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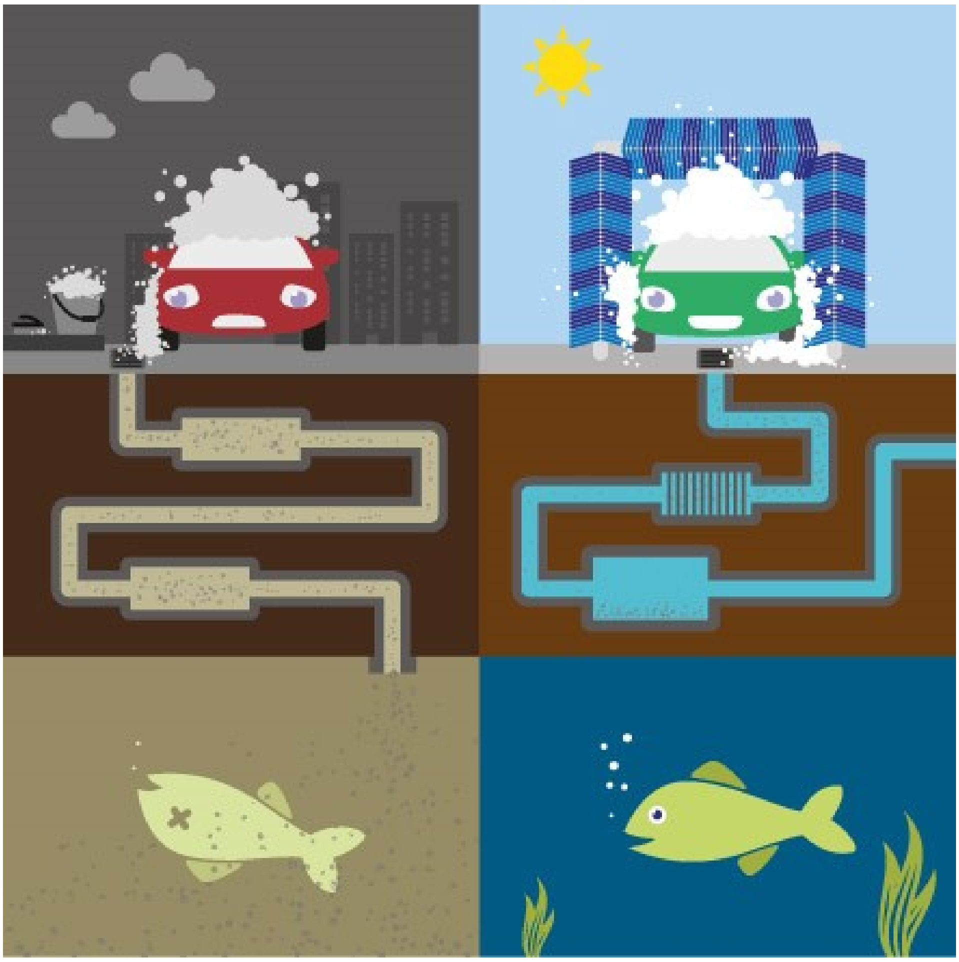

Emissions of Organic Pollutants from Vehicles
A Pilot Study of an Experimental Car Wash

Study Project in the Master's Programme Infrastructure and Environmental Engineering

Verena Munz

Department of Civil and Environmental Engineering
Water Environment Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

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Abstract

In the context of urban runoff and organic pollutants, vehicles serve as pollutant collectors and emitters. This study included the design of an experimental car wash and subsequent laboratory analysis with a focus on organic pollutants and particle size distributions (PSD). The car wash experiment simulated four different scenarios: a high and a low intensity rain simulation and a car wash using a conventional soap and a soap labelled to be ecological. Among the selected priority pollutants, phthalates, aliphatics and polycyclic aromatic hydrocarbons (PAHs), were detected in all four car wash simulations. Among the aliphatics, the long-chained C_{16}-C_{35} were present in the highest concentrations. The dominant phthalate was the high molecular weight di-iso-nonylphthalate (DINP). All sixteen US Enironmental Protection Agency (EPA) PAHs were detected in the vehicle wash-off water. Particles below 100 nm in size were present in the wash-off water from vehicles. In the phase separation, the filtration and the SPE C_{18}-disk reduced the number of particles but did not affect the PSD. The phase distribution tests showed that all selected organic pollutants were below the detection limit in the colloidal phase. A majority of selected pollutants could already be removed through filtration. The PSD results revealed, that there were less particles present in the rain events than in the car wash events. Moreover, the conventional car wash showed high concentrations of pollutants, especially PAHs, even though the total driven distance was approximately half of the other cars. This highlights the effectiveness of vehicle washing regarding the removal of particles and pollutants. Since both the car wash as well as the rain event scenarios released a significant amount of pollutants, it suggests that pollutants are emitted not only during vehicle washing, but also during rain events. Consequently, vehicles are an important source of organic pollution to urban road runoff. Because vehicle washing has shown effective pollutant removal, a solution could be to install a car washing system in a controlled and regulated environment, for example at toll or gas stations.

Keywords: urban runoff; road runoff; vehicle wash-off; organic pollutants; particle size distribution; phase separation; colloidal phase; aliphatics; phthalates; polycyclic aromatic hydrocarbons.

Zusammenfassung

Im Kontext von städtischen Abflüssen und organischen Schadstoffen dienen Fahrzeuge als Schadstoffquelle aber auch als Schadstoffsammler. Diese Studie beinhaltet das Design einer experimentellen Autowaschanlage und eine anschließende Laboranalyse, die vor allem organische Schadstoffe und Partikelgrößenverteilungen untersucht. Das Autowaschexperiment simulierte vier verschiedene Szenarien: Regensimulationen mit je einer hohen und einer niedrigen Intensität und Autowäschen mit je einer herkömmlichen Seife und einer ökologisch etikettierten Seife. Unter den ausgewählten prioritären Schadstoffen wurden Phthalate, Aliphate und polyzyklische aromatische Kohlenwasserstoffe (PAKs) in allen vier Autowaschsimulationen gemessen.

Unter den Aliphaten waren die langkettigen Verbindungen C_{16}-C_{35} in der höchsten Konzentration vorhanden. Das dominierende Phthalat war das hochmolekulare Diiso-nonylphthalat (DINP). Alle sechzehn prioritisierten PAKs der US Enironmental Protection Agency (EPA) wurden im Fahrzeugabwasser nachgewiesen. Partikel im Grössenbereich unterhalb von 100 nm waren im Abwaschwasser von Fahrzeugen vorhanden. In einer Phasentrennung reduzierten die Filtration und die SPE C_{18}-disk die Anzahl der Partikel, beeinflußten jedoch nicht die Partikelgrößenverteilung. Die Phasenverteilung zeigte, dass alle ausgewählten organischen Schadstoffe in der kolloidalen Phase unter der Nachweisgrenze lagen. Ein Großteil ausgewählter Schadstoffe konnte bereits durch Filtration entfernt werden. Die Partikelgrössenverteilung zeigte, dass bei den Regenereignissen weniger Partikel vorhanden waren als bei den Autowaschvorgängen. Darüber hinaus zeigte die herkömmliche Autowäsche hohe Konzentrationen von Schadstoffen, insbesondere PAKs, obwohl die zurückgelegte Distanz des Autos etwa die Hälfte derjenigen der anderen Autos betrug. Dies unterstreicht die Wirksamkeit der Fahrzeugwäsche hinsichtlich der Entfernung von Partikeln und Schadstoffen. Da sowohl die Autowasch- als auch die Regenszenarien eine signifikante Menge an Schadstoffen freisetzten, deutet dies darauf hin, dass Schadstoffe nicht nur während der Fahrzeugwäsche, sondern auch während Regenereignissen emittiert werden. Folglich sind Fahrzeuge eine Quelle organischer Verschmutzung für den städtischen Straßenabfluss. Da die Fahrzeugwäsche eine effektive Entfernung von Schadstoffen gezeigt hat, könnte eine Lösung darin bestehen, ein Autowaschsystem in einer kontrollierten und regulierten Umgebung, beispielsweise an Maut- oder Tankstellen, zu installieren.

Schlüsselbegriffe: Städtischer Abfluss; Strassenabfluss; Fahrzeugabwasser; organische Schadstoffe; Partikelgrößenverteilung; Phasentrennung; kolloidale Phase; Aliphate; Phthalate; polyzyklische aromatische Kohlenwasserstoffe.

Nomenclature

Acronyms

AA	Annual Average
BCF	Bioconcentration Factor
CCME	Canadian Council of Ministers of the Environment
DHI	Dansk Hydraulisk Institut
DLS	Dynamic Light Scattering
DOC	Dissolved Organic Carbon
EC	Effective Concentration
ELS	Electrophoretic Light Scaterring
EU	European Union
FNU	Formazin Nephelometric Units
GC-MS	Gas chromatography - Mass spectrometry
HMW	High Molecular Weight
IACR	International Agency for Research on Cancer
IC	Ion Chromatography
ISO	International Organization for Standardization
LC	Lethal Concentration
LLE	Liquid-Liquid Extraction
LMW	Low Molecular Weight
log K_{OW}	Octanol-water partitioning constanst
MAC	Maximum Allowable Concentration
masl	meter above sea level
MMW	Medium Molecular Weight
na	not available
nm	Nanometre (10^{-9})
OP	Organic Pollutant
ORP	Oxidation Reduction Potential
POP	Persistent Organic Pollutant
PP	Priority Pollutant
PSD	Particle Size Distribution
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
RICH	Ranking and Identification of Chemical Hazards
SFA	Substance Flow Analysis
SMHI	Sveriges Meteorologiska och Hydrologiska Institut
SPBI	Svenska Petroleum & Biodrivmedel Institutet
SPE	Solid Phase Extraction
SPIMFAB	Svenska Petroleum Institut Miljösaneringsfond AB
SVOC	Semi-Volatile Organic Compound

TOC	Total Organic Carbon
TSS	Total Suspended Solids
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WFD	Water Framework Directive

Chemical Names

BBP	benzyl butyl phthalate
DBP	dibutyl phthalate
DDT	dichlorodiphenyl trichloroethane
DEHP	di(2-ethylhexyl)phthalate
DIDP	diisodecyl phthalate
DINP	diisononyl phthalate
oxy-PAH	oxygenated polycyclic aromatic hydrocarbon
PAH	polycyclic aromatic hydrocarbon
PES	polyethersulfone
PVC	polyvinyl chloride

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Introduction

"Measure what is measurable and make measurable that which is not" is a quote from the Italian polymath Galileo Galilei (1564-1642). Surely, Galilei was not aware of the abundance of pollutants that surrounded him during his lifetime. Nowadays, in our hygienic and modern society, we live with different pollutants than Galilei did. It is the task of today's research to quantify these pollutants and find out where they are coming from.

While the urban water quality in the past was mainly polluted through point sources, such as wastewater or industrial effluents, nowadays non point sources gain increasing importance. Non-point, or diffuse pollution, is for example generated through transportation and vehicles. Vehicle runoff contains organic pollutants, derived from the vehicle itself, but also collected through precipitation and atmospheric deposition. Main sources of organic pollutants from vehicles are vehicle exhaust gases, tire wear, lubricant oils, road surface wear, and brake linings (Markiewicz et al., 2017). The pollutants reach receiving waters directly with snow melt and rainfall or indirectly through sewer systems (Björklund, 2011). Runoff from vehicle surfaces is therefore a source for water pollution when it enters the water bodies (Wada et al., 2015). Through the European Water Framework Directive (WFD), a list of substances that should be prioritized in order to eliminate pollution of surface water is set out. The list contains five metallic compounds, while the remaining 28 compounds are organic pollutants (European Communities, 2001). Organic pollutants are problematic, because they may be persistent in the environment and thus can be transported over long distances. Organic pollutants may bioaccumulate and biomagnify in living organisms, where they can cause, among other diseases cancer and hormone disruptions (van der Perk, 2014). In this context, the EU lists road runoff as the main pollutant source for water bodies in the European Union (European Communities, 2001). Consequently, there is a need of studying vehicle wash-off water as an important source of organic pollutants in urban runoff.

1.1 Previous studies

There have been previous studies about the pollutant content from professional car wash facilities (Zaneti et al., 2012; Hashim, Nor Haslina and Zayadi, Nadzirah, 2016; Paxéus, 1996) and sources of organic matter have been investigated in a car wash experiment (Wada et al., 2015). An analysis of the concentration and particle size distribution of the selected priority organic pollutants is however missing. Moreover, the aspect of vehicle washing as a strategy for the removal of organic pollutants from urban runoff has not been investigated yet, and this study aims at filling this gap.

1.2 Aim of the thesis

The overall aim of this thesis is to investigate, how sustainable and effective vehicle washing can be to protect receiving water bodies from contamination, with a focus on organic pollutants. The objective is to design, construct and run a pilot scale experiment for car washing to answer the following research questions:

- What kind of priority organic pollutants can be found in the wash-off water from vehicles?
- In what size range do the particles of the wash-off water from the vehicles occur?
- What kind of vehicle washing is most effective in removing organic pollutants from vehicle surfaces?
- What kind of pollutants are expected to wash off during rain events while driving?

The contribution of vehicle wash-off water as a source of organic pollutants in urban runoff was investigated in this thesis. The research questions aim to find out, if a more regular car washing system, for example at gas or toll stations, could reduce and avoid the diffuse emission of organic pollutants during stormwater events.

1.3 Delimitations

During the scope of this study project, four cars were investigated more in detail. Hereby, the cars themselves, the routes taken, the parking, the weather situation and the precipitation differed. The experiment itself used four different washing methods.

Therefore, the possible comparisons between the four results are limited, since there are multiple influential and unknown factors. The driving and its natural circumstances are hardly reproducible. However, the detailed documentation of the experimental and laboratory work will hopefully allow additional interpretations in the future along with the conclusions drawn today.

2

Theoretical Background

A description of organic pollutants and basic concepts regarding organic pollutants in the context of water contamination and the urban traffic environment will be explained in the theoretical background.

2.1 Description of organic molecules

Organic substances can consist of carbon, oxygen, hydrogen, but also lesser amounts of nitrogen, phosphorus, sulphur, chlorine and other elements. The chemical bonds between carbon and the other elements are formed through covalent bonding. Organic molecules can have single, double or triple bonds between atoms that share electrons. They can form ring and chain structures. If organic compounds consist of four or more carbon atoms, they are able to form substances that can structure spatially in different ways and thus have different physico-chemical properties. They are called isomers. Organic molecules are classified either after a systematic nomenclature, considering their source and use, or based on their physico-chemical properties. Organic compounds can form ring structures, for example the ring structure of cyclohexa-1,3,5-triene C_6H_6, which is called benzene. Benzene rings are very stable structures. Compounds that contain benzene rings are called aromatic. Hydrocarbons, compounds that are made up of only carbon and hydrogen and are not aromatic, are referred to as aliphatic. Aromatic compounds are usually more polar and thus more soluble in water than aliphatic compounds (van der Perk, 2014).

2.2 Contamination through organic pollutants

The main source of organic pollutants (OPs) are man-made industrial products, like fuel, pesticides, plasticizers, or solvents. Some organic pollutants also form naturally through biochemical synthesis, incomplete decomposition of organic matter, volcanic eruptions, forest fires, or lightning. However, the increased human made production of organic pollutants has led to the large quantity of OPs present in the environment today. Organic pollutants enter the environment through industrial processes, their use and applications, spills and leaks, combustion, dumping or incineration. This means that OPs are released intentionally, e.g. through their use as herbicide, or unintentionally, e.g. in form of a byproduct during combustion (Markiewicz et al., 2017). Organic pollutants can either have direct harmful effects on living organisms and the ecosystem or cause indirect harm, for example through the depletion of dissolved oxygen in water bodies. The dispersal and persistence of organic compounds in the environment depends on their physico-chemical properties (van der Perk, 2014).

2.3 Forms of organic compounds

Organic pollutants can occur in gaseous, liquid and solid state. Organic compounds that evaporate completely and remain in the gas phase when exposed to the atmosphere at normal temperatures and pressures are called volatile organic compounds (VOCs). Organic compounds that evaporate slowly and partially when exposed to the atmosphere are called semi-volatile organic compounds (SVOCs). Hydrophilic organic compounds are soluble in water, because they contain a polar functional group that can form hydrogen bonds. Organic pollutants tend to be more soluble in water if they contain oxygen and nitrogen and if they are polar. However, most organic compounds are non-polar and thus hydrophobic. This means, that hydrophobic organic compounds cannot be solved in water, even when they are liquid themselves, because it is not possible for them to form hydrogen bonds (van der Perk, 2014). In general, the higher the molecular weight of the organic compound, the higher the hydrophobicity and lower the volatility. Hydrophobic organic compounds can be attached to solid surfaces or occur as liquid droplets. They interact with organic matter in the solid phase. The affinity of an organic compound for either water or organic matter can be described with the octanol-water partition coefficient log K_{OW} (O'Sullivan and Megson, 2014).

2.4 Organic pollutants in the traffic environment

This study is part of a PhD-thesis that focuses on the investigation of organic pollutants in urban runoff. Urban runoff carries substantial loads of organic pollutants. Its treatment is a pre-requisite for removing organic pollutants and achieving a non-toxic environment. Complementary to stormwater treatment facilities, street sweeping and vehicle washing are suggested as removal strategies. A selection of priority organic pollutants for this study followed Markiewicz et al. (2017). Therein, 1 100 organic pollutants were identified as potentially emitted from road-related sources through a literature research (Markiewicz et al., 2017). This list was further reduced applying a Ranking and Identification of Chemical Hazards (RICH) (Baun et al., 2006). The RICH approach is a methodology to subsequently filter OPs to find priority pollutants (PPs) that are of most environmental concern due to their toxicity and persistency. The process is based on the chemicals' physico-chemical properties and ecotoxicological data. Organic substances with high volatility from aqueous solutions based on Henry's law constant K_H are eliminated from the priority selection. The remaining organic compounds are either bound to water or to sediment, which can be found out with the carbon-water partitioning coefficient K_{OC}. Organic particles with high affinity to suspended solids are characterized with low priority. The persistency of the remaining priority organic pollutants is analyzed with the degradation half-life $T_{1/2}$. The risk of bioaccumulation is considered with the water-octanol distribution coefficient K_{OW} and the bioconcentration factor BCF. Finally, the toxicity is analyzed by determining the lethal concentration at which 50 % mortality occurs (LC_{50}) and the concentration at which 50 % of the expected effect occurs (EC_{50}). The toxicity is considered high if LC_{50} and EC_{50} occur at a dosage smaller than 1 mg/L. The contaminants that are finally considered toxic are ranked as priority pollutants (Baun et al., 2006). Further literature studies and a substance flow analysis (SFA) in a highway case study area in Gothenburg (Sweden) (Markiewicz et al., 2017) narrowed the list down to PPs that are likely to be found in the vehicle wash-off water and can be analyzed in the scope of this study: phthalates, aliphatics, PAHs, monocyclic aromatic hydrocarbons, other aromatics and oxy-polycyclic aromatic hydrocarbons (oxy-PAHs) (Table 2.1).

Table 2.1: Traffic-related sources of organic pollutants along with factors that influence the pollutants' release, adapted from (Markiewicz et al., 2017).

Source, Application	Influencing factors
Tires, tire wear • Softeners • Plasticizers • Aging protection	EU restriction of highly aromatic oils as softeners in rubber processing (European Parliament, Council of the European Union, 2006)
Brake lining, lining wear	Deceleration processes
Vehicle components • Bumpers • Mudguards • Bodywork parts • Motor components • Coating and paint/lacquer	• Temperature dependent release of plastic components • Car design • Fuel consumption and weight
Car care products • Surface protection • Surface preservation • Cleaning	Restricted vehicle washing
Fuels, oils, lubricants • Exhaust gases and particles • Spillage	• Type of vehicle and fuel • Driving pattern • Catalytic converters • Efficiency of combustion engine
Asphalt, concrete • Road wear • Additives	• Traffic characteristics • Studded tires • Weather conditions • Durability and resistance
Road paint and markings • Road wear • Additives	• Abrasion • Renewal cyclus
Road furniture • Traffic signs • Sound berms • Dividers and barriers	• Abrasion • Weather conditions • Durability and resistance

The following descriptions of groups of organic compounds will focus on the pollutants that were found in the scope of this study.

2.4.1 Aliphatics

Aliphatic components originate in petroleum or crude oil and was formed by the anaerobic decay of organic matter while temperature and pressure were increased millions of years ago. Aliphatics of the alkane series make up 95 % of the crude oil. The product range of petroleum refined by distillation varies from light hydrocarbons, such as methane CH_4, to alkane chains with more than 20 carbons (Table 2.2). The four lightest hydrocarbons with one to four carbons are gases used as fuel. The alkane chains with five to seven carbons are volatile and used as solvents. Petrol is made of alkane chains with six to twelve carbons that are mixed together. Diesel fuel contains alkane chains with 10-20 carbons. Gasoline consists of lighter alkanes than diesel. Heavier alkane chains can be found in diesel fuel used in ship engines. Petroleum is liquid, whereas alkane chains with more than 20 carbons are solid at room temperature (van der Perk, 2014).

Table 2.2: Anthropogenic origin of aliphatics in products from petroleum distillation, adapted from (Eneh, 2011).

Name	Application	Carbon number
Gas	Fuel, chemical synthesis	C_1-C_4
Naphtha	Solvents	C_5-C_{10}
Kerosene	Jet fuels, paraffin, domestic oil	C_{10}-C_{16}
Gas oil	Diesel fuel	C_{14}-C_{20}
Distillation residue	Lubricating oil, waxes, bitumen	$> C_{20}$ up to several hundred

2.4.2 Phthalates

Phthalates are formed in the reaction of phthalic ester with alcohol. High molecular weight phthalates are most commonly used to soften plastic products, which is why they are called plasticisers. Phthalates are divided into groups regarding their molecular weight (Table 2.3). Low molecular weight phthalates are used as solvents. Phthalates are found in packaging, toys, automotive plastics but also in hygiene products and detergents (Björklund, 2011).

