10: STABILITET OG REAKTIVITET

10.1. Reaktivitet

Reaktivitet	Ved normal bruk er det ingen kjent reaktivitetsrisiko forbundet med dette kjemikaliet.

10.2. Kjemisk stabilitet

Stabilitet	Stabil under normale temperaturforhold og anbefalt bruk.

10.3. Mulighet for farlige reaksjoner

Risiko for farlige reaksjoner	Ingen under normale forhold.

10.4. Forhold som skal unngås

Forhold som skal unngås	Ingen kjente.

10.5. Uforenlige materialer

Materialer som skal unngås	Ingen kjente.

10.6. Farlige nedbrytningsprodukter

Farlige spaltningsprodukter	Ingen under normale forhold. Se også avsnitt 5.2.

AVSNITT 11: TOKSIKOLOGISKE OPPLYSNINGER

11.1. Opplysninger om toksikologiske virkninger

Øvrige helsefareopplysninger

Vurdering av akutt toksisitet, klassifisering	Kriteriene for klassifisering kan på grunnlag av de foreliggende data ikke anses for å være oppfylt.
Vurdering hudetsende / hudirriterende, klassifisering	Kriteriene for klassifisering kan på grunnlag av de foreliggende data ikke anses for å være oppfylt.
Vurdering øyeskade / øyeirritasjon, klassifisering	Gir alvorlig øyeirritasjon.
Vurdering av luftveissensibilisering, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av hudsensibilisering, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av arvestoffskadelig virkning på kjønnsceller, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering kreftfremkallende egenskaper, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av reproduksjonstoksisitet, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av bestemt målorgan SE, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av bestemt målorgan RE, klassifisering	Kriteriene for klassifisering er på grunnlag av de tilgjengelige data ikke ansett å være oppfylt.
Vurdering av aspirasjonsfare, klassifisering	Kriteriene for klassifisering kan på grunnlag av de foreliggende data ikke anses for å være oppfylt.

Symptomer på eksponering

I tilfelle svelging	Kan forårsake ubehag ved svelging.
I tilfelle hudkontakt	Ingen hudirritasjon forventes.
I tilfelle innånding	Ingen helseeffekter forventet.
I tilfelle øyekontakt	Irriterer øynene og kan fremkalle rødhet, tåreflod og svie.

AVSNITT 12: ØKOLOGISKE OPPLYSNINGER

12.1. Giftighet

Akutt akvatisk fisk	Verdi: 0,7 mg/l

	Effektdose konsentrasjon: LC50 Eksponeringstid: 96 time(r) Art: Pimephales promelas Test referanse: CAS-nr. 68411-30-3 Kommentarer: (Litteraturverdi)
Akutt akvatisk alge	Verdi: 11 mg/l Effektdose konsentrasjon: IC50 Eksponeringstid: 72 time(r) Art: Selenastrum capricornatum Test referanse: CAS-nr. 68411-30-3 Kommentarer: (Litteraturverdi)
Akutt akvatisk Daphnia	Verdi: 1,62 mg/l Effektdose konsentrasjon: EC50 Eksponeringstid: 48 time(r) Art: Daphnia magna Test referanse: CAS-nr. 68411-30-3 Kommentarer: (Litteraturverdi)
Økotoksisitet	Kjemikaliet er ikke klassifisert som miljøskadelig.

12.2. Persistens og nedbrytbarhet

Persistens og nedbrytbarhet, kommentarer	Tensidet(ene) som inngår i denne blandingen oppfyller kriteriene for biologisk nedbrytning i EU regulativ nr. 648/2004 som omhandler vaske- og rengjøringsmidler.

12.3. Bioakkumuleringsevne

Bioakkumulering, kommentarer	Ingen spesifikk informasjon fra produsent.

12.4. Mobilitet i jord

Mobilitet	Løselig i vann. Kan spres i jord og grunnvann.

12.5. Resultater av PBT- og vPvB-vurdering

PBT vurderingsresultat	Blandingen oppfyller ikke gjeldende kriterier for PBT (Persistente, Bioakkumulerbare og Toksiske).
vPvB vurderingsresultat	Blandingen oppfyller ikke gjeldende kriterier for vPvB (veldig Persistent og veldig Bioakkumulerende).

12.6. Andre skadevirkninger

Andre skadevirkninger / annen informasjon	Ikke relevant.

