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Street Sweeping to Reduce Organic Pollutants Sorbed to Small Particles

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Cover: A rainbow from oil spillage on the road.

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Abstract

As cities grow, urban runoff becomes a more significant sink for pollutants. These include vehicle exhaust emissions and vehicle wear and road wear particles. Previous research on urban runoff has focused mostly on metals and polycyclic aromatic hydrocarbons (PAHs). Recently, other organic pollutants (OPs), including oxy-PAHs, phthalates, and phenols, have been found in significant concentrations. In this study the effect of weekly street sweeping to remove OPs from urban street sediment, to prevent further transport of OPs to stormwater and receiving recipient, have been studied. Special attention is given to investigate the presence of micro- and nanoparticles because they may not be removed by existing stormwater treatment techniques, and thus be an effective transport route for OPs. To evaluate the performance of street sweeping, the presence of organic material, OPs and the particle size distribution (PSD) were analyzed in the sediment sampled before and after street sweeping, together with other chemical parameters in the washwater collected by the street sweeping machine.

The results show that washwater samples from the street sweeping machine contain a wide range of small particles < 20 µm, and nanoparticles from just below 1 nm up to ~ 300 nm were identified; and nanoparticles in the range of 25–300 nm were present in the highest concentrations. The washwater contained a significant number of OPs, including PAHs, oxy-PAHs alkanes and aromatics in high concentrations. The dry street sediment was composed of up to 69 % sand and contained fewer and lower concentrations of OPs. However, the concentrations of C_{16} - C_{35} alkanes were far above the Swedish reference values of 100 mg/kg DS for sensitive soil. The evaluation of the street sweeping, performed by the Wet Dust Sampler (WDS), showed that with this method a wide range of particles are collected, including nanoparticles down to 1 nm, and a significant number of OPs, although the brushing motion of the street sweeping machine may also contribute to the resuspension of fine particles fixed to the street surface.

The result in this study show that the washwater from the street sweeping machine contain high concentrations of several groups of OPs and a wide range of nanoparticles, the recommendation is to collect and sorb the fine particles and OPs by onsite filtration techniques, installed at the temporal storages of the material sampled by the street sweeping machine. Further studies are recommended to investigate possible degradation and/or recycling of pollutants and nano- and microparticles in the street sediment.

Keywords: nanoparticles, stormwater, runoff, traffic, street sediment. road dust, particle size distribution

Gatusopning för att Minska Orgnaiska Föroreningar Adsorberade till Små Partiklar
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Sammanfattning

Den växande urbaniseringen resulterar i att mer och mer föroreningar ansamlas i urbant dagvatten. Bland dessa föroreningar finns avgaser från trafiken samt slitagepartiklar från biltrafiken. Dagvattenforskning har tidigare mest fokuserat på metaller och polycykliska aromatiska kolväten (PAH). På senare tid har dock även organiska föroreningar, inklusive oxygenerade-PAH (oxy-PAH), ftalater och fenoler, detekterats i betydande koncentrationer i dagvatten. I denna studie undersöks effekten av veckovis gatusopning för att avlägsna organiska föroreningar från dagvattensediment i syfte att förebygga föroreningarnas vidare transport till recipienter. Studien fokuserar på förekomsten av mikro- och nanopartiklar, eftersom det finns risk att dessa inte avlägsnas i redan befintliga dagvattenlösningar och därför kan bli effektiva bärare av organiska föroreningar. För att utvärdera gatusopningens effekt, har förekomsten av organiskt material och föroreningar samt partikelstorleksfördelning i gatusediment, vilket provtagits före och efter gatusopningen, analyserats. Denna studie visar att gatusopningsvatten, som samplas upp i sopmaskinen innehöll en stor spridning av mikropartiklar <20 µm och nanopartiklar mellan 1 nm och 300 nm, där nanopartiklar av storleken 25–300 nm återfanns i högst koncentration. Gatusopningsvattnet innehöll ett betydande antal organiska föroreningar, inklusive PAH, oxy-PAH, alkaner och aromater. Den torra gatusopningssanden bestod till $\leq$ 69 % av sand och innehöll färre organiska föroreningar än gatusopningsvattnet. Detekterade koncentrationer av alkaner i fraktionen C_{16} - C_{35} översteg Naturvårdsverkets gränsvärde (100 mg/kg) för känslig markanvändning. En utvärdering av sopmaskinen, genomförd med hjälp av Wet Dust Sampler (WDS), visade att sopmaskinen kan plocka upp både ett brett storleksspann av partiklar, inklusive nanopartiklar så små som till 1 nm, och ett stort antal organiska föroreningar. Dock visade studien även att sopmaskinen kan bidra till resuspension av de små partiklarna.

Eftersom resultaten visade att vattnet från sopmaskinen innehöll en hög koncentration av flera grupper av organiska föroreningar och ett brett storleksspann av nanopartiklar, rekommenderas det att avlägsna små partiklar med filter. Dessa filter kan installeras på kommunala platser för tillfällig uppläggning av materialet som samlats upp med sopmaskinen. Framtida studier rekommenderas att undersöka processer för nedbrytning och/eller möjlig återvinning av föroreningar samt nano- och mikropartiklar i gatusediment.

Nyckelord: nanopartiklar, dagvatten, trafik, gatusediment, vägdamm, partikelstorleksfördelning

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Maria Polukarova, Gothenburg, July 2018

Contents

1

Introduction

As cities grow, negative human impact on the environment becomes more significant and therefore more important to consider. Urban areas are pollution hotspots where compounds from many diffuse and point sources are emitted. Among others are pollutant from vehicle exhaust emissions as well as from wear of vehicles (Rogge et al. 1993; Dong et al. 2009) and roads (Kose et al. 2008), which may be transported via precipitation and stormwater. Indeed, urban runoff is today recognised as a top priority for water authorities throughout Europe (Ellis 1991). Therefore, to regulate ecological and chemical status of European waterbodies, the Water Framework Directive has formulated standards, which specify maximum acceptable concentrations for specific water pollutants.

Previously, research about runoff quality mainly focused on investigating physical constituents, such as suspended solids, chemical constituents, including oxygen-demanding compounds, metals including Zn, Cd, Cu, and a limited number of organic compounds, mainly polycyclic aromatic hydrocarbons (PAHs). Other organic compounds, apart from PAHs, have been analyzed only occasionally (Eriksson 2002). The reason why Zn, Cd and Cu have received such attention within this field could be due to the fact that the U.S. EPA, in the late 1970ies, executed an extensive National Urban runoff Program (NURP), which showed that heavy metals are the most frequent priority pollutant found in urban runoff (U.S. EPA 1983).

However, nowadays more and more studies focus on investigation of organic pollutant (OPs) in traffic-related urban runoff. Indeed a considerable number of OPs are frequently observed in runoff from traffic-related areas (Rogge et al. 1993; Murakami et al. 2005). Potential sources of such OPs are tire wear, brake lining, combustion of fuels, as well as wear of road constructions material such as bitumen and road paint. The OPs which have been assumed to be of highest priority for removal are abovementioned PAHs, and also oxygenated PAHs (oxy-PAHs), alkanes C_{20} - C_{40}, alkylphenols, phthalates and phenolics antioxidants (Markiewicz et al. 2017). Many of these OPs are persistent, bioaccumulative and have a variety of adverse effects on living organisms, including chronic toxicity, carcinogenicity, and hormone disruption (Neilson et al. 1998; Machala et al. 2001; Kurihara et al. 2005; ECB 2008). In Sweden the 16 regulated PAH, some of which are carcinogenic, were detected in total concentrations up to 21 mg/kg in stormwater sediments from road runoff, exceeding the Swedish soil quality guideline for less sensitive land use (Strömvall et al. 2006).

Hence, in order to develop techniques to be able to collect released persistent OP as close to the emission sources as possible, more knowledge of the occurrence and transport of OPs is needed. This knowledge may also provide a foundation for a more restrictive legislation which may lead to prevention of these substances from polluting water sources and urban environments.

Recent studies have shown that, occasionally, OPs may sorb to colloids, and become sorbed to the surface of nano- and microplastic particles (da Costa et al. 2016; Kalmykova et al. 2013). It was suggested that this may increase OPs mobility more than previously assumed. Therefore, the development of advanced stormwater treatment facilities in order to retain these forms of OPs are necessary (Kalmykova et al. 2014; Nielsen 2015). However, processes of OPs bonding to above-mentioned particles are not yet fully known. Furthermore, the knowledge of the particle size distribution (PSD) in urban runoff sediment is important for better evaluation and development of treatment processes.