Table 2.3: Groups of phthalates, their carbon numbers and water solubility.

Phthalate group	Carbon atoms	Water solubility
High molecular weight (HMW)	C_7-C_{13}	low
Low molecular weight (LMW)	C_3-C_7	high
Other	$< C_3$	high

With increasing molecular weight, the water solubility and volatility decreases, whereas the log K_{OW} increases. In general, the shorter the carbon chain of the ester group, the more toxic the phthalate (van der Perk, 2014). HMW phthalates have historically dominated the market in Sweden, where more than 90 % of the total mass of phthalates in the years 2000-2010 were HMW. Commonly used phthalates include the HMW di(2-ethylhexyl)phthalate (DEHP), diisononyl phthalate (DINP), benzyl butyl phthalate (BBP) and diisodecyl phthalate (DIDP). The low molecular weight phthalate dibutyl phthalate (DBP) and other short chained phthalates are in declining use (Figure 2.1).

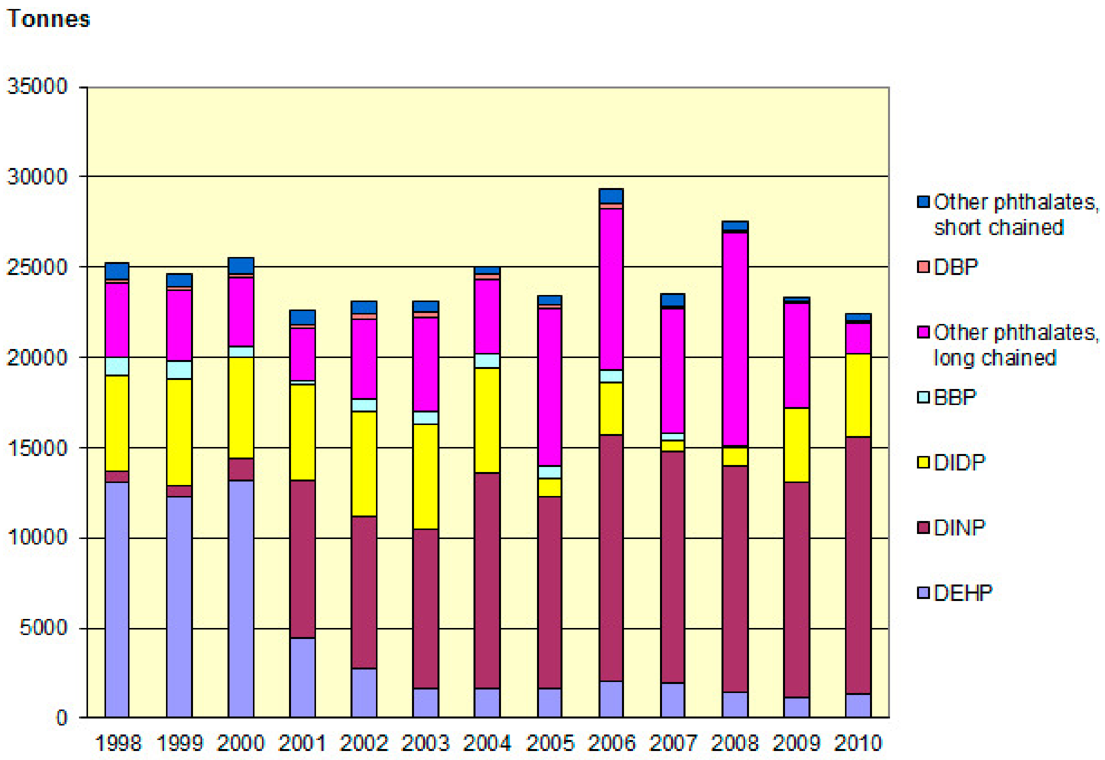

Figure 2.1: Use of phthalates in Sweden as total quantity in the Products Register between 1998 and 2010 (KEMI (Swedish Chemicals Agency), 2011). Exports are excluded.

Phthalates are regulated substances through the European Union regulation Registration, Evaluation, Authorisation and restriction of Chemicals (REACH). This means, that there are EU regulations regarding the use of phthalates, especially DEHP, in childcare articles. DEHP is the only phthalate with an annual average guideline value for surface water in the EU, which is set to 1.3 μg/L (European Communities, 2008). The Canadian freshwater quality guidelines for the protection of aquatic life list 16 μg/L as long-term guideline value for DEHP (CCME (Canadian Council of Ministers of the Environment), 1999). DEHP has been substituted by DINP in Sweden (Figure 2.1) . Future regulations shall also restrict the use of phthalates in electrical and electronic equipment, aiming for a general replacement of phthalates by other plasticizers (European Parliament, Council of the European Union, 2006). In the traffic environment, phthalates are used in car undercoating and other vehicle components, paint and lacquer and reclaimed asphalt (Strömvall et al., 2007).

2.4.3 Polycyclic aromatic hydrocarbons

One can differentiate between monocyclic aromatic hydrocarbons, consisting of one benzene ring, and polycyclic aromatic hydrocarbons (PAHs) which contain two or more connected benzene rings in the same plane. PAHs are formed during incomplete burning processes of coal, oil and gas and other organic substances. Low molecular weight (< 200 g/mol) PAHs contain two to three aromatic rings, whereas high molecular weight (< 228 g/mol) PAHs contain more than three aromatic rings. The volatility of PAHs increases with decreasing molecular weight. PAHs in air occur in vapor form or attached to dust particles smaller than 1-2 μm. Here, they can be broken down through photodegradation, or are otherwise removed from the atmosphere by deposition (van der Perk, 2014). PAH concentrations in air, soil and water are found to be enhanced in urban areas. Urban runoff is particularly responsible for the contamination of surface water with PAHs (Wada et al., 2015). Because PAHs are not very soluble and have a strong affinity to organic particulate matter, they are not exceedingly mobile in water. This is why PAHs concentrations are usually higher in sediments than in surface water. Since there are several hundred different PAHs, the United States Environmental Protection Agency (US EPA) defined 16 PAHs to be of most environmental concern in 1976 (Wise et al., 2015). These 16 PAHs will be analyzed in this study project. The Canadian Council of Ministers of the Environment (CCME) and the European Union provide guideline values for some of the 16 priority PAHs in freshwater life (Table 2.4).

Table 2.4: Existing environmental quality guidelines for PAHs in freshwater, adapted from (CCME (Canadian Council of Ministers of the Environment), 2010; European Communities, 2008).
AA=annual average; MAC=maximum allowable concentration, na=not available.

Name	CCME freshwater [μg/L]	EU, AA inland surface water [μg/L]	EU, AA other surface water [μg/L]	EU, MAC surface water [μg/L]
Naphtalene	1.1	2.4	1.2	na
Acenaphthylene	na	na	na	na
Acenaphthene	5.8	na	na	na
Fluorene	3.0	na	na	na
Phenanthrene	0.4	na	na	na
Anthracene	0.012	0.1	0.1	0.4
Fluoranthene	0.04	0.1	0.1	1
Pyrene	0.02	na	na	na
Benz[a]anthracene	0.018	na	na	na
Chrysene	na	na	na	na
Benzo[a]pyrene	0.015	0.05	0.05	0.1
Dibenz[a,h]anthracene	na	na	na	na
Benz(b)fluoranthene	na	$\sum =$	$\sum =$	na
Benz(k)fluoranthene	na	0.03	0.03	na
Benzo(ghi)perylene	na	$\sum =$	$\sum =$	na
Indeno(123cd)pyrene	na	0.002	0.002	na

The guideline values for stormwater discharges according to the City of Gothenburg Environmental Administration only include benz(a)pyrene as organic pollutant in their list of parameters, following the EU directive with a guideline value of 0.05 μg/L

(Göteborgs Stad, Miljöförvaltningen, 2013). Benz(a)pyrene is the only PAH from the 16 priority PAHs that is listed as a group 1 carcinogenic substance by the International Agency for Research on Cancer (IACR) of the World Health Organization (WHO) since 2012. Group 1 substances are categorized as having sufficient evidence of carcinogenicity in humans (IARC (International Agency for Research on Cancer), 2006).
In a highway case study area in Gothenburg (Sweden), a substance flow analysis showed that the main sources of PAHs in the area were in the following order: vehicle exhaust gases, tire wear, motor lubricant oils, road surface wear and brake linings (Markiewicz et al., 2017). More possible traffic-related sources of PAHs can be found and are named in literature.

2.5 Risk of organic compounds

Organic pollutants exist in enormous quantities with a vast variety of compounds. The following part gives an overview of the risks of organic compounds and provide the reader with some examples of human and environmental health effects with a focus on aliphatics, phthalates and PAHs.

2.5.1 Persistence of organic compounds

The persistence of organic compounds depends on their degradation rate. The degradation rate can be accelerated through microorganisms (biodegradation), or light (photochemical degradation). One can differentiate between reactive and persistent organic pollutants (POPs). POPs degrade very slowly, with environmental half-lives between two months to several decades. POPs are generally hydrophobic. Their hydrophobic characteristics lead to a high solubility in fatty tissues, so that bioaccumulation occurs. The concentration of POPs usually increases through the food chain, because of biomagnification (O'Sullivan and Megson, 2014). Moreover, POPs are often semi-volatile and can therefore be transported over long distances in the atmosphere. This means that POPs can be found in remote areas, where they have neither been used nor produced. Therefore, it becomes extremely difficult to trace and analyze the sources of POPs. The discussion about POPs initiated by the United Nations Environment Programme (UNEP) has led to the international environment treaty of the Stockholm Convention on Persistent Organic Pollutants in 2001, which is reviewed on a regular basis (Stockholm Convention, 2008). The OPs in this study are not yet listed in the Stockholm Convention. However, they are in the focus of attention, since they have characteristics of POPs.
Biodegradation of oil is possible through feeding microorganisms under warm conditions with sufficient supply of oxygen and nutrients. The process is however slow and some compounds, e.g. tar, persist in the environment. Microbial degradation is the dominant breakdown process for phthalates. Degradation becomes more difficult with increasing length of the alkyl chain and molecular weight. Complete degradation is not always achieved (Björklund, 2011). Low molecular PAHs can be broken down by microorganisms more easily than high molecular weight PAHs. The degradation can take weeks to months, but some PAHs are not degradable at all

(van der Perk, 2014). On the list of persistent organic pollutants, four out of the 16 US EPA PAHs are scheduled for reduction to 1990 levels (Jones and de Voogt, 1999).

2.5.2 Examples of human health effects

Considering human health, the severity of effects greatly depends on the exposure to organic pollutants. Effects can occur either in an acute or a latent way and symptoms can be either transient or chronic. To name the most severe problems, organic pollutants are known to cause cancer, allergies, disruption of the immune system, changes to the DNA, damage to the nervous system and reproductive disorders. Organic pollutants are often converted by organisms to more hazardous breakdown products than the original substance. The ingestion of mineral oil can hamper the absorption of vitamin A and frequent contact is associated with skin cancer (van der Perk, 2014). Some phthalates are classified as toxic and toxic to reproduction, i.e. they cause reduced ability to reproduce and damage the unborn child (KEMI (Swedish Chemicals Agency), 2011). Due to the exposure to a various mixture of compounds, PAHs mostly pose chronic risks. Sources are contaminated water, air and food. The most severe effects are cancer and DNA adducts. The heavier the PAH, the more carcinogenic potential it has (van der Perk, 2014).

2.5.3 Examples of environmental effects

Organic substances may lead to a depletion of dissolved oxygen and are therefore considered to cause pollution when entering groundwater or surface water. Even small traces of oil affect odor and taste of water and thus make it inappropriate as drinking water. Phyto-toxicological effects on sandy soils are observed even at concentrations of 0.5 mg/kg, underlying the threat of big oil spills and leaks. Human and animal health effects are quite similar, especially regarding mammals. The exposure rate for animals can however be much higher, for example during oil spills (van der Perk, 2014). Environmental awareness for organic pollutants rose in the 1960s with Rachel Carson's book Silent Spring. Therein, she describes the thinning of eggshells for predatory birds caused by the pesticide dichlorodiphenyl trichloroethane (DDT) and consequent egg breakage (Carson et al., 2002). Organic pollutants can also cause toxic effects for plants. For example, PAHs damage plants due to a photo-enhanced toxicity when UV light is present. They cause chlorosis, inhibit the plants' photosynthesis and diminish biomass accumulation. If PAHs accumulate in the soil, they inhibit root growth. Plant and soil uptake of organic pollutants is however also considered a cleaning technology for contaminated sites. Soluble PAHs are toxic for macrophytes, benthic aquatic invertebrates and fish in the aquatic environment (van der Perk, 2014). The toxicity of phthalates to aquatic organisms is generally low, due to their low water solubility and their degradation in aquatic organisms. However, high molecular weight phthalates have shown carcinogenic, reproductive and other severe toxicity effects in laboratory animals (Gray et al., 2000).

2.6 Transport of organic pollutants

One can distinguish between pollutants that are transported via air or water. To find proper remediation strategies to avoid organic pollutants in urban road runoff, it is important to analyze the quantity and severity of stormwater pollution. The runoff quality mainly depends on precipitation and land use factors. If there is a long dry period before a rain event, pollutants have time to accumulate on surfaces, which will lead to a peak in pollutant concentration. The same effect can be observed if the intensity of the rain increases and therefore removes more particles from the road surface. Seasonal changes in precipitation have to be considered, especially concerning snow and winter road maintenance using de-icing products and gravel (Butler et al., 2018). The land use and land cover, such as the degree of urbanization, traffic intensity, construction material for buildings as well as the vegetation cover influence the emission of organic pollutants. The road surface itself can play a key role trapping pollutants (Helmreich et al., 2010). Local practices can control the degree of pollution, e.g. by controlled street sweeping and car washing. Moreover, the traffic intensity can be controlled through tax and toll systems. The amount of pollutants that accumulates in urban road runoff is dependent on traffic and runoff-related factors (Table 2.5).

Table 2.5: Important traffic- and runoff-related factors that influence the degree of contamination by organic pollutants.

Traffic-related factors	Runoff-related factors
Velocity of vehicles	Antecedent dry period
Traffic count	Duration of rainfall
Vehicle components	Intensity of rainfall
Traffic components	Leaching rate from permanent structures
Street surface type and condition	Seasonal changes (e.g. snow events)
	Restricted vehicle washing
	Controlled street cleaning and sweeping

Further detailed discussions of factors influencing urban road runoff can be found in the literature (Opher and Friedler, 2010; Butler et al., 2018). Pollutants transported with air are either volatilized or bound to small particles. Pollutants transported with water have been deposited before on surfaces and are then washed off. If the deposition occurs on urban, impervious surfaces like roads, the pollutants are very likely to reach the local sewer system. When deposited on pervious areas, the pollutants can percolate and can be stored in sinks other than stormwater. For example, the pollutants are degraded, evaporated, or partitioned in soil (Markiewicz et al., 2017).

Investigations about the fate of exhaust emissions analyze atmospheric transport and deposition on close-by surfaces. Hewitt and Rashed (1990) assume, that only 1.3 % of the total emissions of phenanthrene (a PAH) in the exhaust emissions were deposited on or near the road surface. If deposition occurs on nearby soil and grass, it is much less likely to reach the stormwater system. The rest of the exhaust emissions is transported via air away from the road surface. It was assumed that tires, road materials, brake linings and lubricants are completely deposited on the road surface, because they are large and heavy (Hewitt and Rashed, 1990).

The runoff coefficient relates the received precipitation to the generated runoff. Most road surfaces are considered as impervious, even though some asphalt materials have pore space to retain some amount of runoff. It is assumed that the majority of pollutants that are deposited on road surfaces reach the stormwater sewer system (Hewitt and Rashed, 1990). Many organic pollutants are hydrophobic, thus they tend to bind to organic particulate matter, which simplifies their removal from the water phase by sedimentation. However, heavy rainfall and high turbidity may cause hydrophobic substances to mix with water, so that an emulsion is created (e.g. oil and water). Moreover, OPs can also be found as truly dissolved and in the colloidal phase. Colloids are defined as solid phase, inorganic or organic material, between 1 nm and 1 μm in size. Colloidal particles serve as transport vectors for contaminants via sorption. This has been shown for PAHs in groundwater (Shimizu et al., 1998), as well as in landfill leachate (Kalmykova et al., 2013) and in stormwater (Nielsen et al., 2015). Sorption of OPs to colloidal particles has consequences for the pollutants' mobility, their filterability and consequently toxicity: most treatment facilities use settling as the main treatment technique and are only effective for particles > 450 nm in size that settle readily. Colloidal material is however in the range of 1 - 1000 nm, it does not settle but remains dispersed in the liquid phase. Colloids are therefore able to transport OPs out of stormwater treatment facilities (Kalmykova et al., 2013).

Nanoparticles are in the range between 1 and 100 nm. Both colloids and nanoparticles influence the form of transportation, bioavailaibility and chemistry of OPs (Lead and Wilkinson, 2006). The particle size distribution (PSD) in this study project shall provide greater knowledge of the distribution of pollutants in the total, filtered and colloidal phase.

2.7 Legislative background for vehicle washing

There is no general law concerning private vehicle washing in Sweden. In Gothenburg, car washing on the street is only prohibited in the water protection areas, but the municipality highly recommends using only certified car wash companies, that use environmentally friendly washing detergents (Miljöförvaltningen Göteborgs Stad, 2015).

Germany does not have a law for vehicle washing, either. However, it is not allowed to emit any dangerous substance, including vehicle wash-off water, directly or indirectly into groundwater. Therefore, private vehicle washers have to prove, that they are washing the vehicle on a sealed surface and that the wash-off water is directed into the sewer system. Most communities have additional stricter rules, banning private vehicle washing completely (Umweltbundesamt Deutschland, 2018).

3

Materials and Method

The study is divided into two parts: the first part contains a literature study, which will increase the understanding of the pollutants themselves, their sources and transport. The second part is the experiment, which consists of the set-up of the actual car wash and the laboratory analysis.

3.1 The car wash experiment

The car wash study started with a professional car wash of all vehicles, followed by four weeks of driving, and then a controlled car wash experiment. The car wash experiment simulated four different scenarios: a high intensity rain simulation, a low intensity rain simulation, a car wash using a conventional soap and a car wash with a soap labelled to be ecological. The car wash experiment took place at Campus Johanneberg at Chalmers University of Technology on March 20th and 21st, 2018. Four different car types with similar surface areas were used. One car had a gasoline engine, the others had diesel engines (Table 3.1).

At the beginning of the study, all cars were washed at a commercial car wash company attending the same washing program - Basis from the company 7Eleven at a Shell gas station - before the driving regime began. The car wash program was rated to be ecological by the eco-label Nordic Swan (Nordic Council of Ministers, 2017). It included pre-washing, shampooing, washing by soft brushes and wheel washing. Neither high pressure, nor wax was used and the bottom sides of the cars were not washed. The cars were then driven by their owners for four weeks almost daily until the day of the car wash experiment, while the driving area, rainfall events, driven kilometers and the parking situation was noted.

For all four test drivers, the main driving area was Gothenburg city (population around 550 000). The car for the conventional car wash was used to commute between Partille and Gothenburg city centre. The cars for the simulated rain events were mainly driven in Gothenburg and surrounding communities, including a major trip to Northern or Central Sweden by each car. The car for the ecological car wash was mainly driven in Gothenburg and surrounding communities, and was once used for a trip to Oslo, Norway. The complete driving diaries are found in Appendix A.

In parallel to the driving, precipitation data was collected from two independent weather stations in Gothenburg. The precipitation data is listed in Appendix B.

During the test period, de-icing salt and gravel was used on the streets, since the temperature was below 0 °C during two thirds of the driving time. The average daily temperature is listed in Appendix B. The driving period can be characterized as mainly dry and cold.

Table 3.1: Specifications of the vehicles used in the car wash experiment.

Parameter	1 Conventional Car wash	2 Heavy rain	3 Light rain	4 Ecological Car wash
Experiment [yyyy-mm-dd]	2018-03-20	2018-03-20	2018-03-21	2018-03-21
Brand	Opel	Volkswagen	Ford	Audi
Model	Insignia Kombi	Golf Variant Bluemotion	Mondeo	A4 Avant
Engine	Diesel	TDI Diesel	Gasoline	Diesel
Engine displacement [ccm]	2.0	1.6	2.0	2.0
Engine power [hp]	160	105	146	190
Model year	2009	2010	2006	2015
L*W*H [mm]	4908*1856*1520	4562*2027*1481	4731*1812*1429	4726*1842*1427
Surface area [m^2]	34	33	32	32
Studded tires	no	yes	yes	no
Parking	out- and indoors	outdoors	outdoors	indoors
Driving area	Gothenburg	Gothenburg; Värmland	Gothenburg; Mora	Gothenburg; Oslo
Driven distance [km]	609	1323	1524	1262

3.1.1 Experimental set-up

The discharge from simulated washing and rain events was collected on a polyethylene sheet, laying underneath the car. A basin was created through rectangular support using wooden planks (Figure 3.1).

(a) Schematic **(b)** Photo

Figure 3.1: The experimental set-up for the wash-off water collection.

The washing water was sucked up by a vacuum cleaner and gathered in a stainless steel tank. For the on-site measurements, the collected water was stirred thoroughly in the tank using a stainless steel rod. On-site measurements were performed with the Hanna HI 9829 multiliner probe and included pH, oxidation reduction potential, turbidity, conductivity and dissolved oxygen. The wash water was filled into dark glass bottles and was stored in a refrigerator until the laboratory analysis. Three replicates were taken from each experiment.

3.1.2 Ecological and conventional car wash

The car washing was supposed to simulate a professional car wash, but also to compare the effective removal of pollutants from the car. The experimental design followed a car wash case study conducted by (Zaneti et al., 2012). In the washing process, the car was first wetted completely with a high-pressure washer (pre-soak). Then, the car was hand washed with a soap-water mixture, containing 40 mL soap in 8 L tap water (washing). Sponges were used and rinsed in between, using clean tap water. After the washing, the car was rinsed with a high-pressure washer (final rinse) to remove surfactants and dirt. A total of approximately 90 L of water was used for each washing procedure.