AVSNITT 13: SLUTTBEHANDLING

13.1. Avfallsbehandlingsmetoder

Egnede metoder til fjerning av kjemikaliet	Leveres som farlig avfall til godkjent behandler eller innsamler. Koden for farlig avfall (EAL-kode) er veiledende. Bruker må selv angi riktig EAL-kode hvis bruksområdet avviker.

Avfallskode EAL	Avfallskode EAL: 07 06 99 avfall som ikke er spesifisert andre steder Klassifisert som farlig avfall: Nei
Annen informasjon	Vaskevannet kan regnes som avløpsvann, og kan slippes ut i kommunalt avløp etter avklaring med den lokale vann– og avløpsetaten.

AVSNITT 14: TRANSPORTOPPLYSNINGER

14.1. FN-nummer

Kommentarer	Ikke farlig i forbindelse med transport under UN, IMO, ADR/RID og IATA/ICAO regler.

14.2. FN-forsendelsesnavn

Kommentarer	Ikke relevant.

14.3. Transportfareklasse(r)

Kommentarer	Ikke relevant.

14.4. Emballasjegruppe

Kommentarer	Ikke relevant.

14.5. Miljøfarer

Kommentarer	Ikke relevant.

14.6. Særlige forsiktighetsregler ved bruk

Spesielle forholdsregler	Ikke relevant.

14.7. Bulktransport i henhold til vedlegg II i MARPOL 73/78 og IBC-regelverket

Forurensningskategori	Ikke relevant.

Andre relevante opplysninger

Andre relevante opplysninger	Ikke relevant.

AVSNITT 15: OPPLYSNINGER OM REGELVERK

15.1. Særlige bestemmelser/særskilt lovgivning om sikkerhet, helse og miljø for stoffet eller stoffblandingen

Referanser (Lover/ Forskrifter)	Forskrift om klassifisering, merking og emballering av stoffer og stoffblandinger (CLP) av 16.06.2012 med senere endringer. Forskrift om registrering, vurdering, godkjenning og begrensning av kjemikalier (REACH-forskriften) av 30. mai 2008 med senere endringer. FOR 2009-04-01 nr 384: Forskrift om landtransport av farlig gods med senere endringer, Direktoratet for samfunnssikkerhet og beredskap. Forskrift om gjenvinning og behandling av avfall (avfallsforskriften), 01.06.2004 nr. 930, med endringer. FOR 2004-06-01 nr. 922: Forskrift om begrensning i bruk av helse- og miljøfarlige

	kjemikalier og andre produkter (produktforskriften), med senere endringer; §§2-12, 2-14, Vaskemidler.

15.2. Vurdering av kjemikaliesikkerhet

Vurdering av kjemikaliesikkerhet er gjennomført	Nei

AVSNITT 16: ANDRE OPPLYSNINGER

Leverandørens anmerkninger	Informasjonen i dette dokument skal gjøres tilgjengelig for alle som håndterer kjemikaliet.
Liste over relevante H-setninger (i avsnitt 2 og 3).	H302 Farlig ved svelging. H315 Irriterer huden. H318 Gir alvorlig øyeskade. H319 Gir alvorlig øyeirritasjon. H412 Skadelig, med langtidsvirkning, for liv i vann.
Klassifisering i henhold til CLP (EC) No 1272/2008 [CLP / GHS]	Eye Irrit. 2; H319
Viktige litteraturreferanser og datakilder	Sikkerhetsdatabladet er utarbeidet med basis i opplysninger gitt av produsenten.
Brukte forkortelser og akronymer	PBT: Persistent, Bioakkumulerende og Toksisk (giftig) vPvB: veldig Persistent og veldig Bioakkumulerende ADR: The European Agreement concerning the International Carriage of Dangerous Goods by Road RID: The Regulations concerning the International Carriage of Dangerous Goods by Rail ICAO: The International Civil Aviation Organisation IATA: The International Air Transport Association IMDG: The International Maritime Dangerous Goods Code EAL-kode: kode fra EUs felles klassifiseringssystem for avfall (EWC = European Waste Code) OECD: Organisation for Economic Cooperation and Development.
Opplysninger som er nye, slettet eller revidert	Avsnitt som er endret fra forrige versjon: 1-16
Kvalitetssikring av informasjonen	Dette sikkerhetsdatablad er kvalitetskontrollert av Kiwa Teknologisk Institutt as, som er sertifisert iht. ISO 9001:2008.
Versjon	2
Utarbeidet av	Kiwa Teknologisk Institutt as v/ Hanna M. Storrvik

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