To prevent contamination of water sources and achieve a good water quality, the European Water Framework Directive (WFD) amendment on environmental quality standards (Directive 2008/105/EC) underline the importance of investigating causes of pollution and finding effective solutions for reducing emissions at the source. Today, there are already a number of close to the emission point treatment techniques for polluted stormwater. Among the most common are wet ponds, dry ponds, infiltration basins and trenches, constructed wetlands and permeable pavements (Erickson et al. 2013). Recent research has also investigated disk filtration and filtration through underground sedimentation devices (Nielsen et al. 2013; Kandra et al. 2015; DHI Sverige 2016). Well-designed ponds are effective at retaining suspended solids and pollutants that typically adsorb to or are incorporated in solids. The drawbacks of the sedimentation practices are that they are not effective in retaining dissolved pollutants (Erickson et al. 2013) and require a land use of approximately 2–3 % of the catchment area (Urban Drainage Flood Control District 1992; U.S. EPA 1999), which might not be possible in dense urban areas. Research has also monitored high levels of pollutant in the sediment from such ponds, which might pose an ecological risk (Crane 2014; Strömvall et al. 2006). Post-treatment of stormwater from these pond is recommended to retain the finest particles. The drawback of the filtration practices, which otherwise do not require surface land area, is that they might require pre-treatment of the stormwater. Filters might eventually clog, which will reduce their performance. The hydraulic capacity of the underground filters can also be insufficient if the subsurface space is limited (Erickson et al. 2013). Studies have also shown that some filtration practices are not capable, the particles do not settle, or not efficient for removing the smallest particles (Nielsen et al. 2013; Kandra et al. 2015).

Another technique, which has not yet been evaluated as a method to reduce stormwater pollution on a larger scale in Sweden, is street sweeping. This technique has been investigated as a method to reduce stormwater pollution multiple times over the past 40 years. There are numerous studies, such as German (2003), with main focus on street sweeping to remove street sediment and heavy metals. Nonetheless, frequently performed street sweeping may also be a promising technique for removing organic pollutants before they diffuse further to receiving water sources. Considering the pre-treatment recommended for sedimentation and filtration practices, frequent street sweeping might also function as a complement for filtering and sedimentation practices. Furthermore, street sweeping is an "at the source" practice reducing contamination from traffic-related sources. Currently, there is little research done about how street sweeping might improve the water quality by catching OPs originating from road traffic. Therefore this research aims to increase knowledge about the characteristics of OPs sampled with a street sweeping machine, and research whether the street sweeping may reduce the transport and leaching of OPs with road runoff to receiving watercourses.

1.1 Aim

The aim of this project is to gain knowledge about how OPs are transported from roads with urban runoff as sorbed to road dust particles, with focus on particles $<$ 2 mm, including nanoparticles 0.3 – 450 nm . In addition, the aim is to evaluate the sustainability and efficiency of street sweeping to reduce the transport of OPs and improve stormwater quality.

The hypotheses are:

- The particle size of the street sediment will decrease the longer the sweeping period proceeds and produce nanoparticles
- The introduction of the studded tires will influence the occurrence of finer particles in the nanoscale in the street sediment

1.1.1 Project objectives

The project will give answers to the following question:

- Which sizes of particles occur in the street sediment och washwater?
- Which OPs occur in the collected street sediment och washwater? In which concentrations? How harmful are these substances to the aquatic environment? Are these pollutants distributed on different particle size fractions of the street sediment and in the washwater?
- Is street sweeping an effective method to reduce the amount of urban street sediment contaminated with OPs or can the abrasion process lead to a larger proportion of smaller particles that more easily sorb OPs and thus transport them to receiving waters?

2

Background

A literature study has been conducted to understand which pollutants are most crucial for this type of stormwater study as well as to compare the results from previously performed studies in other countries. The results of the literature study is presented in this chapter.

2.1 Selected organic compounds for further research

As stated earlier, high concentrations of pollutants, including particles and OPs are detected in traffic environments (Björklund 2011; Jensen et al. 2006). The spectrum of detected OPs has shown to be wide; a literature and database search by Markiewicz et al. (2017) identified that 1100 specific OPs are emitted from the road environment. After further evaluation of these substances, ten groups of OPs were identified as priority pollutants. To be classified as a priority pollutant, investigated substances had to meet criteria such as:

- Risk of transport from source to stormwater
- Emission from more than one source
- Significant amounts in the sources estimated by an expert group
- Hazardous effects according to the tool Ranking and Identification of Chemical Hazards (RICH)

The results of this evaluation listed PAHs as the number one priority pollutant in the road environment, while other pollutants have been prioritized in the order as followed: alkanes C_{20} - C_{40} $>$ alkylphenols $>$ phthalates $>$ aldehydes C_1 - C_{40} $>$ phenolic antioxidants $>$ bisphenol A $>$ oxy-PAHs $>$ naphtha C_5–C_{12} (petroleum) $>$ amides $>$ amines.

For the current project, a limitation was made to focus on the presence of the top groups of OPs in the list of ten priority pollutants suggested by Markiewicz et al. (2017). The presence of oxy-PAH was also investigated due to their similarity to PAHs and their high solubility in water. A short summary of the top five listed prioritized pollutants, their origin and properties is presented.

2.2 PAHs

The groups of PAHs, include several hundred of different substances, but the common denominator is that they consist of aromatic rings made up by carbon and hydrogen. The PAHs are created during incomplete combustion of organic material. Incomplete combustion is defined as a process when carbon or hydrocarbon, which are transformed to carbon dioxide in oxygen-rich environments, are converted to PAHs in oxygen lacking environments. The PAHs can be produced from natural combustion such as forest and volcanic eruption, however anthropogenic sources are the main contributor to total PAHs´ emissions. According to the SEPA (2016), small scale wood burning in houses and other premises, together accounts for 78 % of the total amount of anthropogenic emitted PAHs to the total air in Sweden. Today, industries stands for 18 % of the total emissions of PAHs, but their emissions have decreased with 70 % since the 1990s, due to stricter legislation and developed technology. Energy production for district heating stands for 2.8 % and traffic accounts for 0.07 % (SEPA 2017) of the total PAH emissions into the air. Though vehicle exhausts contribute to such a small part of total PAH air emissions, other PAH sources from traffic, which are harder to quantify, have been suggested by recent research. There are for example abrasion of rubber tires, brake linings, motor and lubricant oils and paved road surfaces (Rogge et al. 1993; Markiewicz et al. 2017). Some examples of the most common PAHs, also included in the U.S. EPA's Sixteen PAH Priority Pollutants (16 PAH) list, as well as the corresponding Henry´s constants and their solubility in water, are presented in Table 2.1.

Half of the 16 PAH Priority Pollutants (Table 2.1) has also been proposed as priority substances in the field of water policy by the European Commission (2008). Three of those priority substances, benzo[g,h,i]perylene, benzo[a]pyrene (B[a]P) and indeno[1,2,3-c,d]pyrene have also been labelled as hazardous. The reason for this labelling is that PAHs are fat soluble, often persistent and in some cases bioaccumalative. Due to their high stability, PAHs easily spread to the environment. Moreover, animal studies show, that some PAHs are cancinogenic and cause genetic damage (KEMI 2017). As expressed by the European Commission (2017), PAHs present "a significant risk to or via the aquatic environment" and therefore is the "subject to cessation or phasing out of discharges, emissions and losses within an appropriate timetable not exceeding 20 years" (European Commission 2017).

The distribution of PAHs is to be dependent on their weight. Lighter PAHs, such as phenanthrene, are mostly found in gas phases and heavier PAHs, such as benzo[a]pyrene, are transported being bound to particles and accumulate in the sediment. The majority of PAHs (70 – 90 %) are sorbed to suspended particles at ambient temperature (Ravindra et al. 2008).

While the European Commission (2008) and the U.S. EPA provide guideline values for several individual compounds, the SEPA (2011) provide target values for three groups of PAHs, i.e. PAH-L, PAH-M and PAH-H depending on their molecular weight. These groups distinguish from each other considering physicochemical

Table 2.1: U.S. EPA's PAH 16, their Henry's law constants and solubility (SEPA 2011). Original values for Henry's constant and solubility have been rounded to two significant digits.