3.1.3 Rainfall event

Runoff from vehicle surfaces is produced during rainfall events. For the experiment, water was sprayed onto the top, sides and on the underside of vehicles with a garden hose sprinkler, to simulate both rainfall and splashing. The original thought was to simulate a rainfall intensity from rain data collected during the driving period (approximately 0.5 L/min, cf. Appendix B). However, it was only possible to adjust the water meter attached to the garden hose to a constant throughput of 1.1-1.3 L/min, which was therefore chosen as intensity. A period of thirty minutes was selected for the heavy rain event, where the front and the roof were sprayed for 10 minutes each, while the sides of the car and the underside were sprayed for 5 minutes each. A total of approximately 80 L was used for the heavy rain event. A period of 15 minutes was chosen for the light rain event, where the front and the roof were sprayed for 5 minutes each, while the sides of the car and the underside were sprayed for 2.5 minutes each. A total of approximately 24 L was used for the heavy rain event. The time frames were based on typical driving times of the test drivers in the city of Gothenburg. A discrepancy between the before estimated amount of total water and the actual collected amount of total water was observed and can be explained by leakages in the hose and an inaccurate water meter.

3.2 Experimental materials

Plastic materials could leach organic pollutants and microplastics. Therefore, the application of plastics throughout the experiment and laboratory work was avoided and stainless steel or glass materials were used instead whenever possible (Table 3.2).

Table 3.2: List of the main materials used during the car wash experiment.

Name	Material
Tarpaulin	Polyethylene (100 %)
Vacuum cleaner	Stainless steel bucket
Buckets	Stainless steel
Storage tank	Stainless steel
Water hose	Phthalate free
Sampling bottles	Glass (green)
Funnel	Stainless steel
Sponges	Polyurethane
Microfiber cloth	Polyester (100 %)

3.2.1 Detergents

Two different detergents were used for the car wash scenarios. The ecological-labelled product offered more information about its ingredients. The conventional detergent was chosen because it is commonly available in the stores from 7Eleven from Shell gas stations, where all cars were undergoing the professional car wash. The detergent used for the conventional car wash was named Super Wash from the brand Turtle Wax. The ingredients are listed to be the following: water, $>=$ 30 % aliphatic hydrocarbons, $<$ 5 % aromatic hydrocarbons, $<$ 5 % non-ionic tensides, lemon perfume, preservatives, benzisothiazolinone, zinc pyrithione, methylisothiazolinone. 40 mL of the conventional soap was mixed with ca. 8 L of hot tap water.

The detergent used for the ecological car wash was named Bilshampo BIO from the brand Biltema. The official ingredients listed are: water, paraffin oils, sulfochlorinated, saponified, amide polyglycol ether, tetrasodium N,N-bis(carboxylatomethyl)-L-glutamate, trisodium 5-hydroxy-1-(4-sulphophenyl)-4-(4-sulpho phenylazo)pyrazole -3-carboxylate, bis[hydrogen [4-[4-(diethylamino)-5'-hydroxy-2', 4' disulphonato benzhydrylidene]cyclohexa-2, 5-dien-1-ylidene]diethylammonium] and calcium salt. 40 mL of the ecologic-labelled soap was mixed with ca. 8 L of hot tap water.

3.3 Laboratory work

Samples were stored in completely filled, dark colored 2 L glass bottles in the refrigerator at < 8 °C to avoid any degradation or volatilisation processes. Three replicates were collected from each car wash. Samples were homogenized through shaking prior to each analysis to avoid any attachment of pollutants to the glass surface of the sample bottles. Parameters were tested at three laboratories, mainly following the standards of the European Union International Organization for Standardization (ISO) (Table 3.3). Groups of organic pollutants were selected for analysis, because of their persistency in the environment and their characterization as priority pollutants in stormwater in literature (Björklund, 2011; Markiewicz et al., 2017; Strömvall et al., 2007; van der Perk, 2014). All collected water samples were analyzed for the selected priority pollutants: aliphatics in six fractions (C_5-C_{35}); aromatics in five fractions (C_8-C_{35}); benzene, toluene, ethylbenzene and xylenes (BTEX); metylpyrenes/metylfluoranthenes; metylchrysenes/metylbens(a)anthracenes; 13 specific phthalates; the USA EPA PAH 16 polycyclic aromatic hydrocarbons; nine specific oxygenated PAHs (oxy-PAHs); and general quality parameters including total suspended solids, ions, total and dissolved organic carbon. Total suspended solids were analyzed using a filter size of 1.2 μm. Cations and anions were tested with the ion chromatography (IC) management system Chromeleon. Samples were diluted five times and pre-conditioned with ammonium-acetate. Part of the laboratory work was conducted at the Environmental Chemistry Laboratory (ECL) at Chalmers University of Technology. The rest of the parameters were analyzed at the commercial accredited laboratories ALS Scandinavia AB and Eurofins Environment Testing Sweden AB. For the extraction of organic pollutants, ALS Scandinavia AB used solid phase extraction (SPE), while Eurofins Environment Testing Sweden AB used liquid-liquid extraction (LLE). Gas chromatography-mass spectrometry (GC-MS) was applied for the analysis of organic pollutants. The laboratory Eurofins Environment Testing AB was assigned for the phase distribution analysis (cf. chapter 3.3.2). The official reports from the external laboratories and their methodologies can be found in Appendix C.

Table 3.3: Standards and methods used for analyzing the different parameters in the car wash water samples and corresponding laboratories.

Parameter	Standard	Method	Laboratory
TSS	SS EN ISO 872:2005	Filtration, oven	ECL, Chalmers
Anions	SS EN ISO 10304	IC Chromeleon	ECL, Chalmers
Cations	SS EN ISO 14911	IC Chromeleon	ECL, Chalmers
Aromatics	SPIMFABs kvalitetsmanual	GC-MS	ALS, Eurofins
Aliphatics	SPIMFABs kvalitetsmanual	GC-MS	ALS, Eurofins
BTEX	SPIMFABs kvalitetsmanual	GC-MS	ALS, Eurofins
US EPA PAH 16	CSN EN ISO 6468; US EPA 8270	GC-MS	ALS, Eurofins
Oxy-PAHs	CSN EN ISO 6468	GC-MS	ALS
Metylpyrenes/metylfluoranthenes	SPIMFABs kvalitetsmanual	GC-MS	ALS
Metylchrysenes/metylbens(a)anthracenes	SPIMFABs kvalitetsmanual	GC-MS	ALS
Phthalates (13 specific)	DIN EN ISO 18856	GC-MS	ALS
TOC/DOC	CSN EN 1484/13370	Infrared	ALS

3.3.1 Laboratory materials

It was tried to minimize the contact of samples with plastic components when possible, but it has to be kept in mind, that most laboratory materials are disposable and therefore made of plastic. Whenever possible, plastic materials in the laboratory were substituted by glass (Table 3.4).

Table 3.4: List of products and main materials used in the laboratory.

Name	Material
Syringe filters w/0.45 μm	Polyethersulfone (PES) membrane
Glass microfiber filters w/0.7, 1.2 μm	Borosilicate glass circles, binder free
C_{18}-disk	Octadecyl
Cuvettes	Polystyrol, polystyrene
Beakers	Glass
Funnels	Glass
Sampling bottles	Glass (green and brown)

3.3.2 Phase separation

A phase separation was performed for samples collected from the conventional car wash and the heavy rain experiments. The phase distribution experiment took place at the Environmental Chemistry Laboratory at Chalmers University of Technology on May 2nd, 2018. A risk assessment had been performed prior to the laboratory analysis. Concentrations of organic pollutants were analyzed by the laboratory Eurofins Environment Testing Sweden AB. Their complete report can be found in Appendix C.

Prior to the phase separation, the samples were homogenized by shaking for 2 h to ensure that no pollutants would attach to the glass surface of the sample bottles. The procedure was adapted from (Nielsen et al., 2015) that is based on (Kalmykova et al., 2013). The phase separation was performed by filtering the total water sample through a 0.7 μm binder free glass fiber filter. The colloidal phase was separated from the filtered phase through a C_{18} solid phase extraction (SPE) disk from the company Empore. The C_{18}-disk was conditioned with cyclohexane:ethyl acetate (1:1) followed by methanol and Milli-Q water. The use of SPE-disks is discussed in detail in (Erger and Schmidt, 2014). The filtered phase contains organic pollutants in both the colloidal and the truly dissolved phase. When the filtrate is passed through a SPE disk, the truly dissolved organic pollutants are assumed to be attached to the SPE disk, while the colloidal organic pollutants are transported through the disk, ending up in the water phase (Figure 3.2).

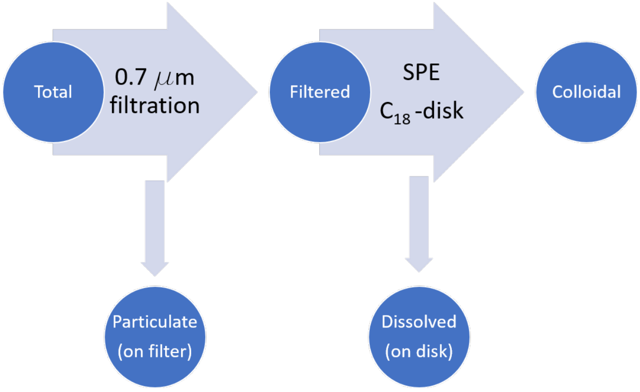

Figure 3.2: Flow-diagram for the method used for separating the total, filtered and colloidal phase.

Concentrations of organic pollutants were analyzed in the total, filtered and colloidal phase. The total phase was included in the analysis for a comparison with initial results. The organic pollutants selected for analyis were: monocyclic aromatics, aliphatics and PAH-16. The filtered and colloidal fractions were analyzed for their particle size distribution (PSD).

3.3.3 Particle size distribution

The particle size was measured with two different instruments, both based on the dynamic light scattering (DLS) measurement principle. The movement of the particles in the liquid samples is dependent on their size: the smaller the particle, the faster it moves. The particles are illuminated with laser light and the scattering is recorded multiple times. By comparing how much the particles have moved in between each recording, the average size of the particles and the size distribution can be calculated (Anton Paar GmbH, 2016). Both instruments require filtered samples in order to obtain reliable results. The water samples of all four car wash events were filtered with a polyethersulfone (PES) membrane of 0.45 μm pore size. The filtered and colloidal water samples of the phase distribution had been filtered by a 0.7 μm binder free glass fiber filter. Therefore, no additional filter was applied.

Results including particle sizes beyond filter sizes were not considered, since the filter might have released particles or a scattering error might have occured.

3.3.3.1 Nanosight measurements

The distribution of the concentration of particles (in mL) in a certain size interval (in nm) was measured with the instrument Nanosight NS3000. The instrument illuminates the particles in the sample with a focused laser beam. The laser position is fixed and particles are illuminated with a side scatter of 90°. The sample passes through the beam path due to Brownian motion, while information on the particle properties are obtained from the light scattering system. Nanoparticles in a size range of 10 - 1 000 nm can be analyzed (Malvern Instruments Limited, 2014). The laser module chamber as well as inlet and outlet tubes were rinsed with ethanol 10 % and with ultra-pure (Milli-Q) water to remove any residual particles. The Nanosight instrument and software allow individual settings (Table 3.5).

Table 3.5: Settings for measuring the particle size distribution with dynamic light scattering using the Nanosight NS3000.

Parameter	Setting
Screen gain	10
Camera level (NTA 3.0 Levels)	10
Slider shutter	600
Slider gain	250
Shutter/ms	15
Detection threshold	5 particles/mL
Laser type	Blue 488 nm
Software version	NTA 3.2 DevBuild 3.2.16
Camera type	sCMOS

3.3.3.2 Litesizer measurements

The instrument Litesizer 500 measures the distribution of particle sizes by analyzing the relative frequency of a volume of particles in a certain diameter range. Nanoparticles in a size range of 0.3 - 10 000 nm can be analyzed (Anton Paar GmbH, 2016). The samples were filtered and then placed in a cuvette in the instrument. The laser can be adjusted to different measurement angles (15°, 90°, 175°). The Litesizer instrument and software allow individual settings (Table 3.6).

Table 3.6: Settings for measuring the particle size distribution with dynamic light scattering using the Litesizer 500.

Parameter	Setting
Cuvette material	Polystyrene, polystyrol
Software version	2001-06-04
Instrument module type	BM10
Laser type	Single frequency diode, 658 nm
Measurement angle used	Automatic, based on transmittance

The Litesizer was also used to measure the zeta potential of the samples. The zeta potential measures the magnitude of the repulsion or attraction between particles. There are two layers in the ionic environment of a particle: the closest layer to the particle is called Stern layer, the outer layer is the diffuse layer. The slipping pane is the boundary between the electric double layer of the two layers attached to the particle surface and the ions in the solution. Measurements of the zeta potential work by using electrophoretic light scattering (ELS). The speed of the particles is measured when an electric field is applied. The speed is dependent on the surface charge at the slipping pane of the particle. If the zeta potential is in the range of -30 to +30 mV, particles will not repel each other and thus attach. This is called dispersion instability (Malvern Instruments Limited, 2016). Since attached particles form bigger surfaces to scatter light, the zeta potential can explain why particles sizes bigger than the filter size were measured (Nielsen et al., 2015).

4

Results

In this section, results are presented in the following order: measurements at site, general parameters, organic pollutants and particle size distribution including zeta potential. Results are presented as mean of three replicates. Data was eliminated if it fell outside two standard deviations of the mean. Organic pollutants that were below the detection limit are presented as half of the detection limit. The complete report for parameters tested at the external laboratories ALS Scandinavia AB and Eurofins Environment Testing Scandinavia AB including their detection limits and testing procedures can be found in Appendix C. For the interpretation of the results, it was assumed that the car wash events would release more pollutants than the rain events, due to the high water pressure and the ingredients of the detergents. If this was not the case, a focus was drawn to the driving mode and the car type.

4.1 General water quality parameters

The pH, conductivity, oxidation reduction potential, dissolved oxygen and turbidity were measured at the experiment site with the Hanna HI 9829 multiliner probe (Table 4.1). Total suspended solids, anions, cations, total and dissolved organic carbon were analyzed in the laboratory. The parameters were used to draw correlations with the organic pollutants measured.

Table 4.1: General water quality parameters measured at the experiment site with the Hanna HI 9829 multiliner probe.

Parameter	Unit	1 Conventional Car wash	2 Heavy rain	3 Light rain	4 Ecological Car wash
pH	-	7.1	6.6	7.8	8.3
Conductivity	μS/cm	609	891	529	426
Oxidation reduction potential (ORP)	mV	240	231	202	160
Dissolved oxygen	ppm	16.7	19.9	16.4	13.1
Turbidity	FNU	330	600	599	595
Total suspended solids (TSS)	mg/L	672	1020	769	871

The pH ranges from 6.6 to 8.3 (Table 4.1). The ecological car wash shows the highest pH with 8.3, which is most likely due to the detergent used. The other events show pH-values near neutral.

The conductivity ranges from 426 to 891 μS/cm (Table 4.1). The heavy rain event has the highest conductivity. De-icing salt during the winter season can lead to increased conductivity. The driver undertook a major trip (600 km) to Värmland in Central Sweden (cf. appendix A), which is most likely the reason for an increased accumulation of de-icing salt in comparison to the other cars. High conductivity also causes particles to flocculate and aggregate (Nielsen, 2015).

The oxidation reduction potential (ORP) ranges from 160 to 240 mV (Table 4.1). The ORP is a tendency to acquire (reduction) or loose electrons (oxidation) and depends on the concentration of redox-active species, such as metals and ions. In comparison to the conductivity, that is also correlated to the presence of ions, the light rain event and the ecological car wash show the lowest values, whereas the conventional car wash and heavy rain event show the highest values for ORP.

The dissolved oxygen ranges from 13.1 to 19.9 ppm DO (Table 4.1). The dissolved oxygen is linked to the ability of aerobic degradation that increases with present oxygen. However, since the sampled water was quite mixed in the collection tank, the dissolved oxygen is not thought to be a very representative parameter.

The turbidity ranges from 13.1 to 19.9 Formazin Nephelometric Units (FNU) (Table 4.1). Turbidity is a measure of dissolved particles in water and provides a first overview of the clarity of the water. All water samples are close to 600 FNU, except for the conventional car wash, with almost half (330 FNU) of the rest of the measures.

The parameters measured at site may have measurement errors. The main reason is that the Hanna HI 9829 multiliner probe is a sensitive instrument. Moreover, sedimentation of particles might have occurred, even though the water sample was mixed using a rod. The mixing itself influences the parameters.

4.1.1 Total suspended solids

Total Suspended Solids range from 672 to 1020 mg/L (Figure 4.1). The value of TSS is a measure of suspended particles in water. Suspended solids reduce the visibility of water and transport high loads of pollutants. The heavy rain event shows the maximum TSS concentration.

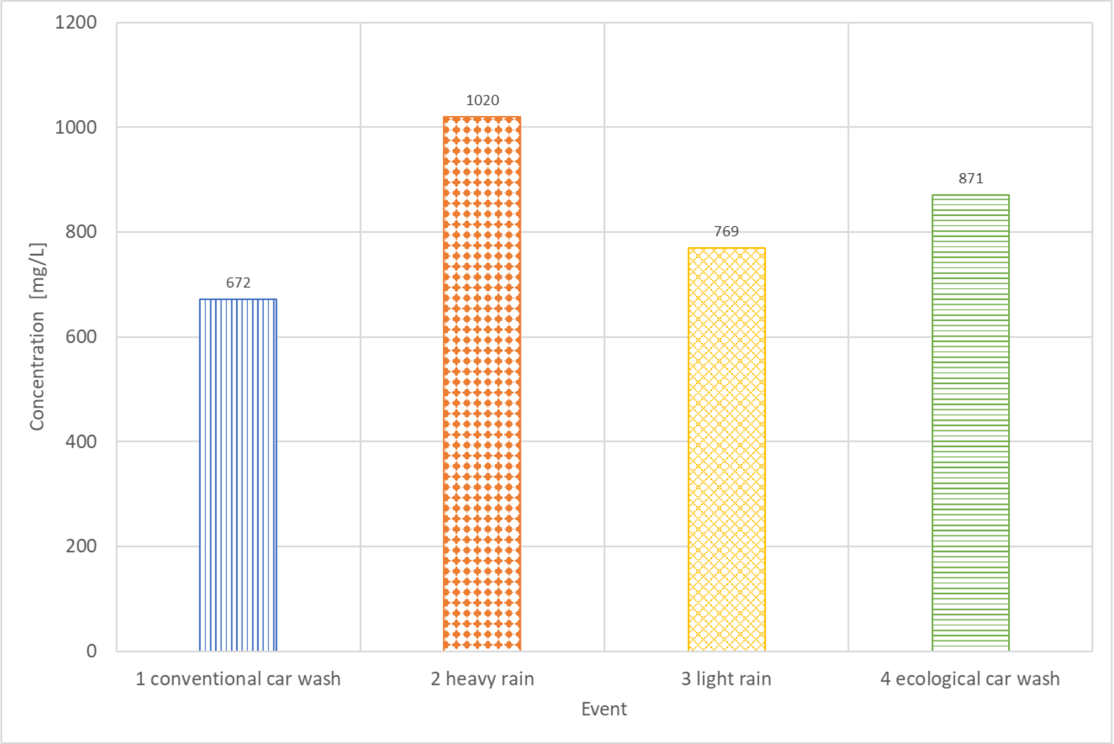

Figure 4.1: Total Suspended Solids (TSS) measured in the vehicle wash-off water samples. The filter size used was 1.2 μm.

4.1.2 Ion chromatography

Detected anions include acetate, chloride, nitrite, nitrate, bromide and sulfate (Figure 4.2). Phosphate is not included in the graph, since it was below the detection limit. Chloride shows elevated values in the range of 1.9-5.8 mmol/L. The maximum level is reached for the heavy rain event. The results correspond to the measured conductivity levels (Table 4.1). De-icing salt (sodium chloride) is most likely the reason for the elevated chloride levels. Another origin of chloride mentioned in the literature is the reaction of sea-salt aerosols with acidifying substances in the atmosphere. This would cause chloride depletion from gaseous hydrochlorid acid and a higher depletion rate of chloride compared to sodium (Blomqvist, 1998).

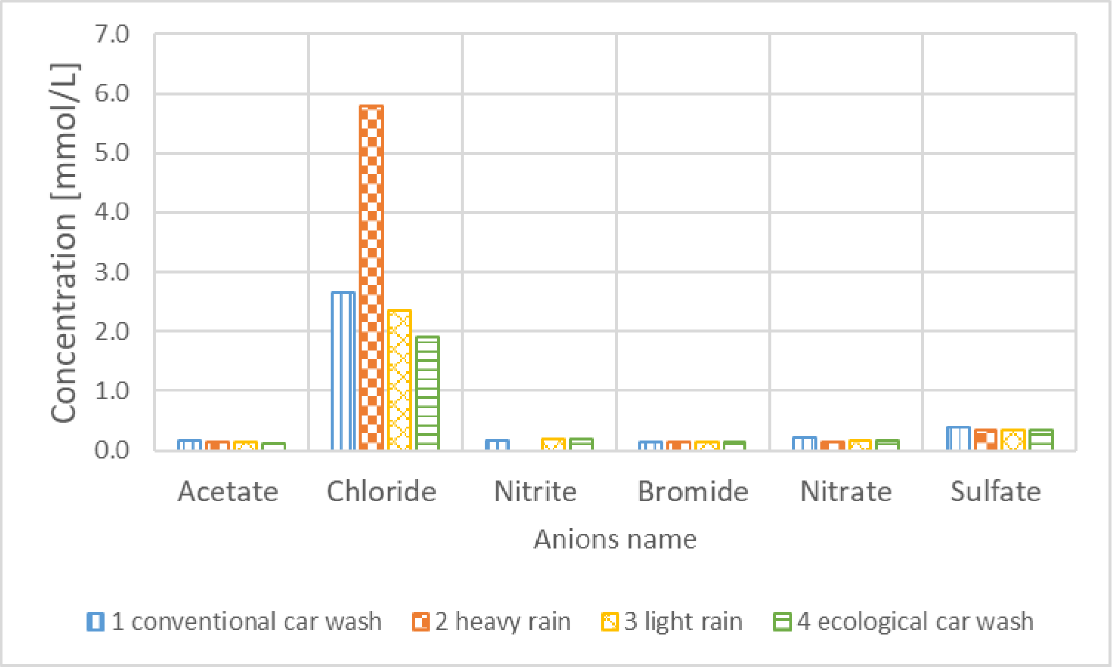

Figure 4.2: Anions measured in the vehicle wash-off water samples.