Examples of PAH	**PS^{a} according to European commision (2008)**	**HS^{b} according to European commision (2008)**	**Henry´s law constant [-]**	**Water Solubility [mg/L]**
Naphthalene	✓		$1.2\cdot10^{-2}$	32
Acenaphthylene			$2.9\cdot10^{-3}$	4.0
Acenaphthene			$1.1\cdot10^{-2}$	2.6
Flourene			$6.2\cdot10^{-3}$	1.3
Phenanthrene			$1.4\cdot10^{-3}$	0.80
Antracene			$9.0\cdot10^{-4}$	$7.1\cdot10^{-2}$
Fluoranthene	✓		$1.6\cdot10^{-3}$	0.20
Pyrene			$7.5\cdot10^{-5}$	0.11
Benzo[a]anthracene			$1.7\cdot10^{-6}$	$1.2\cdot10^{-2}$
Chrysene			$4.7\cdot10^{-6}$	$1.8\cdot10^{-3}$
Benzo[b]fluoranthene			$1.2\cdot10^{-5}$	$1.7\ \cdot10^{-2}$
Benzo[k]fluoranthene			$2.8\cdot10^{-6}$	$4.8\cdot10^{-4}$
Benzo[a]pyrene	✓	✓	$1.6\cdot10^{-5}$	$8.4\cdot10^{-4}$
Dibenz[a,h]anthracene			$3.8\cdot10^{-5}$	$8.3\cdot10^{-4}$
Benzo[g,h,i]perylene	✓	✓	$3.2\cdot10^{-6}$	$1.9\cdot10^{-4}$
Indeno [1,2,3-c,d]pyrene	✓	✓	$1.2\cdot10^{-6}$	$2.6\cdot10^{-4}$

[a] PP - Priority pollutant
[b] HS - Hazardous substance

properties, as well as their toxicity and ecotoxicology.

Considering the large amount of anthropogenic and natural sources of PAHs, and their stability, these substances can be found almost everywhere in the environment (SEPA 2007). Several studies have shown that PAHs are frequently found in stormwater in concentrations above the European Environmental Quality Standard (EQS) for surface waters and that several PAHs may constitute a potential risk to receiving waters (Zgheib et al. 2012; Bressy et al. 2012). This statement can be challenged, because it is often unknown how much this stormwater actually becomes diluted in the receiving water. Furthermore, concentrations of B[a]P in stormwater Zgheib et al. (2012) and Bressy et al. (2012) do exceed even guideline values, formulated by the environmental administration of Gothenburg, which indicate the maximum allowed concentration of a substance in the release point to the receiving water, for example a stormwater sewer outlet. However, PAHs are persistent and accumulate in the environment and will therefore pose a threat to the environment even if they are diluted or released in low concentrations.

2.3 Oxygenated PAHs

Oxygenated-PAHs, as well as PAHs, are formed via incomplete combustion of organic material. Oxy-PAHs are also formed by naturally occurring oxidation reactions (SEPA 2007) and degradation processes of PAHs in water and soil (Lundstedt 2003; Lundstedt et al. 2007).

Similar to other polyaromatic compounds, oxy-PAHs are lipophilic and volatile. Oxy-PAHs have shown acute toxicity to bacteria, crustaceans and plants. Oxy-PAHs have also shown to induce oxidative stress (Kumagai et al. 2002; Shimada et al. 2004), and cause endocrine disruption(Machala et al. 2001; Kurihara et al. 2005), cytotoxic effects in mammals (Zhu et al. 1995) and have been shown to be mutagenic (Chesis et al. 1984; Sakai et al. 1985). Oxy-PAHs do have higher polarity than PAHs, which causes a higher water solubility and lower volatility (Lundstedt et al. 2007). The latter, in turn leads to a greater tendency compared to PAHs, to be distributed to atmospheric particles, which affects the atmospheric deposition process. The relatively high solubility of oxy-PAHs allows them to spread into watercources easier than PAHs do, as well as to increase their dispersalpotential (SEPA 2007). Though oxy-PAHs have relatively high water solubility, calculations have shown that 9-fluorenone, anthracene-9,10-dione och benzo[a]pyrene-6,12-dione are 68–83 % distributed in soil, 15–20 % in water and only approximately 1.7 % in sediment.

Lundstedt et al. (2007) and Brorström-Lundén et al. (2010) conclude that oxy-PAH are present in soil and sediments at concentrations that are not far below the concentrations of PAHs. Oda et al. (2001) have found that concentrations of specific oxy-PAHs in the atmosphere are in the same level as specific PAHs. However, there is a lack of data about the oxy-PAH´s amount in the environment and the knowledge of them needs to be widened (SEPA 2007; Lundstedt et al. 2007).

2.4 Alkanes

Alkanes are saturated aliphatic hydrocarbons, with single carbon-carbon bonds. Aliphatic means that their structure represents either long chain or rings, with generally week bonds. Alkanes are widely used in fuels, such as gasoline, methane and diesel, due to their strong and exothermic reactions with oxygen. As n-alkanes were found to mainly originate from fossil fuel combustion in rural and urban sites (Wu et al. 2007), these substances may be used as indicators for traffic emissions. N-alkanes have also been identified as dominant solvent-extractable compound in tire wear particles and road dust (Rogge et al. 1993).

As the amount of carbon atoms in the alkane chain increase so does its vapour pressure. Hydrocarbons with only a few carbon atoms have low boiling points and are found as gases. Hydrocarbons with five to twelve carbon atoms are usually liquids.

Large hydrocarbons with many carbon atoms have high boiling points and are solids.

By using the RICH tool, Markiewicz et al. (2017) concluded that among other alkanes mainly C_{20} - C_{40} alkanes were identified as toxic. Stormwater sediment in Gårda (Gothenburg) exhibited alkanes C_{10} - C_{35} concentrations ranging between 1.0 and 10 g/kg DS, which is high compared general guidance values for contaminated soil (SEPA 2009).

2.5 Alkylphenols

Alkylphenols (AP) are aromatic compounds with a number of alkyl chains attached. Alkyl chains are the substitutions for a detached hydrogen atom in an alkane chain. According to Björklund (2001), nonylphenols (NPs) and octylphenols are the most frequently used alkylphenols by industries. The ECB stated that the commercially produced NPs are predominantly 4-nonylphenols with a varied and undefined degree of branching in the alkyl group. Alkylphenols are used for the production of alkylphenol ethoxylates (APEOs), which is one of the most used surfactant groups worldwide. For the EU production of the nonylphenol ethoxylates (NPEOs), one group of the APEOs, up to 60 % of of NPs are used (ECB 2002). For the manufacturing of another group of surfactants, octylphenol ethoxylates (OPEOs), 2 % of available 4-tert-octylphenols are used. The main use (98 %) of 4-tert-octylphenol in EU is for production of phenolic resins, used mostly in the manufacturing of tire rubber (DEFRA 2008).

Within the EU, NPEOs and NPs are produced and used for various purposes: industrial and institutional cleaning, textile manufacturing, paint production, degreasing of hides in leather industry, and emulsion polymers (ECB 2002). Soares et al. (2008) conclude that alkylphenolic compounds, released into the environment are clearly correlated to anthropogenic sources, such as effluent from sewage treatment, leachate from landfilling and sewage sludge recycling. The environmental fate of alkylphenols is determined by the branching and length of the alkyl group. However, alkylphenols released into the aquatic environment are likely to be found in sediment and are associated with organic matter. Alkylphenols released in natural waters tend to sorb to particles and subsequently being buried in sediment (Ferguson et al. 2001). Microbial degradation of alkylphenols is affected by bacterial activity both under anaerobic and aerobic conditions(Chang et al. 2004; Yuan et al. 2004).

Results from multiple toxicity studies about NPs (ECB 2002) conclude that NPs bioconcentrate to a significant extent in aquatic species. Nonylphenols are known for their endocrine disruption effects and are classified by European Commission (2008) as being very toxic to aquatic life with long-lasting effects (ECB 2002). Octylphenols are suspected to result in higher estrogenic disorders, than NPs. Despite that, no octylphenols are classified as hazardous substances by the European Commission (2008). However, both nonylphenols and octylphenols are listed as priority substances in WFD and should therefore be released into water only in amount below specified by the EQS values (European Commission 2008a).

Previously APs have mostly been investigated in surface waters and sediments, due to their presence in domestic and industrial wastewater. However, recent research about the occurrence and also the concentrations of octyl- and nonylphenols in stormwater and snow, showed that concentrations frequently exceed the European water quality standards. As Björklund (2011) noted, concentrations of NP and its´ ethoxylates also exceeded the Canadian freshwater quality guidelines (CEQGs) for the protection of the aquatic life CCME in some samples of the collected stormwater and snow.

2.6 Phthalates

Phthalates are formed when phthalic acid binds with an aromatic ring and one or two alcohols. The high molecular weight (HMW) phthalates are primary used as plasticisers, while low molecular weight (LMW) phthalates are used as solvents (ECPI 2010). Commonly used phthalates are the HMW diisononyl phthalate (DINP), and HMW diisodecyl phthalate (DIDP), HMW di(2-propylheptyl) phthalate, HMW di(2-ethylhexyl)phthalate (DEHP) and LMW dimethyl phthalate (DMP) (KEMI 2014). In the past decades and in particularly DEHP has been used in large amounts worldwide, but following restrictions on the marketing and use of DEHP (e.g. Directives 2003/36/EC, 2004/93/EC and 2005/84/EC) resulted in other HMW phthalates, such as DINP, have taking over the European market.

Substance flow analysis (SFA) modelling shows that vehicles and painted or coated roofing material are the major sources of HMW phthalates in a studied urban catchment dominated by traffic (Björklund 2011; Tukker et al. 1996). Similarly, the European Central Bank (ECB) reports imply that car undercoating is a major source of DINP and DIDP emission to surface water (ECB 2003). However, there are also a number of minor phthalate sinks such as atmospheric deposition, sealants and human activities, which are assumed to contribute only with a few percent to the total phthalate emmission to stormwater (Björklund 2011). Examples of possible human related sources of phthalates are: shoe and textile wear, toys, paper and packaging, strollers and bicycles.

Phthalates exhibit a wide variation in physical-chemical properties, which results in significant differences in environmental partitioning. Generally, the solubility and vapour pressure of phthalates show declining trend with the increasing of the alkyl chain length or molar volume. Thus, HMW phthalates are hydrophobic and will sorb strongly to organic matter and surfaces. This increased “stickiness” tends to limit the relative ability of the heavier phthalates to be transported in air or water, as has been demonstrated by Cousins et al. (2003). Studies also show that DEHP is approximately four times less soluble in salt versus fresh water (Turner et al. 2000). Phthalates are not chemically bound to the material and may migrate from a product during use and disposal (Cadogan et al. 1993).

Toxicity of phthalates varies considerably with their alkyl chain length, with higher toxicity for short carbon chains (LMW) (DEPA 2013). Many phthalates are toxic to reproduction and EU candidate list comprises twelve phthalates. Yet, only DEHP, dibutyl phthalate (DBP) and benzyl butyl phthalate (BBP) have been classified as being toxic to reproduction and DBP and BBP have also been classified as being very toxic to aquatic life (European Commission 2008a). This imply that those substances are prohibited to use in the EU, unless permission has been obtained for a specific purpose. Diisobutyl phthalate is also forbidden to use in the EU (KEMI 2014). As Björklund (2011) noted, the toxicity studies of DINP and DIDP are far fewer than for most other phthalates. Oehlmann et al. (2008) pointed out that more studies, providing exposure data for these compound, are needed to be able to evaluate the phthalates´ risk in the environment.

In Sweden, phthalates in urban runoff have been detected by Björklund (2011), but the concentration varied greatly between the samples. Results from this study reveal that of all studied phthalates, DINP have been found at the highest concentration, which may be a result of the current consumption pattern of phthalates in Sweden. The concentration of DEHP in several stormwater and snow samples have also exceeded the European surface water quality standards and the Canadian freshwater quality guidelines.

2.7 Street sweeping for pollution removal

Street sweeping as a measure to reduce street surface pollution, have been investigated numerous times. In the beginning of the 1980s the U.S. EPA's National Urban Runoff Program (NURP) investigated the efficiency of street sweeping as a stormwater pollution control in several studies. Since then, other studies have compared and evaluated the efficiency, considering reduction of stormwater and air pollutants as well as removal efficiency of larger particles, of different types of sweeping machines tested in different environments.

The most common and investigated sweeping machines can be divided into three categories: the mechanical broom sweepers, the regenerative air sweepers and the vacuum sweepers. The mechanical sweeper, the oldest type of sweeping machines, use brooms/brushes to pick up the accumulated material and move it upward with a conveyor system into a hopper. Amato et al. (2010) describes these sweepers as generally used for "gross pollutant pick-up, not chemicals (soluble) sorbed to sands and silt particles (mean aerodynamic diameter 75 µm)". The mechanical sweepers can generally easily pick up particles > 100–125 µm, while for the particles < 100 µm the regenerative type of sweepers are recommended. Machines of this type gather material with a gutter brooms. A hose is directing air jets toward the ground, helping to dislodge the dirt. The other end of the hose is sucking up the material, gathered by the gutter broom, into the hopper , where air and dirt are separated. The idea is that the regenerative machine may access the material within the cracks and uneven sections of the road surface better than the broom sweeper does.

In the past two decades, vacuum sweepers have been developed (Amato et al. 2010). Vacuum sweepers have gutter brooms and strong vacuum head(s), for picking up the road material. To avoid dispersion of inhalable particulate matter (IPM) some models use water suppressors. Figures A.1 and A.2 in Appendix B illustrate the function of the regenerative- and vacuum sweeper.

A study of Gustafsson et al. (2012) showed that in Sweden wet sweeping (by unspecified machine types) is the most commonly used method (70 %), and that 90 % of the municipalities do not have any future plans for improving their street cleaning routines for more effective cleaning. The majority of municipalities, that wants to improve their cleaning routines, requested new cleaning techniques.

In general, studies investigating the performance of sweeping machines have varying research aim, experimental set-up and the resulting data are widely scattered, and in some cases contradictory. A short summary of performed street efficiency studies is presented later in this chapter. In order to evaluate the efficiency the pollutant removal with a street sweeping machine, it is important to keep in mind that the results of this evaluation may be affected by the various street dust deposition and removal processes, (Figure 2.1). The loading amount seems to affect the machine´s particle pick up efficiency. Several studies such as by Pitt et al. (1984) and Walker et al. (1999) proposed a certain threshold below which the street sweeping equipment was unable to remove particles from the street surface. In addition, there may be possible uncertainties in the equipment used and research set up. Hence, this study does not focus on evaluating the efficiency of a certain type of street sweeper for catching organic pollutants, but rather focus on investigation its performance.

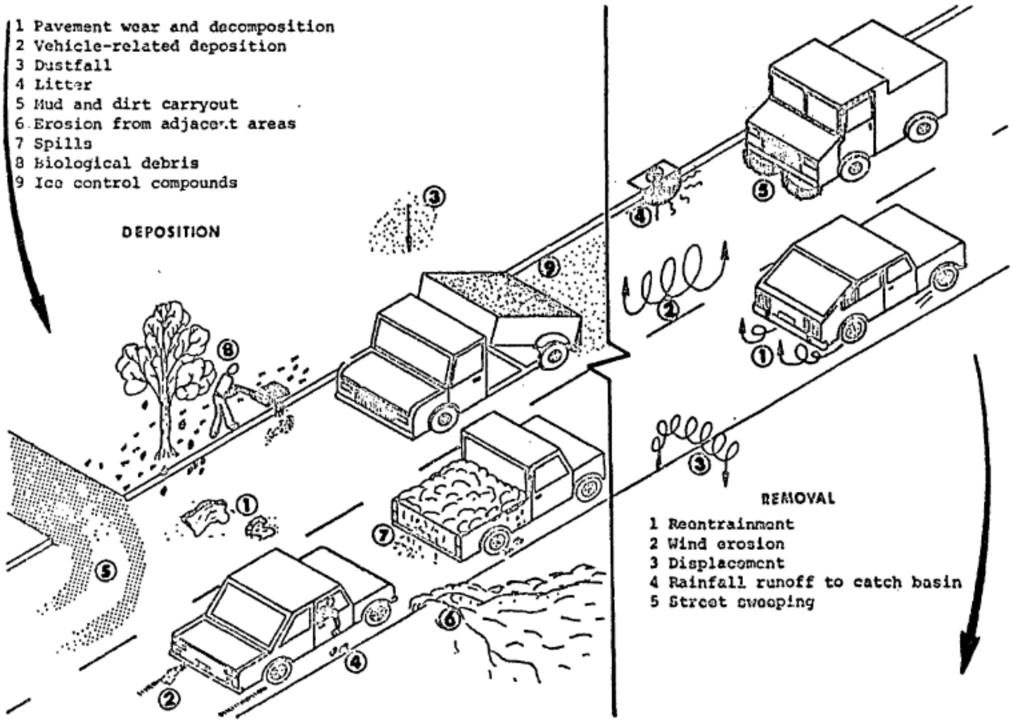


Figure 2.1: Deposition and removal processes of road dust (Axetell et al. 1997), which may contribute to the observed variations of the material sampled by the street sweeping machine.