Detected cations include sodium, potassium and calcium (Figure 4.3). Due to the pre-conditioning of the samples with ammonium acetate, ammonium is not included in the results. Manganese and magnesium are not included in the graph, since they were below the detection limit. Elevated levels of sodium correspond to the results of measured chloride and are most likely due to the accumulation of de-icing salt (sodium chloride). Sodium chloride is the main de-icing salt in Sweden, while sometimes calcium chloride and rarely potassium chloride are used as well (Blomqvist, 1998).

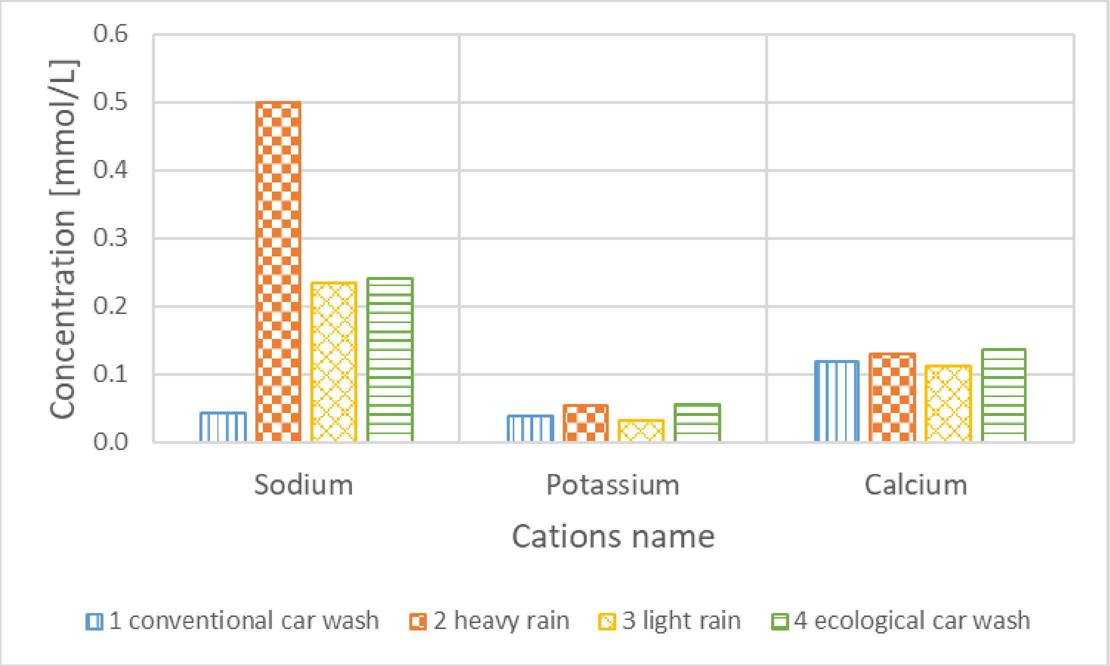

Figure 4.3: Cations measured in the vehicle wash-off water samples.

4.1.3 Total and dissolved organic carbon

Total organic carbon (TOC) is a sum parameter for all organic compounds in a sample. The fraction of dissolved organic carbon (DOC) is the sum of dissolved organic compounds which passes a membrane filter of 0.45 μm pore size. The TOC in all four car wash simulations ranges from 7.1-13.8 mg/L, whereas the DOC ranges from 6.6-12 mg/L (Figure 4.4). The conventional and the ecological car wash events show the highest concentration of TOC (13.8 mg/L and 12.9 mg/L). The heavy and light rain event show lower concentrations of TOC (7.1 mg/L and 8.2 mg/L). The highest DOC concentrations are found in the vehicle wash-off water from the ecological car wash (12 mg/L). Since the difference between TOC and DOC is small, most organic carbons are present in the dissolved phase. The Pearson correlation coefficient shows a very strong positive relationship (r=0.74) between DOC and PAHs with low molecular weight. All sum parameter of PAHs show a strong positive correlation with TOC and a positive correlation with DOC. There is no regular positive correlation pattern between TOC, DOC and aliphatics or phthalates. A complete list of the Pearson correlation coefficients can be found in Appendix E.

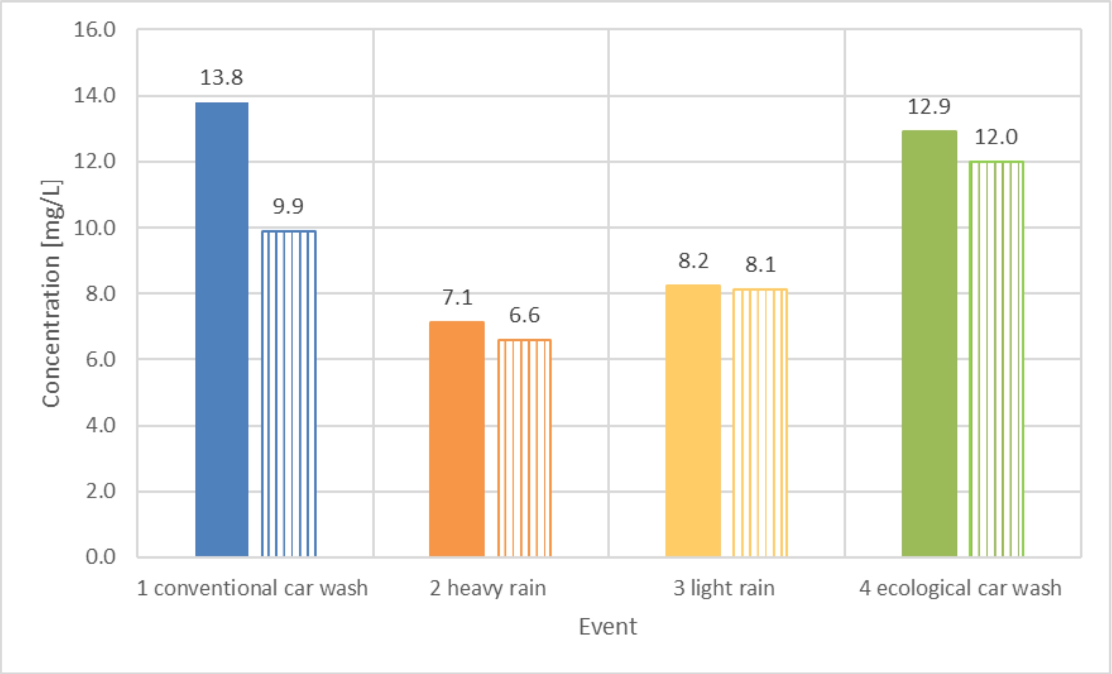

Figure 4.4: The total and dissolved organic carbon in the vehicle wash-off water samples of all four simulation events. The color-filled bars on the left side present TOC, the striped bars on the right side present DOC.

4.2 Organic Pollutants

The organic pollutants that were chosen to be tested are: phthalates, aliphatics, PAHs, monocyclic aromatic hydrocarbons, other aromatics and oxy-polycyclic aromatic hydrocarbons (oxy-PAHs). The complete results are listed in Appendix C. In the following graphics, pollutants that were found to be below the detection limit are presented as half of the detection limit. Groups of pollutants that were completely below the detection limit are monocyclic aromatic hydrocarbons, other aromatics and oxy-PAHs, which is why they are not presented in a graph.

4.2.1 Aliphatics

The heavier, long-chained aliphatics with the carbon number C_{16}-C_{35} dominate the results of aliphatics (Figure 4.5). The conventional car wash and the heavy rain event show results above 300 μg/L, while the light rain event is above 600 and the ecological car wash above 700 μg/L. Long chained aliphatics originate from diesel oil (van der Perk, 2014). Only the car from the light rain event has a gasoline engine, whereas the others have diesel engines. Since the results show high concentrations of long chained aliphatics for the gasoline car, it might indicate the atmospheric deposition of diesel exhaust on this vehicle's surface. During the ecological car wash, oil residues were noticed at the inside of the tire rim.
In a snow analysis in Gothenburg in 2009, the most frequent aliphatics were C_5-C_{16}, C_{12}-C_{16} (2 % each) and C_{16}-C_{35} (96 %) (Björklund, 2011). The distribution for the

car wash is similar with aliphatics C_{12}-C_{16} (4 %), C_{10}-C_{12} (5 %), C_5-C_{16}(8 %) and C_{16}-C_{35} (83 %).

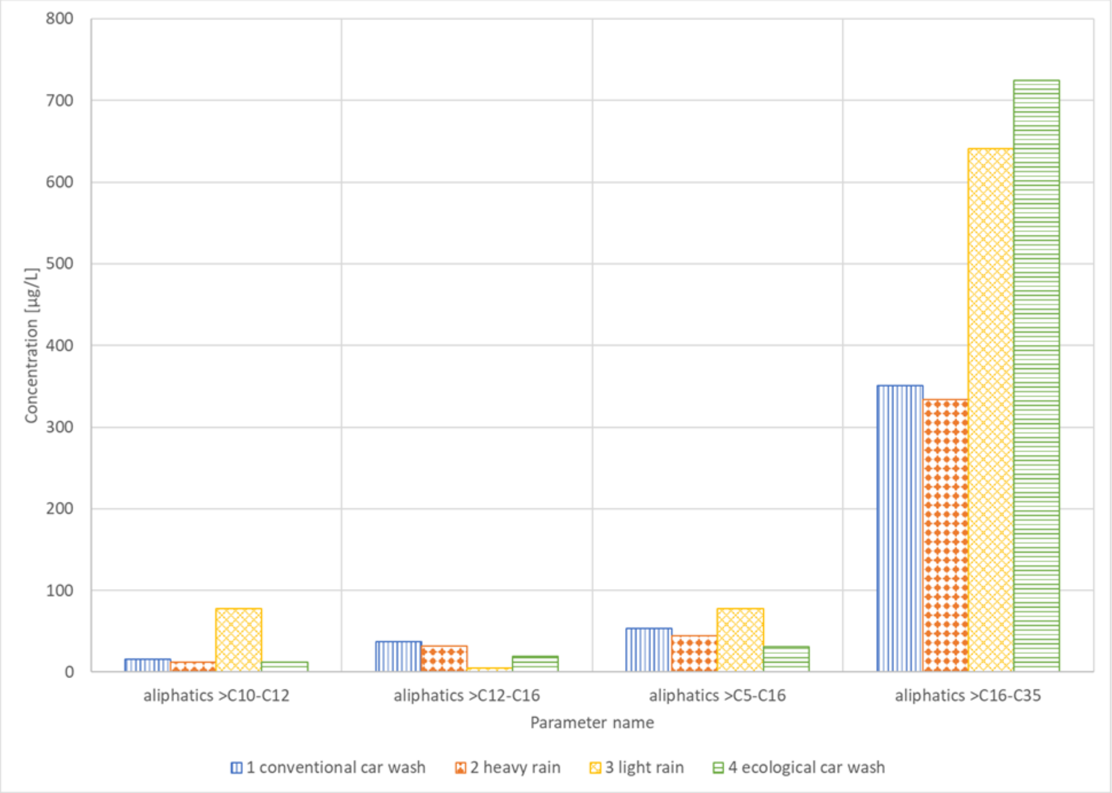

Figure 4.5: Measured concentrations of aliphatics in the vehicle wash-off water samples.

4.2.2 Phthalates

Only the high-molecular weight phthalates diethylphthalate (DEP), di-(2-ethylhexyl)phthalate (DEHP) and DINP are found above the detection limit in the vehicle wash-off water (Figure 4.6). The light rain event exceeds the EU's guideline value of 1.3 μg/L for inland surface waters, whereas the three other car wash events exceed both the European and the Canadian long-term guideline value of 16 μg/L (cf. chapter 2.4.2). The low concentrations of DINP in the car wash events in comparison to the rain events might be due to an effect of the detergents used. The highest concentrations of DINP can be found in the light rain event with 640 μg/L. DINP has substituted DEHP, due to EU regulations, which has led to an increased use (cf. Figure 2.1). DINP is a long-chained phthalate mainly used as plasticizer in PVC. Non-polymer applications are e.g. paints and lacquers. DINP is also part of car undercoating and rubber. The results confirm previous results, which show vehicles as a main source for DINP (Björklund, 2011). The car used for the light rain event is a model from 2006 and thus the oldest of the four cars (Table 3.1). This could be the reason for the release of DINP from paint and lacquer and leaching effects of the undercoating. DINP is supposed to occur at higher concentrations in the environment compared to other phthalates because of

its persistence and increasing use.
In a snow analysis in Gothenburg in 2009, the most abundant occurring phthalates were DEHP (15 %), DIDP (21 %) and DINP (62 %) (Björklund, 2011). The results for phthalates above the detection limit from all car wash events showed that DINP was present with 87 %, DEHP with 9 % and DIDP with only 4 %. An increase of DINP concentrations over the last eight years could be due to the previously mentioned EU regulations.

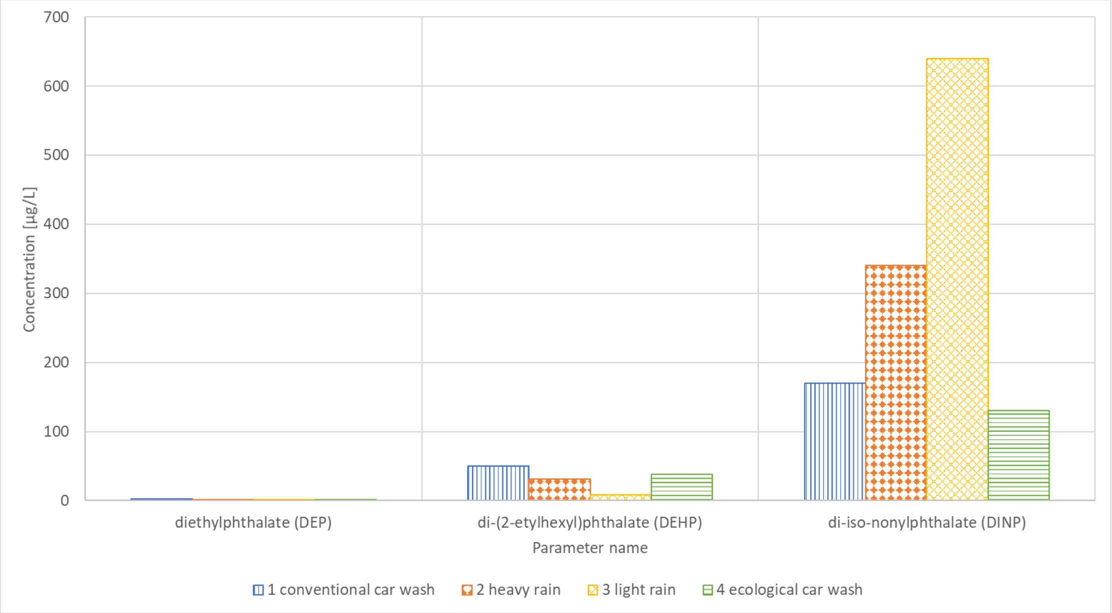

Figure 4.6: Measurement of phthalates in the vehicle wash-off water samples excluding phthalates below the detection limit.

4.2.3 Polycyclic aromatic hydrocarbons

Overall, the highest concentration of PAHs were found in the conventional car wash (Figure 4.7). Molecular weight is indicated by L (low), M (medium) and H (high) (cf. Appendix C). It is concluded that the effectiveness of the car washing outweighs the shorter distance driven (609 km, Table 3.1). A total of 1.5 μg/L of all 16 priority PAHs is found in the water sample of the conventional car wash. Light molecular weight PAHs are found in low concentrations < 0.06 μg/L in all events. Low molecular weight PAHs are likely to volatilize, either prior to the experiment directly from the urban surfaces or during the experiment (Nielsen et al., 2015). Low molecular weight PAHs are rather produced during low temperature processes, such as wood burning, than in high temperature processes that take place during vehicle combustion (Kalmykova et al., 2013). Medium and high molecular weight PAHs are found in concentrations > 0.4 μg/L for all events except for the light rain event. Medium molecular weight PAHs are found at higher total concentrations than the high molecular weight PAHs. High molecular weight originate in the combustion process, whereas medium molecular weight PAHs are also common for rubber tires (Strömvall et al., 2007). The gasoline car washed with light rain shows the lowest results for PAHs compared to the three diesel engine cars.

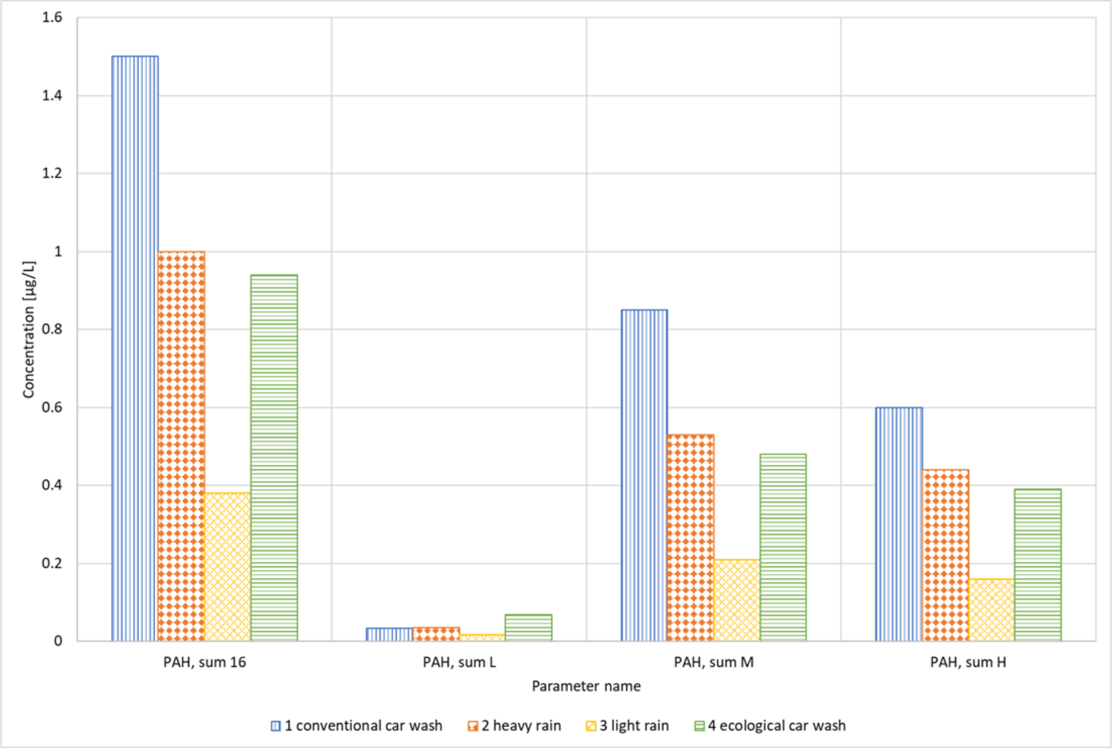

Figure 4.7: Sum μg/L of PAH-16, L-PAH, M-PAH and H-PAH in the vehicle wash-off water samples.

The highest concentrations of PAHs were found for fluoranthene and pyrene in the conventional car wash (Figure 4.8). These PAHs are of medium molecular weight. Fluoranthene is listed as an indicator for other, more dangerous polyaromatic hydrocarbons (European Communities, 2008). Anthracene, fluoranthene, pyrene, benz(a)anthracene and benz(a)pyrene are above the guideline values of the Canadian Council of Ministers for the Environment, with fluoranthene and pyrene greatly exceeding the guideline values. Additional to the Canadian guideline values, benz(b)fluoranthene with benz(k)fluoranthene and benzo(ghi)perylene with indeno(123cd)pyrene exceed the EU's guideline values (Table 2.4). The conventional car wash and the heavy rain event exceed Gothenburg's guideline value of 0.05 μg/L for benz(a)pyrene in stormwater discharge (Göteborgs Stad, Miljöförvaltningen, 2013).

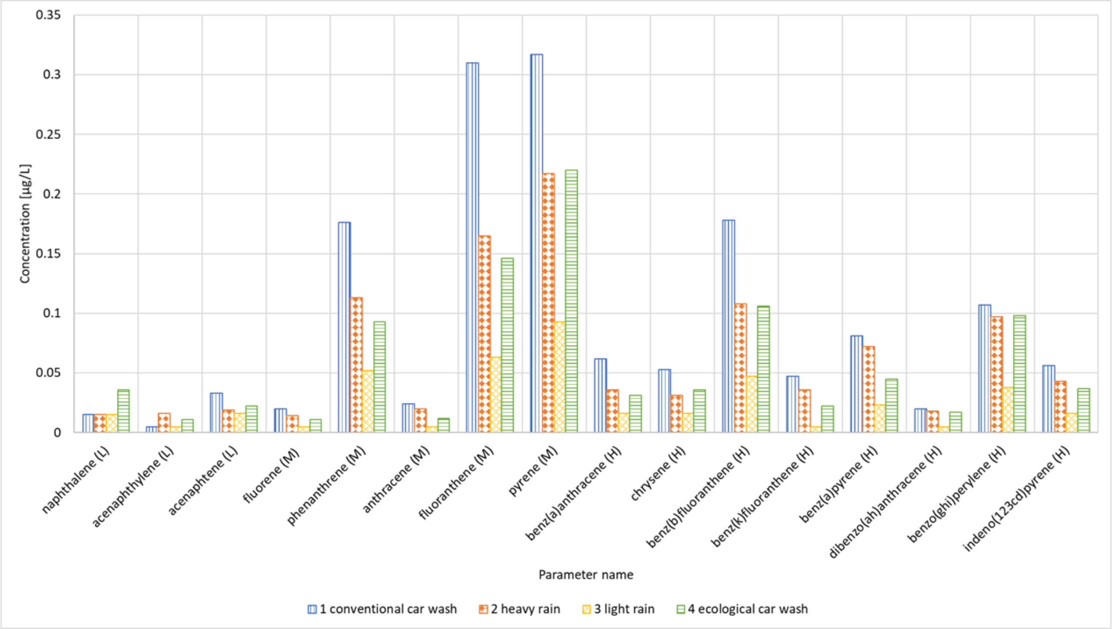

Figure 4.8: Measured concentrations of PAHs in the vehicle wash-off water samples.