2.7.1 The efficiency of street sweeping

Sartor et al. (1984) provide a survey of research conducted before the 1980ies and summarise results presented by the NURP. The report reveals that conventional street sweeping, as a broad-based water quality best management practice (BMP), is not effective for reducing end-of-pipe urban runoff pollution loads. The expected pollution reduction under favourable conditions is about 30 %. However, frequent street sweeping could be an effective practice in locations with following characteristics.

- Strong climatic differences including long dry periods
- Small urban catchment with a waterbody of high local interest
- Strong winter periods followed by a yearly chemical/grit residue removal after snowmelt

The relationship between the average interval between storms and frequency with of the streets being swept, is outlined. According to Sartor et al. (1984), the major finding of tests performed before and in the early 1970s, is that "the removal efficiency of the conventional sweepers was found to be dependent upon the particle size", where litter and coarser dirt particles are easier to remove by routine street sweeping. Also, Pitt (1979), studied mechanical sweepers and vacuum assisted mechanical sweepers and drew the same conclusion. The larger particles have shown to be removed with up to 55 % efficiency, while for the smaller particles in the range of 45–106 µm, the removal efficiency varied between 3.1 % and 40 %. Moreover, the variance of occasional values for total solids removal is quite large; the data ranges of 3 to 1 is not uncommon.

Grottker (1987) found that street sweeping may have an effect on particle removal, but it decreases with the particle size: a negative effect on removal of smaller particles (<250 µm) was reported. However, even removal of larger particles could be beneficial for reducing stormwater pollution, if the smaller particles originate from cracking of coarser particles. Furthermore, Vaze et al. (2002) found that the scrubbing motion of the brush may increase the amount of free load, which the suction sweeper is not capable of removing from the road surface. This finer material may become more available for wash-off by the next storm event.

Two decades later German (2003), shows that vacuum street sweeping could contribute to a reduction of both street sediment and toxic trace metals load from the street surface. The removal efficiency of the street sediment in the fractions finer than 250 µm was clearly less than the removal efficiency for the total fraction. However, the removal efficiency of metals in the fraction finer than 250 µm could be discussed, due to the fact that experiment results varied between -70 % and 80 %. The total sediment removal efficiency varied greatly between -45 % and 70 %. These results indicate the heterogeneity of the samples.

Gromaire et al. (2000), analyzed loads of suspended solids and toxic trace metals in street runoff and street washing water, before and after manual street sweeping (and water flushing) events. It was concluded that street sweeping only has a limited effect on abating runoff pollutants, such as toxic trace metals.

The Swedish National Road and Transport Research Institute (VTI) has studied street sweeping to reduce airborne particle s finer than 10 µm (PM_{10}) in urban environment and to meet the environmental quality standards for air quality formulated by the European Commission (2008). Though this report is not focused on air pollution, the results of VTI´s studies are relevant for this study, because PM_{10} might end up in stormwater.

Gustafsson et al. (2012) and (2014) show that powerful dry vacuum street sweeping does not significantly reduce the amount of PM_{10} in Stockholm´s city centre in the short term. Gustafsson et al. (2011) remarks that many sweeping machines currently in use in Sweden are not designed for reducing concentration of PM_{10}. Hence, further research is recommended of the machines´ capacity to pick up smaller particles and their leakage from the machine. In the USA, existing regulation enforces local governments within the South Coast Air Quality Management District (SCAQMD) to purchase certified new street sweepers. The certification is given when the sweepers´pick-up efficiency is greater or equal to 80 % of the total weight of test material spread over a test track before. Another criteria for the certification is that the normalized mass of entrained PM_{10} is less than or equal to 200 mg/m (SCAQMD 1997). It may be worth to add that the efficiency of this certification test has been much disputed (Gustafsson 2002). Sweden does not yet have such a regulation, neither do studies about the commonly practiced sweeping machines exist (Gustafsson et al. 2011).

Several other sweeping experiments, such as Bouma et al. (2005), Göteborgs Stad (2006), Vägverket Region Stockholm. (2007) were performed in Sweden to reduce air pollution. A 20 days long experiment of frequent street sweeping of Stockholm´s city centre, revealed no contribution to reducing concentrations of PM_{10}.

It is important to emphasize that, within the issue of street sweeping as a measure to reduce street sediment and associated pollutants, studies reviewed in this report are only a fraction of the available information. However, specific information about the reduction of OPs by street sweeping is difficult to find. The amount of street sweeping technologies available is large, but many of them are only used for case studies or events such as spring cleaning (mostly practiced in Scandinavian countries) or tunnel cleaning. The scattered results of discussed studies are likely to depend on variations in factors such as the type of sweeping machine used, analyzed sediment fractions, traffic volume in the test area and precipitation amount and intensity during the study.

3

Methods

3.1 Case studied area

The study was conducted close to the hospital area Sahlgrenska in Gothenburg in Sweden (Figure 3.1). The annual average daily traffic (AADT) for this area is approximately 2000–24 000 (Göteborgs Stad 2018b). The road runoff and stormwater is transported to the creek Vitsippsbäcken, situated in the natural reserve Änggårdsberget. The catchment area of Vitsippsbäcken is approximately 55 ha and consists of hilly residential areas and the hospital area. Vegetation accounts for approximately 60 % of the total area, paved streets for 17 %, building for 13 % and roads for 10 % (Göteborgs Stad 2018a). The area has a separated stormwater pipe system. The area of Sahlgrenska has a private pipe system and treats its stormwater via an end-of-pipe BMP. This treated stormwater is then released into Vitsippsbäcken (Göteborg Stad 2018).

The stormwater from the catchment area of Vitsippsbäcken showed to be highly contaminated by metals, such as Cu, Pb, Zn and Cr (Medin 2004). Following studies by the Gothenburgs Environmental Department confirmed that Vitsippsbäcken is highly contaminated by metals, such as Cu, Zn, Cr, Mn (Miljöförvaltningen. Göteborgs Stad 2013). The contaminant found in highest concentrations was Cu, which could be the result of a combination of high amount of copper roofs in the area. The mean flow of stormwater into the creek is also high, in relation to Vitsippsbäckens own mean flow (Göteborgs Stad 2018a). Therefore Vitsippsbäcken has been labelled as "very vulnerable" by the environmental administration of the City of Gothenburg. To reduce the stormwater contamination in the area the impact of stormmwater filters in the gully pots was evaluated in 2016 (Göteborg Stad 2018).

Under normal conditions, the streets in the study area are swept once or twice per month during autumn, spring and summer season. During winter, December to March, the streets are not swept but instead maintained, i.e. graveled and clearance from snow was needed.

3.2 Field sampling/experimental setup

Street sweeping in this study was performed once per week week, between 17th of August and 26th of November 2017. The swept streets are: parts of Per Dubbsgatan,