In a snow analysis in Gothenburg in 2009, the most frequent PAHs were pyrene (26 %), phenanthrene (22 %) and fluoranthene (18 %) (Björklund, 2011). Pyrene (22 %), fluoranthene (18 %) and phenanthrene (11 %) also belong to the most abundant PAHs found in the car wash water (Figure 4.9).

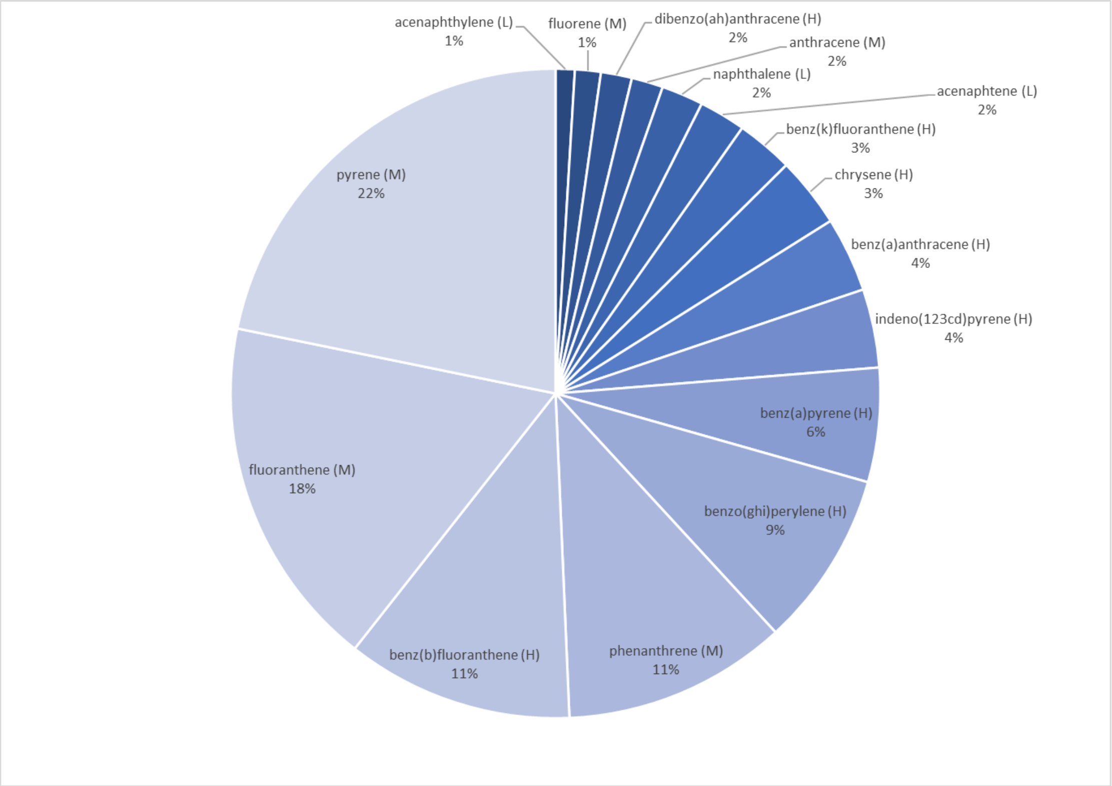

Figure 4.9: Relative distribution of the mean values for PAHs in the vehicle wash-off water samples of all four car wash simulations.

The Pearson correlation coefficient was calculated for TSS and all organic pollutants and found to be in a strong positive linear relationship only for acenaphtylene (r=0.96). The correlation was expected to be higher, since organic pollutants tend to bind to particulate matter due to their hydrophobic characteristics (Björklund, 2011; Kalmykova et al., 2013; Markiewicz et al., 2017). A complete list of the correlation coefficients can be found in Appendix E.

4.2.4 Phase distribution

The pollutant content in the total, filtered and colloidal phase was additionally analyzed for the conventional car wash and the heavy rain event and compared to the total phase of the original results obtained in the first analysis (total 1). From the selected groups of organic pollutants (aliphatics, PAH-16 and monocyclic aromatics) only aliphatics and PAHs were present in the results of the phase distribution. In both water samples of the conventional car wash and the heavy rain event, long-chained aliphatics C_{12}-C_{35} were present in the total phase (total 2), but not in the filtered phase (0.7 μm pore size). The conventional car wash showed presence of the PAHs naphtalene, phenanthrene, fluoranthene and pyrene in the filtered phase (Figure 4.10) while the heavy rain event showed only phenanthrene to be above the detection limit in the filtered phase (Figure 4.11). There were no organic pollutants found above the detection limit in the colloidal phase in the water samples of both events, which shows the effectiveness of the SPE C_{18}-disk in its removal capabilities for organic pollutants.

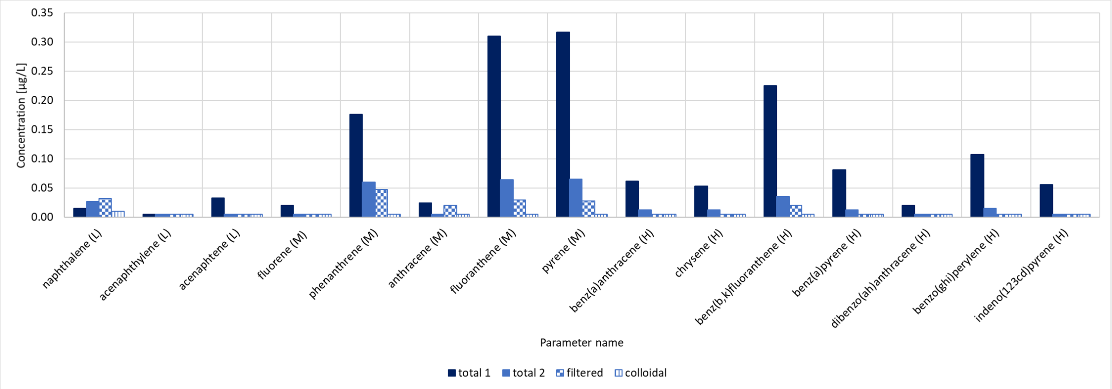

Figure 4.10: Comparison of the concentration of PAHs in the vehicle wash-off water samples from the conventional car wash in the original test (total 1) and the three phases of the phase distribution: total 2, filtered (0.7 μm) and colloidal.

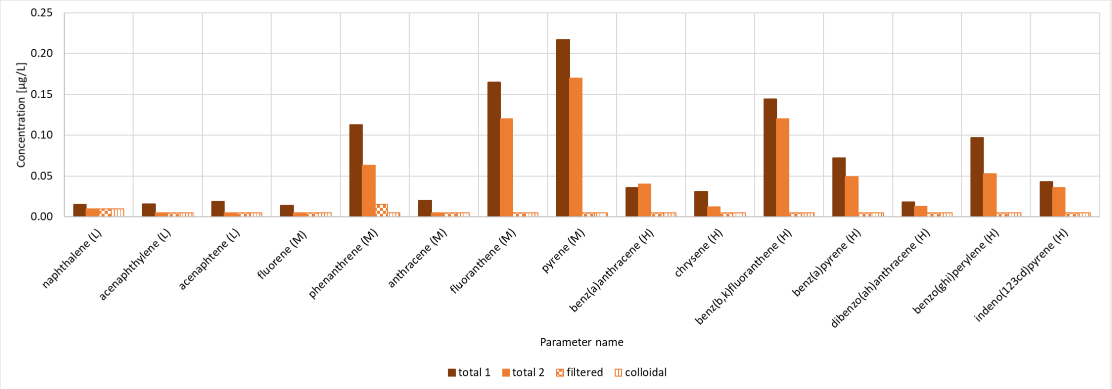

Figure 4.11: Comparison of the concentration of PAHs in the vehicle wash-off water samples from the heavy rain event in the original test (total 1) and the three phases of the phase distribution: total 2, filtered (0.7 μm) and colloidal.

It is assumed that the concentration in the total phase (total 2) was already too low for the phase separation methodology. This is most likely due to sedimentation effects and attachments of organic pollutants on the glass bottle surface, since the experiment took place more than one month after sampling.

4.3 Particle Size Distribution

The particle size distribution provides information about the particle sizes present in the water sample. This is decisive for the removal strategies for organic pollutants, e.g. filtration and sedimentation (Kalmykova et al., 2013). The particle size distributions for all four car wash events were measured on a volume based measurement with the Litesizer 500 and a concentration based measurement with the Nanosight NS3000 (cf. chapter 3.3.3). All water samples were filtered with a PES filter (0.45 μm pore size). The D90 is a common parameter for both Nanosight and Litesizer instruments. It means, that 90 % of all particles are smaller than the size of the D90 particle diameter. A complete comparison of the statistical data obtained from the two instruments can be found in Appendix E, Table E.2.

4.3.1 Nanosight results

In the PSD of the four car wash simulations, more particles were present in the two car wash events in comparison to the two rain events (Figure 4.12). The car wash events show peaks between 100-150 nm, while the rain events show peaks between 150-200 nm particle size. The D90 for the two rain events is 237 nm for the heavy rain and 247 nm for the light rain event. The D90 for the conventional car wash is 166 nm and 249 nm for the ecological car wash respectively.

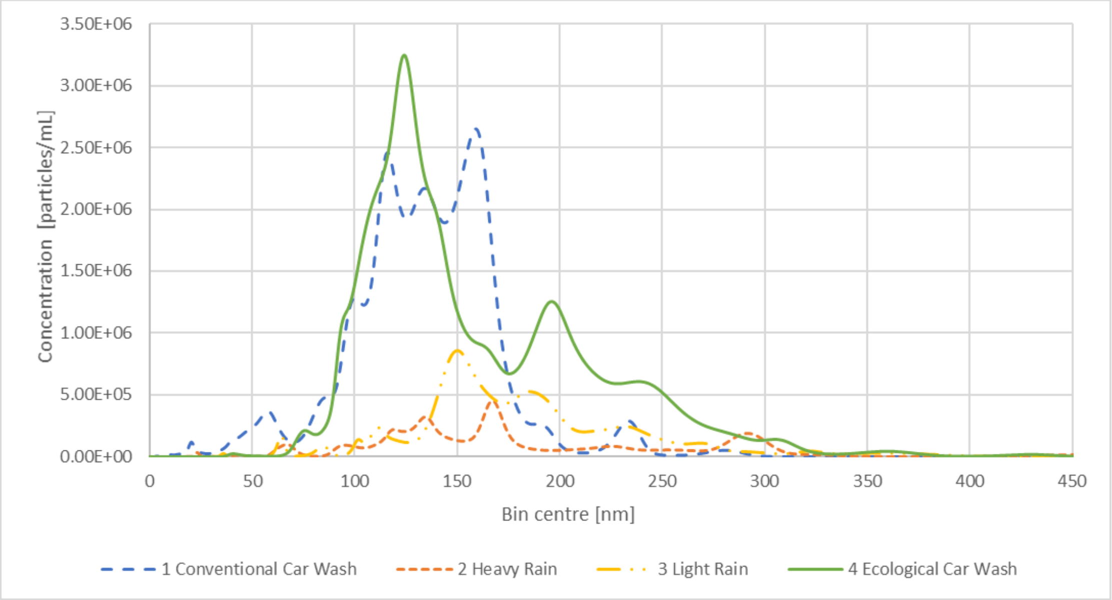

Figure 4.12: The average particle size distribution (1-450 nm) in the filtered phase (0.45 μm) of vehicle wash-off water samples, measured with dynamic light scattering (Nanosight NS3000).

There was only a small peak in the nanosize range visible for the conventional car wash between 50 and 60 nm (Figure 4.13).

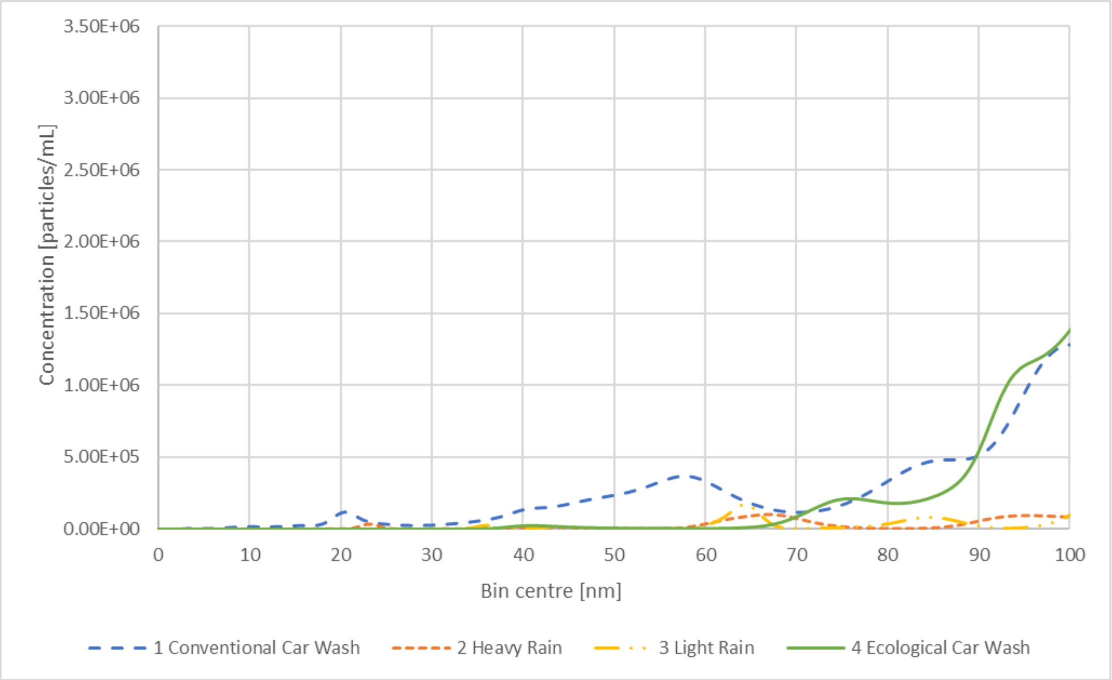

Figure 4.13: The average particle size distribution (1-100 nm) in the filtered phase (0.45 μm) of vehicle wash-off water samples, measured with dynamic light scattering (Nanosight NS3000).

4.3.1.1 Phase distribution

A PSD was additionally conducted for the colloidal and filtered phase of the conventional car wash and the heavy rain event. The filtered phase of the phase distribution has passed a 0.7 μm binder free glass fibre filter. The colloidal phase was separated from the filtered phase using a SPE C_{18}-disk. The results were compared to the PSD of the filtered phase of a 0.45 μm PES filter.

In the PSD of colloidal and filtered phases in the wash-off water from the conventional car wash, the particle concentration was much lower for the colloidal phase compared to both filtered phases (Figure 4.14). Only $1.05*10^8$ particles/mL were measured in the colloidal phase compared to $4.63*10^8$ particles/mL in the filtered phase (0.7 μm pore size). The size range is similar for all phases and mainly varies from 100-200 nm. There are nanoparticles $<$ 100 nm present in all phases.

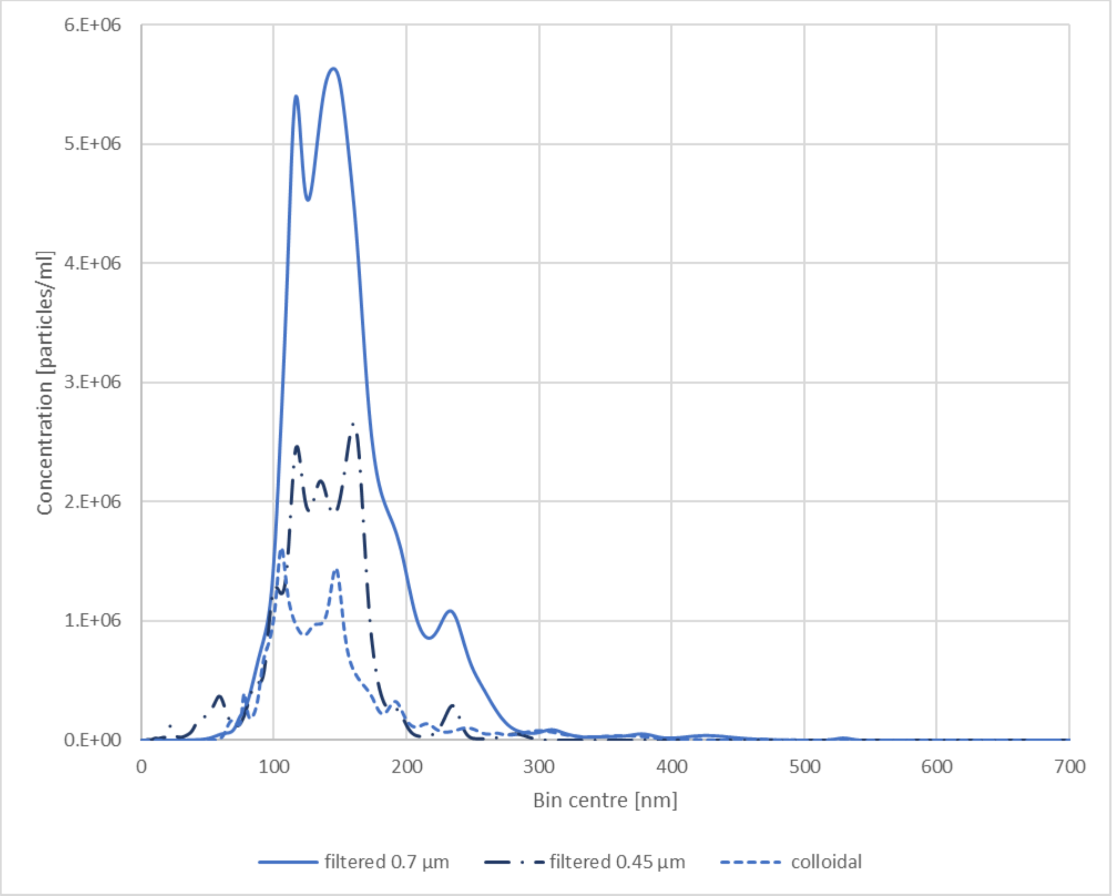

Figure 4.14: The average particle size distribution (1-700 nm) in the filtered and colloidal phases of vehicle wash-off water samples from the conventional car wash, measured with dynamic light scattering (Nanosight NS3000).

In the PSD of colloidal and filtered phases in the wash-off water from the heavy rain event, the particle concentration was much lower for the colloidal phase compared to both filtered phases (figure 4.15). Only $6.17*10^7$ particles/mL were measured in the colloidal phase compared to $2.12*10^8$ particles/mL in the filtered phase (0.7 μm pore size). The particle size range mainly varies from 100-300 nm for all three phases. There are nanoparticles $<$ 100 nm present in all phases.

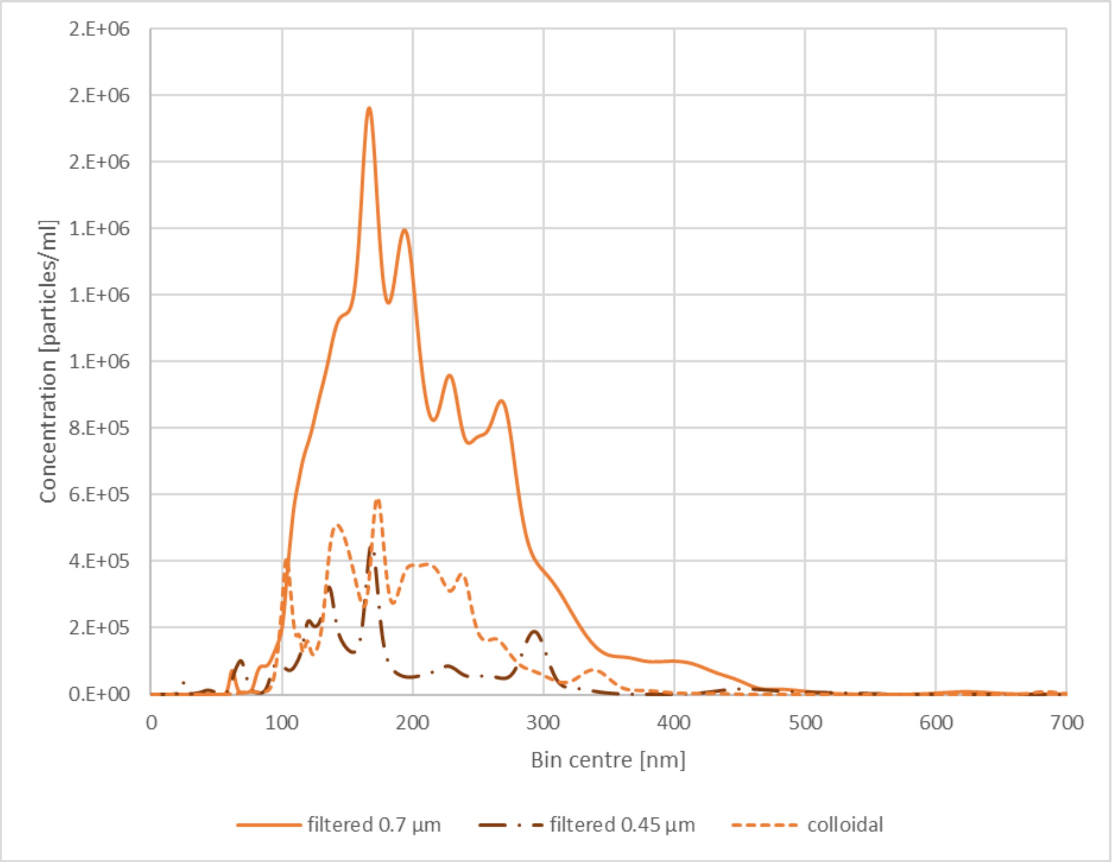

Figure 4.15: The average particle size distribution (1-700 nm) in the filtered and colloidal phases of vehicle wash-off water samples from the heavy rain event, measured with dynamic light scattering (Nanosight NS3000).