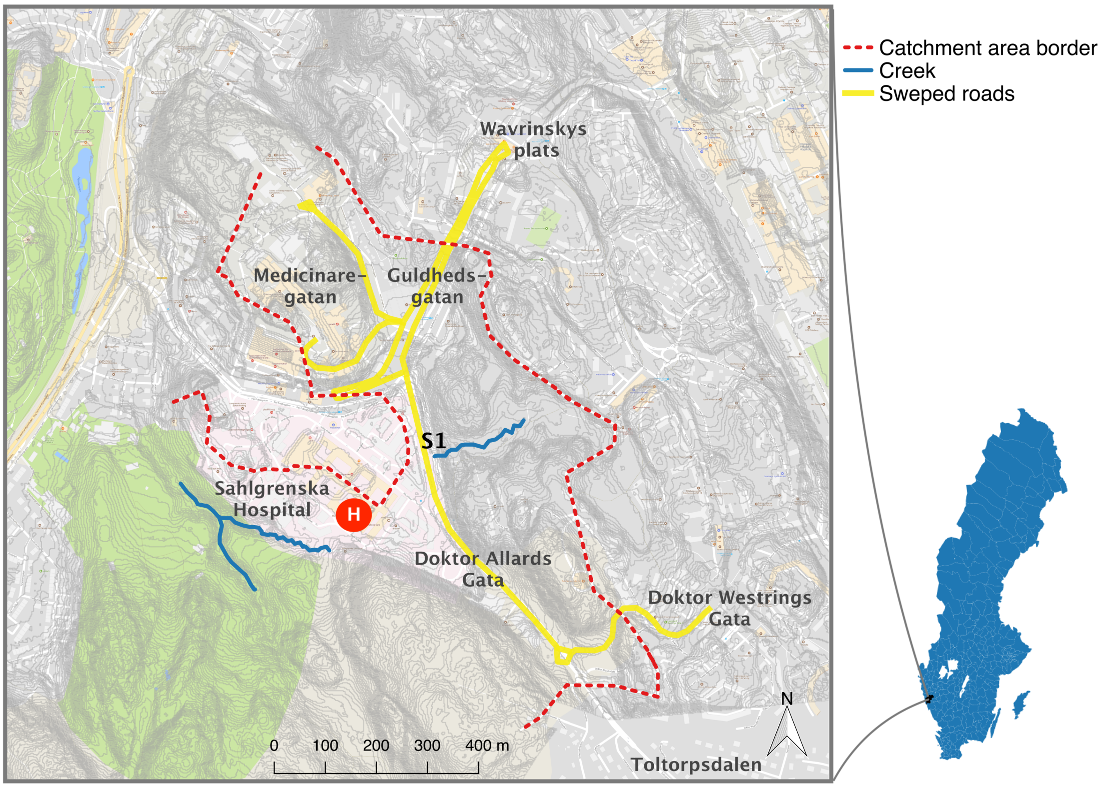


Figure 3.1: The study area for performed street sweeping. S1 is the the point where sampling with WDS was performed.

Ehrenströmsgatan, Doktor Allards gata, Medicinaregatan and Guldhedsgatan (Figure 3.1). Two additional street sweeping event were performed: on 7th of December 2017 the contribution from studded tires, on the pollution accumulation was investigated. Studded tires, are by law allowed in Sweden from 1st of October and are compulsory during winter road conditions from 1st of December. The second additional occasion for street sweeping was performed after the winter break in street sweeping. This event occurred during the night between 26th and 27th of March 2018. At this occasion, another technique for sampling street sediment, the Wet Dust Sampler (WDS), designed and operated by the Swedish National Road and Transport Research Institute (VTI) was tested.

Streets on which sweeping occurred were not closed off for other traffic during sweeping, which have resulted in slight variations of the sweeping distance. In most cases, the sweeping was done on the right side of the road, closer to the curb than to the marking separating the lanes.

During the sampling period the maximum daily precipitation intensity varied between 0 and 166 mm (Figure 3.2), while the accumulated amount of precipitation during the 11 sampling weeks varied between 2.2 and 24 mm (Table 3.1).

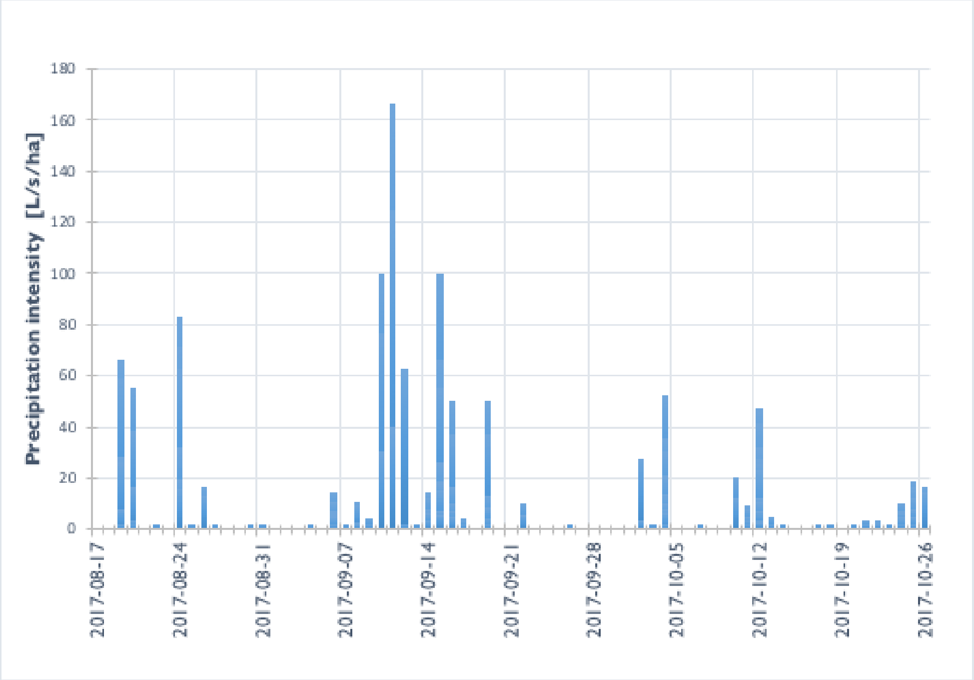


Figure 3.2: Maximum daily precipitation intensity [L/s/ha] during the street sweeping study at Vitsippsbäcken. The precipitation measuring device was situated at Blå stråket in the area of Sahlgrenska. (Data is provided by DHI Sverige.)

Table 3.1: The precipitation amount accumulated between the sampling occasions at Sahlgrenska. (Data was provided by DHI Sverige.)

Date	**Accumulated depth^a [L/s/ha]**	**Maximum intensity [mm]**
2017-08-24	5.2	66
2017-08-31	12	83
2017-09-07	20	14
2017-09-14	21	167
2017-09-21	24	100
2017-09-28	2.2	10
2017-10-05	22	53
2017-10-12	8	20
2017-10-19	10	48
2017-10-26	28	19
Meanvalue	15	58

^{a} - during the week before sampling

The sweeping machine used for this study was of the vacuum type and was produced by Johnston Beam (Figure 3.3). To suspend the finest airborne particles during sweeping, the pipe, which sucks the road particles, was moisturized with water. During dry weather conditions, the machine also sprayed water on the street to suspend airborne particles. The total volume of water storage in the machine is approximately 1.3 m^3 (Friggeråkers Verkstäder AB 2017). The amount of sprayed water varied between the events, representing the ordinary sweeping routine. Since the machine´s width is approximately only three quarters of the road´s width, the entire road surface was not swept each time.

Figure 3.3: Road sweeper VTJB651, produced by Johnston Beam. The brushes were made of steel.

The sampled matter consisted mostly of urban street sediment, settled or carried with the washwater. Other constituents of the sampled matter was cigarette butts, plastic bottles, metal pieces and suspected fecal matter because of the specific odor the sampled sand and washwater after weeks of storage. The amount of sampled sediment started to decline drastically when the defoliation begun, which occurred in the beginning of October.

After each sweeping event the street sweeping machine was driven to the waste dump located close to the busstop Bergsjödalen, where samples were collected separately by hand. The samples consisted of the in the machine settled street sediment and washwater. The washwater contained particles and included: undrained stormwater sucked up by the sweeping machine during the sweeping, and water used by the sweeper to suspend the dust during street sweeping and the street sediment that did not settle in the sweeping machine. The machine was used for sweeping other streets during the experiment, but it was was washed with water and in some cases soap, before each sweeping of the case study area.

The street sediment was also sampled before and after the street sweeping at point S1 in Figure 3.1, with a wet dust sampling (WDS) technique. The aim of this study was to evaluate the effectiveness of the street sweeping machine. The WDS, illustrated in Figure A.3 in Appendix A, was developed to combine a pressure and vacuum technology. With the WDS samples were collected in the right lane across the road before and after the sweeping. The "before" sample consisted of randomly collected across the road (from the curb to the lane marking) subsamples of the street sediment. The sample collected after the street sweeping, consisted of the subsamples collected approximately 2 cm from the curb, right wheel position, between wheels, left wheel position, 2 cm from the lane marking) of approximately similar volume (2 L). Mixing of the subsamples to composite samples was to represent the actual road pollution level before and after the street sweeping was performed.

3.3 Laboratory analysis

Collected samples of street sediment and washwater collected during street sweeping, as well as the water from the WDS, were analyzed for different chemical parameters, occurrence of nanoparticles and several OPs. Particle size distribution (PSD) for the sampled sediment was performed. The PSD is important for evaluating the correlation between the organic pollutants and particles of different sizes. A summary of performed analyses is presented in Table 3.2. Furthermore, TSS, PSD, conductivity and turbidity analysis were performed on the washwater from the street sweeping machnine and on the the stormwater from the catchment area. These results are available in Figure B.1 and in Table B.1 Appendix B. The stormwater was collected during several rain events in the Autumn 2017 by DHI Sverige through flow-proportional automatic sampling. The water sampling device was situated at Blå Stråket.