4.3.2 Litesizer results

In the PSD of the four car wash simulations, the Litesizer results showed similarities between the two rain events and the conventional car wash, that show a major peak between 100 and 150 nm particle size (Figure 4.16). The D90 is 163 nm for the conventional car wash and 149 and 153 nm for the heavy and light rain event. The ecological car wash shows a major peak at 30 nm, with D90 at 45 nm (Figure 4.17).

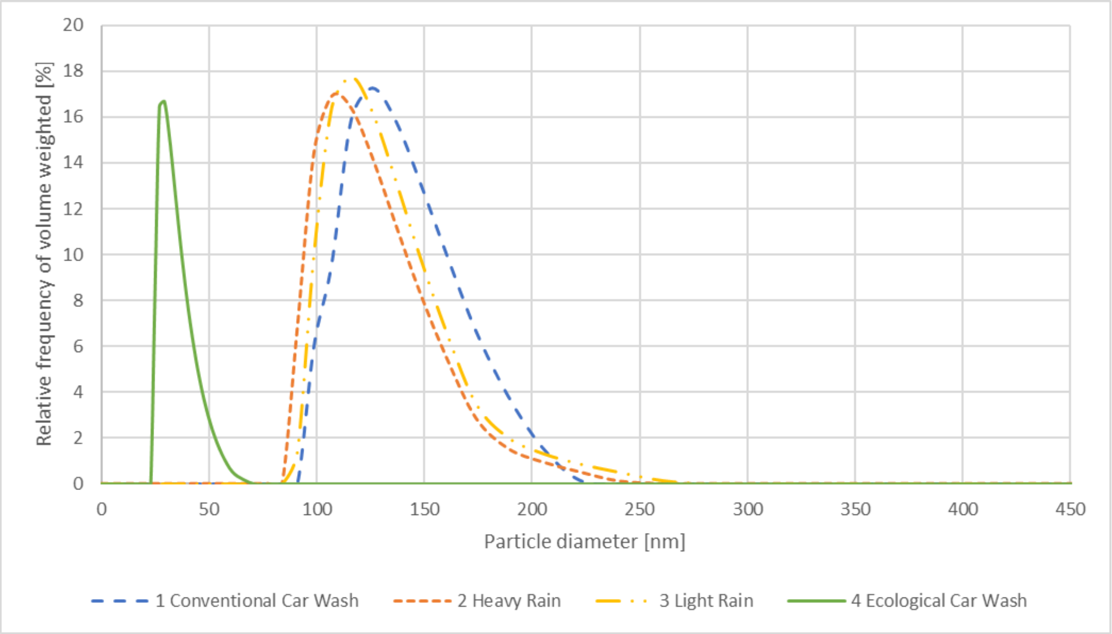

Figure 4.16: The average particle size distribution (1-450 nm) in the filtered phase (0.45 µm) of vehicle wash-off water samples, measured with dynamic light scattering (Litesizer 500).

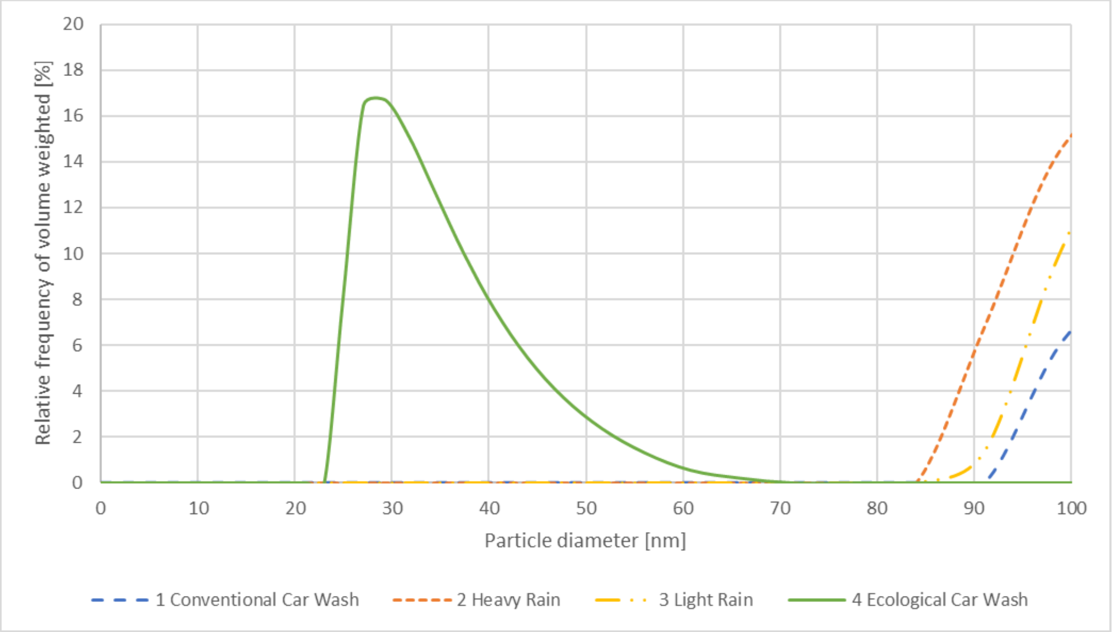

Figure 4.17: Particle size distribution (1-100 nm) of nanoparticles in the filtered phase (0.45 µm) of vehicle wash-off water samples, measured with dynamic light scattering (Litesizer 500).

4.3.2.1 Zeta potential results

The zeta potential was measured for all four car wash scenarios for the original total phase (total 1), and for the conventional car wash and heavy rain event, it was measured additionally for the filtered and colloidal phase. For the total phase, the zeta potential was in the range of -2 to -19 mV in all samples. For both colloidal and filtered phase, the zeta potential was found to be negative in the range of -10 to -23 mV. A zeta potential in the range of -30 to +30 mV indicates instability, because the particles do not repel each other strongly enough and thus prone to coagulate and flocculate (Malvern Instruments Limited, 2016). It is also a sign for negative surface charge, that is typical for clay, silt, and organic acids such as humic and fulvic acids (Nielsen et al., 2015).

5

Discussion

In the first part of this chapter, parameters regarding the vehicle and the driving circumstances and their effect on the results are discussed. In the second part of this chapter, possible sources of error of the particle size distribution applying dynamic light scattering are highlighted.

5.1 Factors influencing the water quality results

This section will reflect upon factors that are likely to have influenced the results. The focus is drawn to the results of the organic pollutants and the particle size distribution. Since the experiment included many unknowns, the factors are narrowed down into three groups: vehicle-related parameters, factors that concern the driving conditions and effects of the experimental measures.

5.1.1 Vehicle-related factors

The car used for the conventional car wash was driven the shortest distance, with only 609 km in comparison to more than 1200 km for the other cars. If the pollution concentration would be expressed as μg/L*km, the conventional car wash results would show a higher concentration of pollutants in the majority of the results compared to the other events. This stresses the efficiency of the conventional car wash in removing organic pollutants. Aliphatics were present in gasoline and diesel engine cars, which could indicate an atmospheric deposition of diesel exhaust (Figure 4.5). The age of the car might affect its release of phthalates, especially from the undercoating, paint and lacquer. The oldest car has released the most phthalates (Figure 4.6). It cannot be confirmed that the use of studded tires led to an increased accumulation of pollutants, but it is a seasonal factor that should be kept in mind. The car surface was very similar for all vehicles and is therefore not an influential factor in this study project.

5.1.2 Influential factors of the driving conditions

Seasonal effects of an experiment conducted during winter include the use of de-icing salt and gravel, which led to elevated results of chloride and sodium (Figures 4.2 and 4.3). The precipitation was quite low, which improved the capability of pollutant build-up instead of wash-off. The temperature was below 0 °C during two thirds of the driving period. The removal of pollutants is assumed to increase with higher temperatures, due to temperature dependent solubility characteristics. An influence of the driving pattern, e.g. number of deceleration times due to stop-and-go traffic in the city centre, could not be demonstrated, as this data was not collected. However, the only commuter among the test drivers was the owner of the conventional car wash vehicle, who regularly drove on the highway. The regular driving pattern does not seem to decrease the collection of pollutants. The highway might play a key role here. The parking is considered to be a less influential factor, since the precipitation amount was low during the experiment.

5.1.3 Influential factors of the experimental conditions

The effect of the use of detergents was especially visible in the particle size distribution, which showed that the concentration of particles was of one magnitude higher if detergents were used (Figure 4.12 and Appendix E, Table E.2). The presence of detergents in the water sample is most likely changing the availability of pollutants in the analysis (Figure 4.6). A comparison between ecological and conventional detergents is difficult, because of the few samples collected.

5.2 Dynamic Light Scattering

Dynamic light scattering (DLS) is a non-invasive technique for investigating particle size distributions and zeta potentials. It requires minimal sample preparation. The instruments offer a user-friendly digital interface and exportable and compatible data. Stormwater contains an unknown mixture of particles and colloids with different sizes and shapes (Nielsen, 2015). It is therefore a challenging sample to analyze. The results for the particle size distributions repetitively showed occurrence of particles that were larger than the pore size of used filters. Moreover, the results obtained from the Litesizer 500 match the results obtained from the Nanosight NS3000 in only a limited way. While the Litesizer results were mono-dispersed with a single peak, the Nanosight results were poly-dispersed with many peaks (Figure 4.12 and 4.16). The size range did not match completely either, especially in the nanosize range (Figure 4.13 and 4.17). Therefore, this section discusses the limitations of DLS and possible error sources based on the manuals provided for the two different instruments, and a detailed discussion of DLS and the zeta potential in (Bhattacharjee, 2016). A focus is drawn to factors that can be improved in future measurements.

5.2.1 Sample preparation

The samples were filtered with a 0.45 μm PES syringe filter and a 0.7 μm binder free glass fibre filter. The glass fibre filter is suspected to have sorption effects of PAHs on its surface (Nielsen et al., 2015). The sorption effect of PAHs on glass surfaces is an obvious problem for storing and working with PAHs in the laboratory environment (Qian et al., 2011). A solution for the glass fibre filter could be to use a different glass material, such as silanized glass and increase the ratio of volume to contacted surface area (Nielsen et al., 2015).

During the application of the 0.45 μm PES filter, particle sizes larger than the filter pore size were measured. It is assumed, that the PES filter releases particles itself.

This could be solved by using a different material and washing the filter material properly before. If substituted by glass fiber material, the filters could even be burnt. The laboratory environment needs to be sterile for the experiment, which also includes reassessing the quality of the ultra-pure water (Milli-Q).

Insufficient homogenization of the samples could lead to precipitation of bigger particles and attachment of pollutants to the sample bottle surface. Therefore, the shaking should be performed 24 h or more before analysis (Bhattacharjee, 2016).

The sampled water of the ecological and conventional car wash showed foam from the detergent use. Bubbles are a source for specular reflection (Malvern Instruments Limited, 2014). The samples should be de-gased.

5.2.2 Sample concentration

High concentrations of particles lead to multi-scattering. This means, that the scattered light interacts between particles before it reaches the detector. It looses intensity, so that the obtained size is smaller than in reality (Bhattacharjee, 2016). Agglomeration is also common for high particle concentrations. Bigger agglomerates scatter too much light, which on the one hand masks low intensity scattering from smaller particles and on the other hand can even lead to a damage of the detector. A too high concentration can also lead to particles no longer undergoing Brownian motion (Anton Paar GmbH, 2016). The instrument is then mistaken particle settling as Brownian motion (Nielsen, 2015). When the concentration of particles is too low, the scattered light might be too little to generate proper results.

Nanosight instruments can work with particle concentrations in the range of 10^7-10^9 particles/mL (Malvern Instruments Limited, 2014), which was the case for the measurements. The Litesizer manual provides a guideline table for a suitable concentration depending on the expected particle size (Anton Paar GmbH, 2016). The optimal concentration should be determined by using multiple dilutions.

5.2.3 Scattering angle

While the laser is at a fixed position in the Nanosight instrument (90°), the Litesizer allows three different angles (15°, 90°, 175°) to choose from. Even though the scattering angle was chosen to be automatic for the Litesizer, it would be interesting to see, how much results differ when a series of different scattering angles is selected. While the rotation of nanoparticles is not dependent on the scattering angle, the translational diffusion is dependent on different scattering angles. Intensity peaks at smaller sizes between 1-10 nm usually occur due to rotation of nanoparticles (Bhattacharjee, 2016).

5.2.4 Instrument errors

Instruments that analyze in the nano-size range are very sensitive to vibration. It is recommended to leave the instrument undisturbed for at least 30 minutes after turning it on to let the laser stabilize (Bhattacharjee, 2016).

The software setting should be varied in order to identify the most influential parameters and what a change in settings actually leads to.

5.2.5 Zeta potential

The zeta potential was originally measured to find out, if particles were likely to agglomerate. However, throughout all measurements, the zeta potential showed that samples were unstable and are likely to form agglomerations. The zeta potential varies with pH, particle concentration and ionic strength. It is itself a sensitive parameter. Moreover, it should only be understood as an indicator for colloid stability. Van der Waals attractive forces and electric double layer repulsive forces play an additional role. Metallic ions can react with the electrodes in cells for ZP measurements, which means that the metallic concentration of samples should be evaluated prior to the analysis (Bhattacharjee, 2016).

6

Conclusions

This study included the design of an experimental car wash and subsequent laboratory analysis with a focus on organic pollutants and particle size distributions. It has been shown, what kind of pollutants occur in the wash-off water from vehicles, along with their concentrations. The size range of particles in the vehicle wash-off water was determined. The most important conclusions from the results are the following:

- Among the selected priority pollutants, phthalates, aliphatics and PAHs were measured in all car wash simulations, including the heavy and light rain event. This suggests that organic pollutants are easily released from vehicles during rain events while driving and/or parking.
- Among the aliphatics, the long-chained compounds with carbon number C_{16}-C_{35} were present in the highest concentration. The dominant phthalate was the high molecular weight di-iso-nonylphthalate (DINP). All sixteen US EPA PAHs were detected in the vehicle wash-off water. Medium molecular weight PAHs were detected at higher concentrations than low and high molecular weight PAHs.
- Particles below 100 nm were present in size in the wash-off water from vehicles. The maximum D90 for all four car wash scenarios in all phases, including filtered and colloidal, was found to be 250 nm. The filtration and the SPE C_{18}-disk reduced the number of particles but did not affect the PSD.
- The phase distribution tests showed that all selected organic pollutants were below the detection limit in the colloidal phase. A majority of selected pollutants could already be removed through filtration. It is therefore concluded that organic pollutants remained in the particulate and dissolved phases.
- The Nanosight results revealed, that there were less particles present in the rain events than in the car wash events. Moreover, the conventional car wash showed high concentrations of pollutants, especially PAHs, even though the total driven distance was approximately half of the other cars. This highlights the effectiveness of vehicle washing regarding the removal of particles and pollutants.

The results of this study show, that vehicles serve as pollutant collectors and emitters at the same time. Since both the car wash as well as the rain event scenarios released a significant amount of pollutants, it suggests that pollutants are emitted not only during vehicle washing, but also during rain events. Consequently, vehicles are a source of organic pollution to urban road runoff. A solution could be to install a car washing system in a controlled and regulated environment, e.g. at toll or gas stations, that could reduce the diffuse emission at status quo.

7

Outlook

To improve the usage of the results of this study, the following recommendations and suggestions are made:

- Further understanding of the dynamic light scattering principle, the different instruments Nanosight NS3000 and Litesizer 500 and their software is crucial to obtain reliable results.
- Since the different car wash scenarios can only be compared in a limited way, it would be interesting to obtain a test with an equal driving pattern. This however is only possible on a shorter time frame and it would therefore be difficult to guarantee that enough pollutants accumulate on the vehicle surface to obtain results above the detection limit. A zero-case with a freshly fabricated vehicle without any prior driving could provide results for the release of pollutants only from the vehicle and not from the traffic environment.
- In order to investigate only driving patterns, it would be interesting to study the effects of deceleration and acceleration processes, for example at traffic lights. While this experiment investigated parked vehicles, driving and splashing effects could be better analyzed when the vehicle is in motion.
- A comparison to a similar study conducted during a different seasonal period would eliminate factors such as de-icing salt and studded tires but include new factors such as an elevated amount of natural organic matter (e.g. pollen) and an increased leaching effect of plastics with higher temperatures.
- Regular sampling during a longer time-period from commercial car wash facilities could improve the statistical reliability of the results.

This study project is part of a PhD-thesis and the InfraSweden 2030 project. Consecutive research will include further analysis about the metal and microplastic content in vehicle wash-off water.

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A

Appendix - Driving Diaries

Table A.1: Driving diary - car 1 - conventional car wash.

Date 2018-mm-dd	Start km	End km	Driving area	Rainfall/Snow	Parking under a roof
02-19	0	1.3	Gothenburg	yes	home:yes; Chalmers:no
02-20	1.3	30.6	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-21	30.6	61.2	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-22	61.2	132	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-23	132	177	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-26	177	225	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-27	225	271	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
02-28	271	305	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
03-01	305	327	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
03-02	327	358	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
03-04	358	411	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
03-05	411	435	Partille E20, Chalmers Johanneberg	yes	home:yes; Chalmers:no
03-06	435	463	Partille E20, Chalmers Johanneberg	no	home:yes; Chalmers:no
03-07	463	490	Partille E20, Chalmers Johanneberg	yes	home:yes; Chalmers:no
03-08	490	518	Partille E20, Chalmers Johanneberg	yes	home:yes; Chalmers:no
03-19	518	587	Partille E20, Chalmers Johanneberg	yes	home:yes; Chalmers:no
03-20	587	609	Partille E20, Chalmers Johanneberg	yes	home:yes; Chalmers:no

Table A.2: Driving diary - car 2 - heavy rain.

Date 2018-mm-dd	Start km	End km	Driving area	Rainfall/Snow	Parking under a roof
02-19	132 679	132 685	Mölnlycke	snow on street	no
02-20	132 685	132 690	Gothenburg	no	no
02-20	132 690	132 696	Mölndal	no	no
02-20	132 696	132 701	Mölndal	no	no
02-20	132 701	132 710	Mölndal	no	no
02-21	132 710	132 716	Gothenburg	no	no
02-21	132 716	132 721	Mölndal	no	no
02-22	132 721	132 727	Gothenburg	no	no
02-22	132 727	132 733	Mölndal	no	no
02-23	132 733	132 739	Gothenburg	no	no
02-23	132 739	133 026	Gothenburg, Åmotfors, Värmland	no	no
02-25	133 026	133 315	Värmland, Gothenburg	no	no
02-26	133 315	133 210	Gothenburg	no	no
02-26	133 210	133 327	Mölndal	no	no
02-27	133 327	133 332	Gothenburg	no	no
02-27	133 332	133 343	Mölndal	no	no
02-27	133 343	133 350	Mölndal	no	no
02-28	133 350	133 373	Gothenburg	no	no
02-28	133 373	133 379	Mölndal	no	no
03-01	133 379	133 385	Mölndal	no	no
03-01	133 385	133 403	Mölndal	no	no
03-02	133 403	133 411	Mölndal	no	no
03-03	133 411	133 432	Gothenburg	no	no
03-04	133 432	133 527	Gothenburg	yes	no
03-04	133 527	133 548	Gothenburg	yes	no
03-05	133 548	133 563	Mölndal	no	no
03-05	133 563	133 569	Mölndal	no	no
03-06	133 569	133 575	Mölndal	no	no
03-06	133 575	133 596	Gothenburg	no	no
03-07	133 596	133 602	Mölndal	wet street	no
03-07	133 602	133 608	Mölndal	wet street	no
03-08	133 608	133 614	Mölndal	no	no
03-08	133 614	133 624	Gothenburg	no	no
03-08	133 624	133 630	Mölndal	no	no
03-09	133 630	133 636	Mölndal	no	no
03-09	133 636	133 724	Gothenburg	no	no
03-10	133 724	133 777	Gothenburg	no	no
03-11	133 777	133 789	Gothenburg	no	no
03-12	133 789	133 801	Mölndal	no	no
03-13	133 801	133 821	Gothenburg	no	no
03-14	133 821	133 836	Mölndal	no	no
03-15	133 836	133 850	Mölndal	no	no
03-16	133 850	133 863	Mölndal	no	no
03-17	133 863	133 913	Mölndal, Långedrag, Majorna, Partille	no	no
03-18	133 913	133 929	Långedrag	no	no
03-19	133 929	133 986	Mölndal	no	no
03-20	133 986	134 002	Gothenburg	no	no

Table A.3: Driving diary - car 3 - light rain.

Date 2018-mm-dd	Start km	End km	Driving area	Rainfall/Snow	Parking under a roof
02-21	0	21.1	Gothenburg	no	no
02-22	21.1	26.8	Gothenburg	no	no
02-22	26.8	32.6	Gothenburg	no	no
02-23	32.6	38.2	Gothenburg	no	no
02-23	38.2	44	Gothenburg	no	no
02-23	44	52.5	Gothenburg	no	no
02-23	52.5	57.9	Gothenburg	no	no
02-24	57.9	551.6	Gothenburg, Mora	no	no
02-26	551.6	1 154.6	Mora, Gothenburg	no	no
02-27	1 154.6	1 163.1	Gothenburg	no	no
02-28	1 163.1	1 168.7	Gothenburg	no	no
02-28	1 168.7	1 212	Gothenburg	no	no
03-01	1 212	1 218	Gothenburg	yes	yes
03-01	1 218	1 227.3	Gothenburg	no	no
03-10	1 227.3	1 301	Gothenburg, Vårgårda	no	no
03-10	1 301	1 356	Vårgårda	no	no
03-10	1 356	1 427	Vårgårda, Gothenburg	no	no
03-11	1 427	1 453	Gothenburg, Lerum	yes	no
03-11	1 453	1 479	Lerum, Gothenburg	yes	no
03-12	1 479	1 488	Gothenburg	no	no
03-12	1 488	1 494	Gothenburg	no	no
03-13	1 494	1 500	Gothenburg	no	no
03-13	1 500	1 507	Gothenburg	no	yes
03-18	1 507	1 519	Gothenburg	no	no
03-18	1 519	1 522	Gothenburg	no	yes
03-21	1 522	1 524	Gothenburg	no	no

Table A.4: Driving diary - car 4 - ecological car wash. A roof box was installed during two weeks of the driving period.

Date 2018-mm-dd	Start km	End km	Driving area	Rainfall/Snow	Parking under a roof
02-19	0	11	Gothenburg	yes (snow)	yes
02-20	11	13	Gothenburg	yes (snow)	yes
02-22	13	31	Gothenburg	no	yes
02-23	31	671	Gothenburg, Oslo (Norway), Gothenburg	no	yes
02-24	671	731	Gothenburg	no	yes
02-25	731	777	Gothenburg	no	yes
02-26	777	815	Gothenburg	no	yes
02-27	815	858	Gothenburg	no	yes
02-28	858	863	Gothenburg	no	yes
03-03	863	923	Torslanda	no	yes
03-04	923	928	Gothenburg	no	yes
03-05	928	952	Gothenburg	yes (snow)	yes
03-06	952	976	Gothenburg	yes (snow)	yes
03-07	976	1 000	Gothenburg	yes (snow)	yes
03-08	1 000	1 015	Gothenburg	no	yes
03-09	1 015	1 045	Gothenburg	yes (snow)	yes
03-10	1 045	1 051	Gothenburg	yes (snow)	yes
03-11	1 051	1 066	Gothenburg	yes (rain)	yes
03-12	1 066	1 096	Gothenburg	no	yes
03-13	1 096	1 126	Gothenburg	no	yes
03-14	1 126	1 133	Gothenburg	no	yes
03-16	1 133	1 138	Gothenburg	no	yes
03-17	1 138	1 143	Gothenburg	yes (rain)	yes
03-19	1 143	1 193	Gothenburg, Torslanda	no	yes
03-20	1 193	1 250	Gothenburg, Partille	no	yes
03-21	1 250	1 262	Gothenburg	no	yes

B

Appendix - Meteorological Data

Table B.1: Recorded precipitation data during the time of driving at Chalmers Johanneberg weather station (DHI (Dansk Hydraulisk Institut) Sverige AB, 2018).

Precipitation start 2018-mm-dd	Time hh:mm	Precipitation end 2018-mm-dd	Time hh:mm	Total Volume [mm]	Duration [h]	Rain intensity [mm/h]
02-18	22:40	02-19	17:44	15.1	19.07	0.79
03-05	20:44	03-06	05:23	8.2	8.65	0.95
03-07	23:59	03-08	20:52	7	20.88	0.34
03-11	09:06	03-11	21:20	7.9	12.23	0.65
03-12	00:17	03-12	03:42	6.2	3.42	1.81
03-21	21:50	03-22	02:52	4	5.03	0.80

Table B.2: Recorded precipitation data during the time of driving at Göteborg weather station, climate number 71420. The station is located at latitude 57.7157, longitude 11.9925 at 5 masl. The rain is collected over 24 hours, from 06:00 am in the morning of the testing date until 06:00 am in the morning of the following day (SMHI (Sveriges meteorologiska och hydrologiska institut), 2018).

Testing day 2018-mm-dd	Total volume [mm]
02-18	10.4
02-19	7.1
02-20	0.1
02-21	1.0
02-22	0.0
02-23	0.0
02-24	0.0
02-25	0.0
02-26	0.1
02-27	0.0
02-28	0.0
03-01	0.0
03-02	0.0
03-03	0.0
03-04	0.0
03-05	9.5
03-06	0.1
03-07	3
03-08	2.2
03-09	0.0
03-10	0.0
03-11	12.9
03-12	0.0
03-13	0.0
03-14	0.0
03-15	0.0
03-16	0.0
03-17	0.0
03-18	0.0
03-19	0.7
03-20	0.0
03-21	4

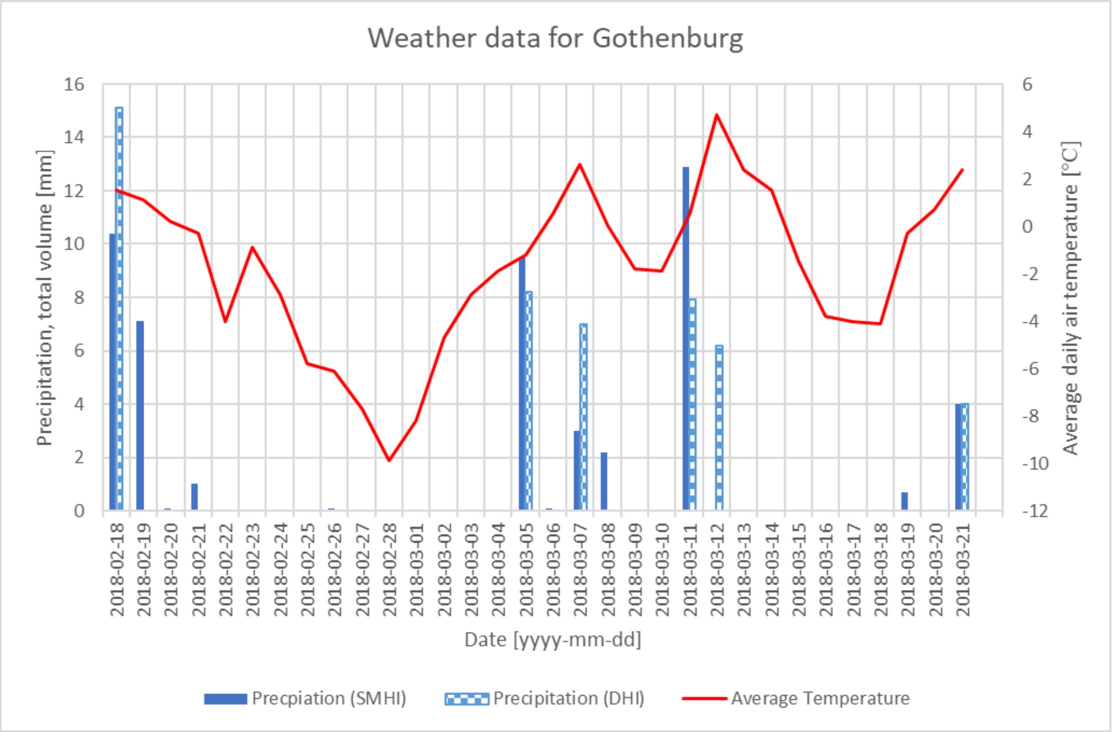

Figure B.1: Weather data for Gothenburg during the driving period. The precipitation data is recorded by DHI and SMHI as total volume [mm] and is presented at the day of beginning precipitation. The average daily air temperature is recorded at Göteborg weather station, climate number 71420. The station is located at latitude 57.7157, longitude 11.9925 at 5 masl. The average temperature is calculated from hourly values collected over 24 hours, beginning at midnight of the testing date until midnight of the following day (SMHI (Sveriges meteorologiska och hydrologiska institut), 2018).

C

Appendix - Report Organic Pollutants

The following section contains the official reports for organic pollutants. The first part shows the results for the original total phase for all four car wash events received from the commercial accredited laboratory ALS Scandinavia AB. The second part shows the results for the total, filtered and colloidal phase for the conventional car wash and the heavy rain event after the phase distribution experiment received from the commercial accredited laboratory Eurofins Environment Testing Sweden AB.

Rapport

T1808449

N023PQG3DD

Ankomstdatum **2018-03-23**
Utfärdad **2018-04-10**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning **1 Car wash standard detergent**

Provtagare **V.Munz/A.Markiewicz**

Labnummer O10988426

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	CL
dietylftalat	**2.5**	0.40	µg/l	1	1	CL
di-n-propylftalat	**<1.0**		µg/l	1	1	CL
di-n-butylftalat	**<1.0**		µg/l	1	1	CL
di-iso-butylftalat	**<1.0**		µg/l	1	1	CL
di-pentylftalat	**<1.0**		µg/l	1	1	CL
di-n-oktylftalat (DNOP)	**<3.0**		µg/l	1	1	CL
di-(2-etylhexyl)ftalat (DEHP)	**50**	7.9	µg/l	1	1	CL
butylbensylftalat	**<1.0**		µg/l	1	1	CL
di-cyklohexylftalat	**<1.0**		µg/l	1	1	CL
di-iso-decylftalat (DIDP)	**<65**		µg/l	1	1	CL
di-iso-nonylftalat (DINP)	**170**	27	µg/l	1	1	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	CL

Er beteckning **2 high intensity rain**

Provtagare **V.Munz/A.Markiewicz**

Labnummer O10988427

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	CL
dietylftalat	**<1.0**		µg/l	1	1	CL
di-n-propylftalat	**<1.0**		µg/l	1	1	CL
di-n-butylftalat	**<1.0**		µg/l	1	1	CL
di-iso-butylftalat	**<1.0**		µg/l	1	1	CL
di-pentylftalat	**<1.0**		µg/l	1	1	CL
di-n-oktylftalat (DNOP)	**<10**		µg/l	1	1	CL
di-(2-etylhexyl)ftalat (DEHP)	**31**	4.9	µg/l	1	1	CL
butylbensylftalat	**<1.0**		µg/l	1	1	CL
di-cyklohexylftalat	**<1.0**		µg/l	1	1	CL
di-iso-decylftalat (DIDP)	**<15**		µg/l	1	1	CL
di-iso-nonylftalat (DINP)	**340**	54	µg/l	1	1	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	CL

X

Er beteckning **3 low intensity rain**

Provtagare **V.Munz/A.Markiewicz**

Labnummer O10988428

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	CL
dietylftalat	**<1.0**		µg/l	1	1	CL
di-n-propylftalat	**<1.0**		µg/l	1	1	CL
di-n-butylftalat	**<1.0**		µg/l	1	1	CL
di-iso-butylftalat	**<1.0**		µg/l	1	1	CL
di-pentylftalat	**<1.0**		µg/l	1	1	CL
di-n-oktylftalat (DNOP)	**<12**		µg/l	1	1	CL
di-(2-etylhexyl)ftalat (DEHP)	**7.9**	1.2	µg/l	1	1	CL
butylbensylftalat	**<1.0**		µg/l	1	1	CL
di-cyklohexylftalat	**<1.0**		µg/l	1	1	CL
di-iso-decylftalat (DIDP)	**<25**		µg/l	1	1	CL
di-iso-nonylftalat (DINP)	**640**	100	µg/l	1	1	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	CL

Er beteckning **4 car wash bio detergent**

Provtagare **V.Munz/A.Markiewicz**

Labnummer O10988429

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	CL
dietylftalat	**<1.0**		µg/l	1	1	CL
di-n-propylftalat	**<1.0**		µg/l	1	1	CL
di-n-butylftalat	**<1.0**		µg/l	1	1	CL
di-iso-butylftalat	**<1.0**		µg/l	1	1	CL
di-pentylftalat	**<1.0**		µg/l	1	1	CL
di-n-oktylftalat (DNOP)	**<3.0**		µg/l	1	1	CL
di-(2-etylhexyl)ftalat (DEHP)	**38**	6.0	µg/l	1	1	CL
butylbensylftalat	**<1.0**		µg/l	1	1	CL
di-cyklohexylftalat	**<1.0**		µg/l	1	1	CL
di-iso-decylftalat (DIDP)	**<20**		µg/l	1	1	CL
di-iso-nonylftalat (DINP)	**130**	21	µg/l	1	1	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	CL

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Paket OV-4B. Bestämning av 13st ftalater. Bestämning enligt metod DIN EN ISO 18856. Rev 2017-05-22

	Godkännare
CL	Camilla Lundeborg

	Utf[1]
1	För mätningen svarar GBA, Flensburger Straße 15, 25421 Pinneberg, Tyskland, som är av det tyska ackrediteringsorganet DAkkS ackrediterat laboratorium (Reg.nr. D-PL-14170-01-00). DAkkS är signatär till ett MLA inom EA, samma MLA som SWEDAC är signatär till. Laboratorierna finns lokaliserade på följande adresser: Flensburger Straße 15, 25421 Pinneberg Daimlerring 37, 31135 Hildesheim Brekelbaumstraße1, 31789 Hameln Im Emscherbruch 11, 45699 Herten Bruchstraße 5c, 45883 Gelsenkirchen Meißner Ring 3, 09599 Freiberg Goldtschmidtstraße 5, 21073 Hamburg Kontakta ALS Stockholm för ytterligare information.

Mätosäkerheten anges som en utvidgad osäkerhet (enligt definitionen i "Evaluation of measurement data - Guide to the expression of uncertainty in measurement", JCGM 100:2008 Corrected version 2010) beräknad med täckningsfaktor lika med 2 vilket ger en konfidensnivå på ungefär 95**%.**
Mätosäkerhet anges endast för detekterade ämnen med halter över rapporteringsgränsen.

Mätosäkerhet från underleverantör anges oftast som en utvidgad osäkerhet beräknad med täckningsfaktor 2. För ytterligare information kontakta laboratoriet.

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.
Resultaten gäller endast det identifierade, mottagna och provade materialet.
Beträffande laboratoriets ansvar i samband med uppdrag, se aktuell produktkatalog eller vår webbplats www.alsglobal.se

Den digitalt signerade PDF filen representerar originalrapporten. Alla utskrifter från denna är att betrakta som kopior.

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[1] Utförande teknisk enhet (inom ALS Scandinavia) eller anlitat laboratorium (underleverantör).

Rapport

SWEDAC ACKREDITERING
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Provning
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Ankomstdatum	**2018-04-03**
Utfärdad	**2018-04-19**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning	**1 car wash standard detergent**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990588

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	MB
alifater >C8-C10	**<10**		µg/l	1	1	MB
alifater >C10-C12	**16**	5	µg/l	1	1	MB
alifater >C12-C16	**37**	11	µg/l	1	1	MB
alifater >C5-C16 *	**53**		µg/l	1	1	MB
alifater >C16-C35	**351**	105	µg/l	1	1	MB
aromater >C8-C10	**<0.30**		µg/l	1	1	MB
aromater >C10-C16	**<0.775**		µg/l	1	1	MB
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	MB
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	MB
aromater >C16-C35	**<1.0**		µg/l	1	1	MB
bensen	**<0.20**		µg/l	1	1	MB
toluen	**<0.20**		µg/l	1	1	MB
etylbensen	**<0.20**		µg/l	1	1	MB
m,p-xylen	**<0.20**		µg/l	1	1	MB
o-xylen	**<0.20**		µg/l	1	1	MB
xylener, summa *	**<0.20**		µg/l	1	1	MB
TEX, summa *	**<0.40**		µg/l	1	1	MB
naftalen	**<0.030**		µg/l	2	1	MB
acenaftylen	**<0.010**		µg/l	2	1	MB
acenaften	**0.033**	0.010	µg/l	2	1	MB
fluoren	**0.020**	0.005	µg/l	2	1	MB
fenantren	**0.176**	0.046	µg/l	2	1	MB
antracen	**0.024**	0.006	µg/l	2	1	MB
fluoranten	**0.310**	0.096	µg/l	2	1	MB
pyren	**0.317**	0.098	µg/l	2	1	MB
bens(a)antracen	**0.062**	0.017	µg/l	2	1	MB
krysen	**0.053**	0.015	µg/l	2	1	MB
bens(b)fluoranten	**0.178**	0.066	µg/l	2	1	MB
bens(k)fluoranten	**0.047**	0.017	µg/l	2	1	MB
bens(a)pyren	**0.081**	0.020	µg/l	2	1	MB
dibenso(ah)antracen	**0.020**	0.006	µg/l	2	1	MB
benso(ghi)perylen	**0.107**	0.043	µg/l	2	1	MB
indeno(123cd)pyren	**0.056**	0.020	µg/l	2	1	MB
PAH, summa 16 *	**1.5**		µg/l	2	1	MB

Er beteckning	**1 car wash standard detergent**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990588

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
PAH, summa cancerogena *	**0.50**		µg/l	2	1	MB
PAH, summa övriga *	**0.99**		µg/l	2	1	MB
PAH, summa L *	**0.033**		µg/l	2	1	MB
PAH, summa M *	**0.85**		µg/l	2	1	MB
PAH, summa H *	**0.60**		µg/l	2	1	MB
9-fluorenon *	**<0.1**		µg/l	3	2	LISO
9,10-antrakinon	**<0.1**		µg/l	3	2	LISO
2-metylantracen-9,10-dion	**<0.1**		µg/l	3	2	LISO
7H-bens(de)antracen-7-on *	**<0.1**		µg/l	3	2	LISO
bens(a)antracen-7,12-dion *	**<0.1**		µg/l	3	2	LISO
6H-bens(cd)pyren-6-on	**<0.1**		µg/l	3	2	LISO
bens(a)fluorenon	**<0.1**		µg/l	3	2	LISO
4H-cyklopenta(def)fenantrenon	**<0.1**		µg/l	3	2	LISO
naftacen-5,12-dion	**<0.1**		µg/l	3	2	LISO

Er beteckning	**2 high intensity rain**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990589

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	MB
alifater >C8-C10	**<10**		µg/l	1	1	MB
alifater >C10-C12	**12**	4	µg/l	1	1	MB
alifater >C12-C16	**32**	10	µg/l	1	1	MB
alifater >C5-C16 *	**44**		µg/l	1	1	MB
alifater >C16-C35	**334**	100	µg/l	1	1	MB
aromater >C8-C10	**<0.30**		µg/l	1	1	MB
aromater >C10-C16	**<0.775**		µg/l	1	1	MB
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	MB
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	MB
aromater >C16-C35	**<1.0**		µg/l	1	1	MB
bensen	**<0.20**		µg/l	1	1	MB
toluen	**<0.20**		µg/l	1	1	MB
etylbensen	**<0.20**		µg/l	1	1	MB
m,p-xylen	**<0.20**		µg/l	1	1	MB
o-xylen	**<0.20**		µg/l	1	1	MB
xylener, summa *	**<0.20**		µg/l	1	1	MB
TEX, summa *	**<0.40**		µg/l	1	1	MB
naftalen	**<0.030**		µg/l	2	1	MB
acenaftylen	**0.016**	0.005	µg/l	2	1	MB
acenaften	**0.019**	0.006	µg/l	2	1	MB
fluoren	**0.014**	0.004	µg/l	2	1	MB
fenantren	**0.113**	0.029	µg/l	2	1	MB
antracen	**0.020**	0.005	µg/l	2	1	MB
fluoranten	**0.165**	0.051	µg/l	2	1	MB
pyren	**0.217**	0.067	µg/l	2	1	MB
bens(a)antracen	**0.036**	0.010	µg/l	2	1	MB
krysen	**0.031**	0.009	µg/l	2	1	MB
bens(b)fluoranten	**0.108**	0.040	µg/l	2	1	MB
bens(k)fluoranten	**0.036**	0.013	µg/l	2	1	MB
bens(a)pyren	**0.072**	0.018	µg/l	2	1	MB
dibenso(ah)antracen	**0.018**	0.006	µg/l	2	1	MB
benso(ghi)perylen	**0.097**	0.039	µg/l	2	1	MB
indeno(123cd)pyren	**0.043**	0.015	µg/l	2	1	MB
PAH, summa 16 *	**1.0**		µg/l	2	1	MB
PAH, summa cancerogena *	**0.34**		µg/l	2	1	MB
PAH, summa övriga *	**0.66**		µg/l	2	1	MB
PAH, summa L *	**0.035**		µg/l	2	1	MB
PAH, summa M *	**0.53**		µg/l	2	1	MB
PAH, summa H *	**0.44**		µg/l	2	1	MB
9-fluorenon	**<0.1**		µg/l	3	2	LISO
9,10-antrakinon	**<0.1**		µg/l	3	2	LISO
2-metylantracen-9,10-dion	**<0.1**		µg/l	3	2	LISO
7H-bens(de)antracen-7-on *	**<0.1**		µg/l	3	2	LISO
bens(a)antracen-7,12-dion	**<0.1**		µg/l	3	2	LISO
6H-bens(cd)pyren-6-on	**<0.1**		µg/l	3	2	LISO

Er beteckning	**2 high intensity rain**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990589

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
bens(a)fluorenon *	**<0.1**		µg/l	3	2	LISO
4H-cyklopenta(def)fenantrenon *	**<0.1**		µg/l	3	2	LISO
naftacen-5,12-dion	**<0.1**		µg/l	3	2	LISO