Table 3.2: Methods for the chemical and physical analyses performed on the street sediment and washwater collected by the street sweeping machine.

Analyzed feature	Matrix	Test method specification	Standardized method/ Used equipment
PSD	sediment	Wet sieving analysis of dry mortar	ISO 13765-5
PSD	sediment	Wet sieve analysis using laser diffraction (fraction from 2 µm to 63 mm). Fractions >2 mm, 1–2 mm, 0.5–1 mm, 0.25–0.50 mm, 0.125–0.25 mm and 0.063-0.125 mm were determined by wet sieving method.	ISO 11277:2009
PSD	washwater	Dynamic light scattering	The Litesizer™ 500 by Anton Paar; Nanosight NS300 by Malvern Instruments Ltd.
Concentration of OPs	sediment	GS-MS was used for analyzing PAH-16, oxy-PAHs, aromatics and alkanes substances	Dry matter: SS 028113/1 PAH-16, Alkane & aromatic substances: ALS internal intuitions TKI45a och TKI42a based on SPIMFAB PAHs: a method by SEPA 2008 Phthalates: E DIN 19742 (2012-04).
Concentration of OPs	washwater	GS-MS was used for analyzing PAH-16, oxy-PAHs; aromatics and alkanes substances as well as phenols	PAHs: US EPA8270, CSN EN ISO 6468, SEPA 2008 Alkane and aromatic substances: SPIMFAB Phthalates: DIN EN ISO 18856 Phenols: ISO 18857–2.
Conductivity	washwater WDS water stormwater	Multiline® Multi 3630 IDS by WTW	
Turbidity	washwater WDS water stormwater	Portable turbidity meter TURB® 430 IR by WTW	
TSS & VSI	washwater WDS water stormwater	Analysis were replicated 3 times	ISO 11923:1997
LOI	sediment	drying > dry sieving with a handheld sieve shaker > ignition	SS 02 81 13

3.3.1 PSD of the street sediment - Sieve analysis

Particle size distribution (mm) of the collected urban runoff sediment was determined by wet sieve analysis of dry mortar ; performed according to ISO13765-5. According to ISO13765-5 wet sieve analysis of the dry mortar gives a more reproductive results than dry sieving of the dry mortar. For this reason wet sieve analysis of the dry mortar was chosen. The aperture of the used sieves are: 20, 16, 11.2, 8 5.6, 4, 2, 1, 0.5, 0.25, 0.125 and 0.063 mm. The amount dried runoff sediment used for determining each sieving curve was between 1.8 and 3.0 kg. For each curve, three samples of the same dry weight, were sieved and the average value was obtained. For confirming the method validity, street sediment sampled from three sweeping events were also analyzed at a commercial laboratory according to standardized methods (Table 3.2). This grain size method for characterizing the particles from 2 µm to 63 mm, uses the wet sieve analysis and laser diffraction analysis. Fractions $>$ 2 mm, 1–2 mm, 0.5–1 mm, 0.25–0.50 mm, 0.125–0.25 mm and 0.063–0.125 mm were determined by wet sieving method. Fractions finer than 0.063 mm, were analyzed by laser particle size analyzer using liquid dispersion mode.

3.3.2 PSD in water

The size distribution of the particles in the washwater and WDS samples were analyzed by the Litesizer$^{\text{TM}}$ 500 (by Anton Paar). The range for the particle sizes that Litesizer $^{\text{TM}}$ 500 measure is: 0.3 nm – 10 µm. However, this instrument can not identify and measure the concentrations of the particles. For this reason the samples was also analyzed with Nanosight NS 300 instrument (Malvern Intruments Ltd.), which is also based on laser dynamic light scattering, and also able to do the quantification of particles concentration. This instrument can on the other hand not measure particles $<$ 10 nm and $>$ 2 µm why both instruments are good to use in combination.

The settings used for the instruments are summarized in Table A.1 in Appendix A. In most cases, the sampled water was stored frozen in test tubes before the analysis, and prior to the analysis defrosted in the cold water, and well mixed by shaking and filtered through a cellulose acetate 0.45 µm filter. Measurements for almost all samples from each occasion were analyzed three times and then a mean value was calculated. However, washwater from 2017-09-14 was analyzed only two times. From a visual assessment some suspension of particulate matter has occurred during freezing, which despite shaking of test tube, could influence the results.

3.3.3 Screening for organic pollutants

Selected washwater and sediment samples were also sent to a commercial laboratory for chemical analysis of the presence of 16 specific PAHs, nine oxy-PAHs, 16 phthalates, alkylphenols, aldehydes, aromatics and aliphatics (alkanes). More information about the standardized methods applied for these analyses is available in Table 3.2

The street sediment from four sampling occasions was analyzed for the presence of OPs (Table 3.3). Both dry and wet sediment of different fractions: unsieved (total), < 250 µm, 250–125 µm and < 67 µm was screened for OPs. To simplify the process of sieving, the sediment was dried in room temperature or in the oven at 105 °C before sieving. It was assumed that the street sediment sampled after the winter break would be more contaminated than the sediment sampled during autumn 2017 when the sweeping was performed weekly. Therefore, the sediment sampled 2018-03-26 was also screened for the presence of oxy-PAHs, phenols and aldehydes.

Table 3.3: A summary of chemical analysis performed for quantification of different organic pollutants in street sediment collected with the street sweeping machine.

	2017-08-17	**2017-08-24**	**2017-08-31**	**2017-08-17**		**2018-03-26**	
		Total		**<250 µm**		**63–125 µm**	**<63 µm**
		wet		**dry***	**wet**	**dry****	
PAHs	✓	✓	✓	✓	✓	✓	✓
Oxy-PAHs							✓
Phthlates	✓	✓	✓	✓	✓	✓	✓
Alkanes	✓	✓	✓	✓	✓	✓	✓
Aromatics	✓	✓	✓	✓	✓	✓	✓
Aldehydes							✓
Alkylphenols							✓

[a] - dried at 105 °C
[b] - dried at room temp.

3.3.4 Loss on ignition

Loss on ignition (LOI) analysis was performed according to Swedish standard SS028113 on sediment samples from 2017-08-24, 2017-08-31 and 2018-03-26. For one dried (105 °C) from each date, nine fractions were ignited: < 25 µm, 25–35 µm, 35–45 µm, 45–60 µm, 60–80 µm, 80–120 µm, 120–170 µm, 170–230 µm and > 230 µm. The sieving was done with a handheld sieve shaker.

4

Results and discussion

4.1 General discussion for the evaluation of street sweeping

In total, the washwater and the street sediment sampled by the street sweeping machine were analyzed for 70 different OPs, including 16 specific PAHs, nine oxy-PAHs, 13 phthalates, six groups of alkanes and 12 different groups of aromatics, five aldehydes and nine phenols and their ethoxylates. Up to 33 OPs were detected in the washwater and up to 14 in the street sediment sampled by the street sweeping machine, and a lesser amount of up to 13 in the sediment sampled by the WDS (Table 4.1). The chemical analysis therefore showed that the street sweeping machine is capable to collect a substantial number of these OPs. The highest number of OPs were found in the washwater.

The median value for the concentrations of C_{16} - C_{35} alkanes was shown to be higher than the median value for the previously detected C_{16} - C_{35} in the street sediment sampled by the street sweeping machine (Bjerking AB 2012). The concentrations of alkanes in the street sediment are also above values for the sensitive soil (SS) given by the SEPA. The concentrations of PAHs analyzed on the washwater was much higher than previously measured in stormwater (Pettersson et al. 2005) and well above the guideline values for polluted groundwater at gasoline stations (SEPA 1998). Oxy-PAHs in the washwater are in the same range as the concentrations of PAHs they derive from. The risk of nanosized particles, detected in the washwater sampled by the street sweeping machine and the WDS, should not be underestimated. Nanoparticles may pose a health risk, because they are likely to pass biological membranes and affect the functioning of cells, including blood cells and photosynthesis (Bergmann et al. 2015). Furthermore, nanoparticles have showed an ability to transport strongly toxic substances (Velzeboer et al. 2014).

The analysis of the street sediment sampled by the WDS showed that although the street sweeping machine leaves out some particles, it also contributes to the resuspension of fine street dust particles. The street sweeping machine also manages to collect a wider range of fine particle sizes than it leaves out. That implies that street sweeping may contribute to the reduction of street sediment particles and OPs in the urban environment. However, local conditions such as wind speed and direction, which greatly affect the PSD of the ultra-fine nanoparticles in the air (Molnár et al. 2002), have not been studied. Neither was the contribution of rain and snow on

Table 4.1: Number of detected substances and minimum, maximum and mean values of concnetrations for the detected OPs in the street sediment, washwater sampled by the street sweeping machine and in the sediment sampled by WDS.