Er beteckning **3 low intensity rain**

Provtagare **V.Munz/A.Markiewicz**

Labnummer O10990590

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	MB
alifater >C8-C10	**<10**		µg/l	1	1	MB
alifater >C10-C12	**78**	23	µg/l	1	1	MB
alifater >C12-C16	**<10**		µg/l	1	1	MB
alifater >C5-C16 *	**78**		µg/l	1	1	MB
alifater >C16-C35	**641**	192	µg/l	1	1	MB
aromater >C8-C10	**<0.30**		µg/l	1	1	MB
aromater >C10-C16	**<0.775**		µg/l	1	1	MB
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	MB
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	MB
aromater >C16-C35	**<1.0**		µg/l	1	1	MB
bensen	**<0.20**		µg/l	1	1	MB
toluen	**<0.20**		µg/l	1	1	MB
etylbensen	**<0.20**		µg/l	1	1	MB
m,p-xylen	**<0.20**		µg/l	1	1	MB
o-xylen	**<0.20**		µg/l	1	1	MB
xylener, summa *	**<0.20**		µg/l	1	1	MB
TEX, summa *	**<0.40**		µg/l	1	1	MB
naftalen	**<0.030**		µg/l	2	1	MB
acenaftylen	**<0.010**		µg/l	2	1	MB
acenaften	**0.016**	0.005	µg/l	2	1	MB
fluoren	**<0.010**		µg/l	2	1	MB
fenantren	**0.052**	0.014	µg/l	2	1	MB
antracen	**<0.010**		µg/l	2	1	MB
fluoranten	**0.063**	0.020	µg/l	2	1	MB
pyren	**0.093**	0.029	µg/l	2	1	MB
bens(a)antracen	**0.016**	0.004	µg/l	2	1	MB
krysen	**0.016**	0.005	µg/l	2	1	MB
bens(b)fluoranten	**0.047**	0.017	µg/l	2	1	MB
bens(k)fluoranten	**<0.010**		µg/l	2	1	MB
bens(a)pyren	**0.023**	0.006	µg/l	2	1	MB
dibenso(ah)antracen	**<0.010**		µg/l	2	1	MB
benso(ghi)perylen	**0.038**	0.015	µg/l	2	1	MB
indeno(123cd)pyren	**0.016**	0.006	µg/l	2	1	MB
PAH, summa 16 *	**0.38**		µg/l	2	1	MB
PAH, summa cancerogena *	**0.12**		µg/l	2	1	MB
PAH, summa övriga *	**0.26**		µg/l	2	1	MB
PAH, summa L *	**0.016**		µg/l	2	1	MB
PAH, summa M *	**0.21**		µg/l	2	1	MB
PAH, summa H *	**0.16**		µg/l	2	1	MB
9-fluorenon	**<0.1**		µg/l	3	2	LISO
9,10-antrakinon *	**<0.1**		µg/l	3	2	LISO
2-metylantracen-9,10-dion	**<0.1**		µg/l	3	2	LISO
7H-bens(de)antracen-7-on	**<0.1**		µg/l	3	2	LISO
bens(a)antracen-7,12-dion *	**<0.1**		µg/l	3	2	LISO
6H-bens(cd)pyren-6-on	**<0.1**		µg/l	3	2	LISO

Er beteckning	**3 low intensity rain**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990590

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
bens(a)fluorenon	**<0.1**		µg/l	3	2	LISO
4H-cyklopenta(def)fenantrenon	**<0.1**		µg/l	3	2	LISO
naftacen-5,12-dion	**<0.1**		µg/l	3	2	LISO

Er beteckning	**4 car wash bio detergent**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990591

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	MB
alifater >C8-C10	**<10**		µg/l	1	1	MB
alifater >C10-C12	**12**	4	µg/l	1	1	MB
alifater >C12-C16	**19**	6	µg/l	1	1	MB
alifater >C5-C16 *	**31**		µg/l	1	1	MB
alifater >C16-C35	**725**	218	µg/l	1	1	MB
aromater >C8-C10	**<0.30**		µg/l	1	1	MB
aromater >C10-C16	**<0.775**		µg/l	1	1	MB
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	MB
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	MB
aromater >C16-C35	**<1.0**		µg/l	1	1	MB
bensen	**<0.20**		µg/l	1	1	MB
toluen	**<0.20**		µg/l	1	1	MB
etylbensen	**<0.20**		µg/l	1	1	MB
m,p-xylen	**<0.20**		µg/l	1	1	MB
o-xylen	**<0.20**		µg/l	1	1	MB
xylener, summa *	**<0.20**		µg/l	1	1	MB
TEX, summa *	**<0.40**		µg/l	1	1	MB
naftalen	**0.036**	0.012	µg/l	2	1	MB
acenaftylen	**0.011**	0.003	µg/l	2	1	MB
acenaften	**0.022**	0.007	µg/l	2	1	MB
fluoren	**0.011**	0.003	µg/l	2	1	MB
fenantren	**0.093**	0.024	µg/l	2	1	MB
antracen	**0.012**	0.003	µg/l	2	1	MB
fluoranten	**0.146**	0.045	µg/l	2	1	MB
pyren	**0.220**	0.068	µg/l	2	1	MB
bens(a)antracen	**0.031**	0.008	µg/l	2	1	MB
krysen	**0.036**	0.010	µg/l	2	1	MB
bens(b)fluoranten	**0.106**	0.039	µg/l	2	1	MB
bens(k)fluoranten	**0.022**	0.008	µg/l	2	1	MB
bens(a)pyren	**0.045**	0.011	µg/l	2	1	MB
dibenso(ah)antracen	**0.017**	0.005	µg/l	2	1	MB
benso(ghi)perylen	**0.098**	0.039	µg/l	2	1	MB
indeno(123cd)pyren	**0.037**	0.013	µg/l	2	1	MB
PAH, summa 16 *	**0.94**		µg/l	2	1	MB
PAH, summa cancerogena *	**0.29**		µg/l	2	1	MB
PAH, summa övriga *	**0.65**		µg/l	2	1	MB
PAH, summa L *	**0.069**		µg/l	2	1	MB
PAH, summa M *	**0.48**		µg/l	2	1	MB
PAH, summa H *	**0.39**		µg/l	2	1	MB
9-fluorenon *	**<0.1**		µg/l	3	2	LISO
9,10-antrakinon	**<0.1**		µg/l	3	2	LISO
2-metylantracen-9,10-dion	**<0.1**		µg/l	3	2	LISO
7H-bens(de)antracen-7-on	**<0.1**		µg/l	3	2	LISO
bens(a)antracen-7,12-dion	**<0.1**		µg/l	3	2	LISO
6H-bens(cd)pyren-6-on	**<0.1**		µg/l	3	2	LISO

Er beteckning	**4 car wash bio detergent**
Provtagare	**V.Munz/A.Markiewicz**
Labnummer	O10990591

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
bens(a)fluorenon	**<0.1**		µg/l	3	2	LISO
4H-cyklopenta(def)fenantrenon *	**<0.1**		µg/l	3	2	LISO
naftacen-5,12-dion	**<0.1**		µg/l	3	2	LISO

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Paket OV-21C. Bestämning av alifatfraktioner och aromatfraktioner. Bestämning av metylpyrener/metylfluorantener och metylkrysener/metylbens(a)antracener. Bestämning av bensen, toluen, etylbensen och xylen (BTEX). Metod baserad på SPIMFABs kvalitetsmanual. Mätning utförs med GC-MS. Rev 2013-10-14
2	Paket OV-1 Bestämning av polycykliska aromatiska kolväten, PAH (16 föreningar enligt EPA), enligt metod baserad på US EPA 8270 och CSN EN ISO 6468. Mätning utförs med GC-MS. PAH cancerogena utgörs av benso(a)antracen, krysen, benso(b)fluoranten, benso(k)fluoranten, benso(a)pyren, dibenso(ah)antracen och indeno(123cd)pyren. Bestämning av polycykliska aromatiska kolväten; summa PAH L, summa PAH M och summa PAH H. Summa PAH L: naftalen, acenaften och acenaftylen. Summa PAH M: fluoren, fenantren, antracen, fluoranten och pyren Summa PAH H: benso(a)antracen, krysen, benso(b)fluoranten, benso(k)fluoranten, benso(a)pyren, indeno(1,2,3-c,d)pyren, dibenso(a,h)antracen och benso(g,h,i)perylen) Enligt nya direktiv från Naturvårdsverket oktober 2008 Rev 2013-09-18
3	Bestämning av oxy-PAHer (9 föreningar). Mätningen utförs med GCMS. Rev 2011-06-09

	Godkännare
LISO	Linda Söderberg
MB	Maria Bigner

	Utf[1]
1	För mätningen svarar ALS Laboratory Group, Na Harfě 9/336, 190 00, Prag 9, Tjeckien, som är av det tjeckiska ackrediteringsorganet CAI ackrediterat laboratorium (Reg.nr. 1163). CAI är signatär till ett MLA inom EA, samma MLA som SWEDAC är signatär till. Laboratorierna finns lokaliserade i; Prag, Na Harfě 9/336, 190 00, Praha 9, Ceska Lipa, Bendlova 1687/7, 470 01 Ceska Lipa, Pardubice, V Raji 906, 530 02 Pardubice. Kontakta ALS Stockholm för ytterligare information.
2	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).

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[1] Utförande teknisk enhet (inom ALS Scandinavia) eller anlitat laboratorium (underleverantör).

Mätosäkerheten anges som en utvidgad osäkerhet (enligt definitionen i "Evaluation of measurement data - Guide to the expression of uncertainty in measurement", JCGM 100:2008 Corrected version 2010) beräknad med täckningsfaktor lika med 2 vilket ger en konfidensnivå på ungefär 95**%.**
Mätosäkerhet anges endast för detekterade ämnen med halter över rapporteringsgränsen.

Mätosäkerhet från underleverantör anges oftast som en utvidgad osäkerhet beräknad med täckningsfaktor 2. För ytterligare information kontakta laboratoriet.

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.
Resultaten gäller endast det identifierade, mottagna och provade materialet.
Beträffande laboratoriets ansvar i samband med uppdrag, se aktuell produktkatalog eller vår webbplats www.alsglobal.se

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AR-18-SL-081856-01

EUSELI2-00528377
Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150101**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	1 Conventional carwash total		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**0.095**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**0.10**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Ospec**				a)*
Bens(a)antracen	**0.012**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**0.012**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**0.035**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**0.012**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**0.027**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

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Fenantren	**0.060**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**0.064**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**0.065**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**0.015**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

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AR-18-SL-081857-01

EUSELI2-00528377

Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150102**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	2 Conventional carwash filtrated		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Utgår**				a)*
Bens(a)antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**< 0.020**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**0.032**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

Förklaringar

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

AR-18-SL-081857-01

EUSELI2-00528377

Fenantren	**0.047**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**0.029**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**0.028**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

Förklaringar

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

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AR-18-SL-081858-01

EUSELI2-00528377

Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150103**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	3 Conventional carwash colloidal		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Utgår**				a)*
Bens(a)antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**< 0.020**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**< 0.020**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

Förklaringar

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

Fenantren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

Förklaringar

AR-003v47

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

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AR-18-SL-081859-01

EUSELI2-00528377

Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150104**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	4 Heavy rain total		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**0.15**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**0.15**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Ospec**				a)*
Bens(a)antracen	**0.040**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**<0.060**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**0.12**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**0.049**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**0.036**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**0.013**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**0.29**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**< 0.020**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

Förklaringar

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

Fenantren	**0.063**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**0.12**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**0.17**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**0.053**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**0.43**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**0.36**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**0.34**	µg/l		LidMiljö.0A.01.35	a)

Kemisk kommentar
Höjd rapporteringsgräns för Krysen på grund av svår matris.

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

eurofins

SWEDAC ACKREDITERING
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AR-18-SL-081860-01

EUSELI2-00528377

Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150105**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	5 Heavy rain filtrated		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Utgår**				a)*
Bens(a)antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**< 0.020**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**< 0.020**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

Fenantren	**0.015**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

SWEDAC
ACKREDITERING
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AR-18-SL-081861-01

EUSELI2-00528377

Kundnummer: SL8432101

Uppdragsmärkn.
Karin Björklund Kst 202301

Analysrapport

Provnummer:	**177-2018-05150106**	Ankomsttemp °C	14,5
Provbeskrivning:		Provtagare	Karin Björklund
Matris:	Övrigt förorenat vatten		
Provet ankom:	2018-05-14		
Utskriftsdatum:	2018-05-16		
Provmärkning:	6 Heavy rain colloidal		

Analys	Resultat	Enhet	Mäto.	Metod/ref	
Bensen	**< 0.00050**	mg/l	30%	LidMiljö.0A.01.09	a)
Toluen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Etylbensen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
M/P/O-Xylen	**< 0.0010**	mg/l	30%	LidMiljö.0A.01.09	a)
Summa TEX	**< 0.0020**	mg/l		LidMiljö.0A.01.21	a)
Alifater >C5-C8	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C8-C10	**< 0.020**	mg/l	35%	SPI 2011	a)
Alifater >C10-C12	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C5-C12	**< 0.030**	mg/l	25%	LidMiljö.0A.01.21/34	a)
Alifater >C12-C16	**< 0.020**	mg/l	20%	LidMiljö.0A.01.34	a)
Alifater >C16-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Alifater >C12-C35	**< 0.050**	mg/l	25%	LidMiljö.0A.01.34	a)
Aromater >C8-C10	**< 0.010**	mg/l	30%	SPI 2011	a)
Aromater >C10-C16	**< 0.010**	mg/l	20%	LidMiljö.0A.01.34	a)
Aromater >C16-C35	**< 0.0050**	mg/l	25%	LidMiljö.0A.01.34	a)
Oljetyp < C10	**Utgår**				a)*
Oljetyp > C10	**Utgår**				a)*
Bens(a)antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Krysen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(b,k)fluoranten	**< 0.020**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(a)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Indeno(1,2,3-cd)pyren	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Dibens(a,h)antracen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa cancerogena PAH	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Naftalen	**< 0.020**	µg/l	30%	LidMiljö.0A.01.35	a)
Acenaftylen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Acenaften	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)

Förklaringar

Laboratoriet/laboratorierna är ackrediterade av respektive lands ackrediteringsorgan. Ej ackrediterade analyser är markerade med *

Mätosäkerheten, om inget annat anges, redovisas som utvidgad mätosäkerhet med täckningsfaktor 2. Undantag relaterat till analyser utförda utanför Sverige kan förekomma. Ytterligare upplysningar samt mätosäkerhet och detektionsnivåer för mikrobiologiska analyser lämnas på begäran.

Denna rapport får endast återges i sin helhet, om inte utförande laboratorium i förväg skriftligen godkänt annat. Resultaten relaterar endast till det insända provet.

Fenantren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Antracen	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Fluoranten	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Pyren	**< 0.010**	µg/l	25%	LidMiljö.0A.01.35	a)
Benso(g,h,i)perylen	**< 0.010**	µg/l	30%	LidMiljö.0A.01.35	a)
Summa övriga PAH	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med låg molekylvikt	**< 0.20**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med medelhög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)
Summa PAH med hög molekylvikt	**< 0.30**	µg/l		LidMiljö.0A.01.35	a)

Utförande laboratorium/underleverantör:

a) Eurofins Environment Testing Sweden AB, SWEDEN

Paola Nilson, Rapportansvarig

Denna rapport är elektroniskt signerad.

D

Appendix - Report TOC and DOC

The following section contains the official report for total and dissolved organic carbon (TOC and DOC) received from the commercial accredited laboratory ALS Scandinavia AB.

Rapport

T1814886

Sida 1 (2)

QTN6QTPDOP

Ankomstdatum **2018-05-21**
Utfärdad **2018-05-25**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning **1.conventional car wash**

Provtagare **A.Markiewicz, V.Munz**

Labnummer O11007832

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TOC	**13.8**	2.75	mg/l	1	1	MB
DOC	**9.88**	1.98	mg/l	2	1	MB

Er beteckning **2.heavy rain**

Provtagare **A.Markiewicz, V.Munz**

Labnummer O11007833

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TOC	**7.11**	1.42	mg/l	1	1	MB
DOC	**6.59**	1.32	mg/l	2	1	MB

Er beteckning **3.light rain**

Provtagare **A.Markiewicz, V.Munz**

Labnummer O11007834

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TOC	**8.23**	1.65	mg/l	1	1	MB
DOC	**8.13**	1.63	mg/l	2	1	MB

Er beteckning **4.ecological car wash**

Provtagare **A.Markiewicz, V.Munz**

Labnummer O11007835

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TOC	**12.9**	2.58	mg/l	1	1	MB
DOC	**12.0**	2.40	mg/l	2	1	MB

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Bestämning av TOC med IR detektion enligt metod baserad på CSN EN 1484 och SCN EN 13370. Dekantering ingår för grumliga prover. Rev 2014-11-14
2	Bestämning av DOC med IR detektion enligt metod baserad på CSN EN 1484 och CSN 13370. Rev 2013-09-19

	Godkännare
MB	Maria Bigner

	Utf[1]
1	För mätningen svarar ALS Laboratory Group, Na Harfê 9/336, 190 00, Prag 9, Tjeckien, som är av det tjeckiska ackrediteringsorganet CAI ackrediterat laboratorium (Reg.nr. 1163). CAI är signatär till ett MLA inom EA, samma MLA som SWEDAC är signatär till. Laboratorierna finns lokaliserade i; Prag, Na Harfê 9/336, 190 00, Praha 9, Ceska Lipa, Bendlova 1687/7, 470 01 Ceska Lipa, Pardubice, V Raji 906, 530 02 Pardubice. Kontakta ALS Stockholm för ytterligare information.

Mätosäkerheten anges som en utvidgad osäkerhet (enligt definitionen i "Evaluation of measurement data - Guide to the expression of uncertainty in measurement", JCGM 100:2008 Corrected version 2010) beräknad med täckningsfaktor lika med 2 vilket ger en konfidensnivå på ungefär 95**%.**
Mätosäkerhet anges endast för detekterade ämnen med halter över rapporteringsgränsen.

Mätosäkerhet från underleverantör anges oftast som en utvidgad osäkerhet beräknad med täckningsfaktor 2. För ytterligare information kontakta laboratoriet.

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.
Resultaten gäller endast det identifierade, mottagna och provade materialet.
Beträffande laboratoriets ansvar i samband med uppdrag, se aktuell produktkatalog eller vår webbplats www.alsglobal.se

Den digitalt signerade PDF filen representerar originalrapporten. Alla utskrifter från denna är att betrakta som kopior.

---

[1] Utförande teknisk enhet (inom ALS Scandinavia) eller anlitat laboratorium (underleverantör).

E

Appendix - Further Results

Table E.1: Pearson correlation coefficients between organic pollutants above detection limit, total suspendes solids (TSS), total organic carbon (TOC) and dissolved organic carbon (DOC). The assigned group of molecular weight is noted in brackets behind the name of each polycyclic aromatic hydrocarbon (PAH): low (L), medium (M), high (H).

Group	Parameter name	Correlation TSS	Correlation TOC	Correlation DOC
Phthalates	dietylphthalate (DEP)	-0.72	0.66	0.21
	di-(2-etylhexyl)phthalate (DEHP)	-0.17	0.75	0.46
	di-iso-nonylphthalate (DINP)	0.002	- 0.75	-0.64
Aliphatics	aliphatics >C10-C12	-0.34	-0.42	-028
	aliphatics >C12-C16	0.07	0.33	-0.06
	aliphatics >C5-C16	-0.47	-0.40	-0.47
	aliphatics >C16-C35	-0.08	0.15	0.58
PAHs	naphthalene (L)	0.17	0.48	0.82
	acenaphthylene (L)	0.96	-0.43	-0.30
	acenaphtene (L)	-0.59	0.81	0.42
	fluorine (M)	-0.18	0.53	0.11
	phenanthrene (M)	-0.30	0.58	0.14
	anthracene (M)	0.003	0.33	-0.08
	fluoranthene (M)	-0.38	0.65	0.22
	pyrene (M)	-0.20	0.67	0.32
	benz(a)anthracene (H)	-0.36	0.62	0.19
	chrysene (H)	-0.35	0.78	0.43
	benz(b)fluoranthene (H)	-0.31	0.68	0.29
	benz(k)fluoranthene (H)	-0.04	0.40	-0.002
	benz(a)pyrene (H)	0.06	0.29	-0.11
	dibenzo(ah)anthracene (H)	0.16	0.50	0.25
	benzo(ghi)perylene (H)	0.16	0.54	0.32
	indeno(123cd)pyrene (H)	-0.08	0.54	0.17
PAHs, sum parameter	PAH, sum 16	-0.21	0.64	0.26
	PAH, sum L	0.29	0.64	0.74
	PAH, sum M	-0.28	0.63	0.23
	PAH, sum H	-0.12	0.57	0.20

Table E.2: Comparison of the statistical data from the particle size distribution for the two instruments Nanosight and Litesizer.
1=conventional car wash, 2=heavy rain, 3=light rain, 4=ecological car wash. na=not available.

Event	Nanosight NS3000	Litesizer 500
	D90 [nm]	**D90 [nm]**
1 filtered 0.45 μm	166	163
1 filtered 0.7 μm	214	na
1 colloidal	190	na
2 filtered 0.45 μm	237	149
2 filtered 0.7 μm	300	na
2 colloidal	266	na
3 filtered 0.45 μm	247	153
4 filtered 0.45 μm	249	45
	Mode [nm]	**Peak intensity [nm]**
1 filtered 0.45 μm	150	152
1 filtered 0.7 μm	122	na
1 colloidal	121	na
2 filtered 0.45 μm	151	138
2 filtered 0.7 μm	160	na
2 colloidal	178	na
3 filtered 0.45 μm	152	160
4 filtered 0.45 μm	117	41
	Mean [nm]	**Hydrodynamic diameter [nm]**
1 filtered 0.45 μm	132	192
1 filtered 0.7 μm	154	na
1 colloidal	146	na
2 filtered 0.45 μm	152	205
2 filtered 0.7 μm	209	na
2 colloidal	198	na
3 filtered 0.45 μm	192	2659
4 filtered 0.45 μm	166	48
	NA	**Zeta potential [mV]**
1 filtered 0.45 μm	na	-19.1
1 filtered 0.7 μm	na	-23.0
1 colloidal	na	-14.2
2 filtered 0.45 μm	na	-3.5
2 filtered 0.7 μm	na	-9.8
2 colloidal	na	-19.8
3 filtered 0.45 μm	na	-10.4
4 filtered 0.45 μm	na	-2.3
	Particle concentration [particles/mL]	**NA**
1 filtered 0.45 μm	1.83E+08	na
1 filtered 0.7 μm	4.63E+08	na
1 colloidal	1.05E+08	na
2 filtered 0.45 μm	3.10E+07	na
2 filtered 0.7 μm	2.12E+08	na
2 colloidal	6.17E+07	na
3 filtered 0.45 μm	6.17E+07	na
4 filtered 0.45 μm	2.26E+08	na

F

Declaration of Academic Honesty

I, Verena Munz, hereby confirm that the document in hand titled

> Emissions of Organic Pollutants from Vehicles
> A Pilot Study of an Experimental Car Wash

is solely my own work and that every text passage, figure or diagram from books, papers, the Web or any other source copied or in any other way used has been acknowledged and fully cited.

Gothenburg, June 4th 2018 Verena Munz