		Street sweeping machine							
Substances		**Washwater**				**Sediment**			
	Number analyzed	Number Detected	Min conc. [µg/L]	Max conc. [µg/L]	Mean conc. [µg/L]	Number Detected	Min conc. [mg/kg]	Max conc. [mg/kg]	Mean conc. [mg/kg]
PAHs	16	8-16	0.010	14	1.9	0-7	0.083	0.28	0.15
Oxy-PAHs	9	5	0.11	0.30	0.20	0	-	-	-
Phthalates	13	0-2	1.2	150	39	0-3	0.052	3.3	0.71
Alkanes	6	4-5	12	37500	2609	0-3	68	780	309
Aromatics	12	1-5	0.06	58	13	0	-	-	-
Aldehydes	5	0	-	-	-	2	5.1	7.6	6.4
Alkylphenols and its ethoxylates	9	0	-	-	-	1	0.15	0.15	0.15

		Wet Dust Sampler							
Substances		**Sediment (Before)**				**Sediment (After)**			
	Number analyzed	Number detected	Min conc. [µg/L]	Max conc. [µg/L]	Mean conc. [µg/L]	Number detected	Min conc. [µg/kg]	Max conc. [µg/L]	Mean conc. [µg/L]
PAHs	16	12	0.017	0.34	0.13	13	0.019	0.49	0.18
Oxy-PAHs	9	n.a.[a]	-	-	-	n.a.[a]	-	-	-
Phthalates	13	1	3.60	3.60	3.6	1	4.2	4.20	4.2
Alkanes	6	1	633	633	633	1	924	924	924
Aromatics	12	0	-	-	-	3	0.18	1.1	0.79
Aldehydes	5	n.a.[a]	-	-	-	n.a[a]	-	-	-
Alkylphenols and its ethoxylates	9	n.a[a]	-	-	-	n.a.[a]	-	-	-

[a] - not analyzed

sediment deposition and removal investigated. Other factors, which may effect the sediment removal, are design and rotation frequency of the brush, as well as travelling speed (Snilsberg et al. 2016; Vanegas-Useche et al. 2015). Therefore, more studies are needed to evaluate street sweeping as a method for reducing OPs and fine particles from stormwater.

Even though it was previously shown that the street sweeping machine is capable of removing a significant number of OPs and fine particles from the urban street, a proper selection of the dumping site and the effective treatment of the material collected by the sweeping machine are crucial. Today, the street sediment and the washwater is either dumped in a temporary dumping site, from where the street sediment is screened/sieved and washed, or sent to a waste receiving station (Göteborgs Stad 2018a). Since the analysis showed that the washwater contains both high numbers and concentrations of OPs, a wide range of nanoparticles, a recommendation can be given to treat the washwater on the site for the temporal dumping, with for example granular filter of active carbon, peat or bark. Furthermore, microplastics, rubber and bitumen particles were detected in both the washwater and the street sediment (Göteborgs Stad 2018a). By covering the temporary stored street sediment and reducing the time of temporal storage, leaching of pollutants during rain events may be eliminated.

Up to date, the samples of the dumped sediment were taken for analysis of pollutants, the guideline values for which are given by SEPA (2009). However, this list of guideline pollutants does not include pollutants such as phthalates, oxy-PAHs and aldehydes, the toxicity of which includes endocrine disruption (Machala et al. 2001; Kurihara et al. 2005; ECB 2002), mutagenicity (Chesis et al. 1984; Sakai et al. 1985) and carcinogenicity (ECB 2003; ECB 2008). Therefore the toxicity of the street sediment may be underestimated.

Another uncertainty, which may lead to underestimation of the toxicity of the street sediment dumped by the street sweeping machine, is the sampling method. The questions are if the samples are taken from the dumped street sediment or from the soil surrounding the dumping site and how those samples are treated before the analysis. Sampling of the dumped street sediment for screening off the pollutants listed by the SEPA (2009), might not disregard the negative effect of the washwater on the groundwater. Therefore, this issue is crucial to study further, due to the fact that the analyzed washwater had high concentrations of many OPs detected, and a much higher frequency and number of OPs detected, compared to the street sediment.

Lastly, for complete evaluation of the street sweeping as a method to reduce OPs, metal, fine particles and microplastics in urban runoff, the problem of recycling of the washed and screened street sediment should be addressed. Up to date, there is a lack of studies about the recycling procedure of the material sampled by street sweeping machines. A study about street sediment sampled in Sweden during the spring street cleaning event shows that several municipalities, excluding Gothenburg, were using the street sediment as construction material, materials for de-icing, and as drainage material (Johansson 2008). However, the process for recycling of the street sediment sampled during regular street sweeping events, is not being routinised in Gothenburg. Future studies are therefore recommended to focus on this topic.

4.2 Particle size distribution in street sediments

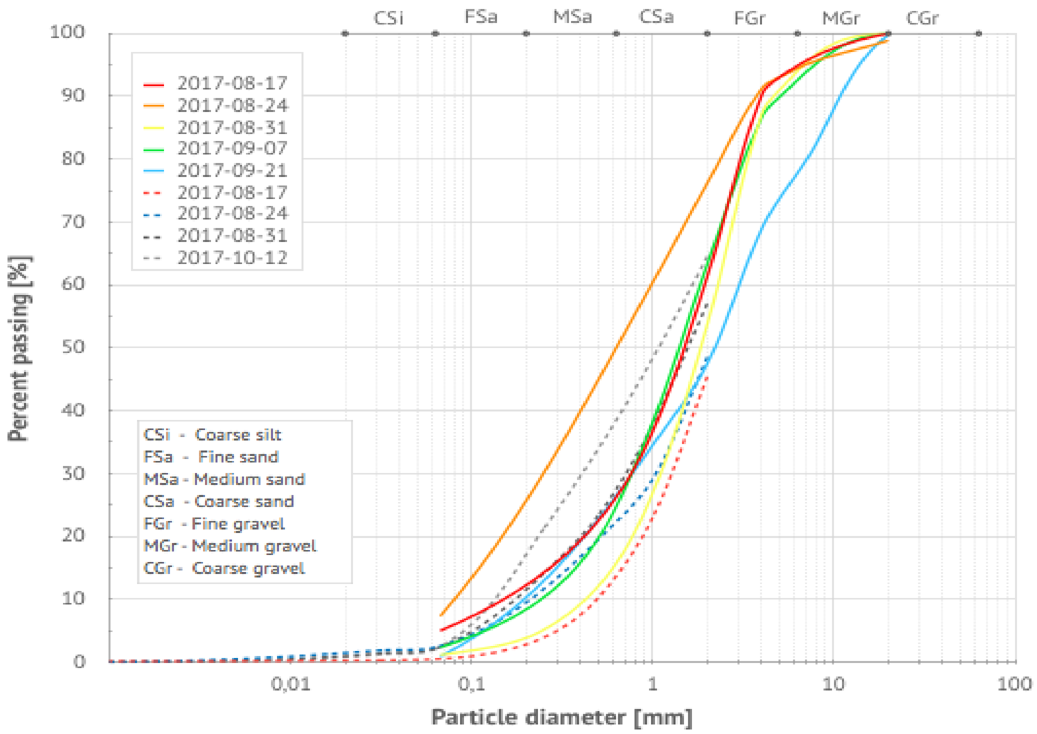


Figure 4.1: Sieving curves of street sediment sampled by the street sweeping machine during autumn 2017. Median particle size ranges between 0.6 mm and 2.0 mm. Grain-size classification is performed according to IS0 14688-1: 2002. Solid lines are curves determined in the interval 0.63–20 mm. Dashed lines are curves determined in the interval <0.002–2 mm.

According to the sieving curves (Figure 4.1), the median particle size of the sampled street sediment, D50 value, was 600–2000 µm, which implies that the samples contained a significant amount of coarse sand. In fact, the analyzed street sediment consists of up to 70 % of sand. These results are far above the reported median particle diameters of particles in stormwater of 8–95 µm provided with auto- and grab sampling of runoff (Charters et al. 2015), 8–95 µm by autosampling runoff in a basin outlet (Selbig 2015) and 29–300 µm by a sampling runoff in a settling tank (Kim et al. 2008). A more extensive comparison of studies on urban runoff and sediment PSDs with median particle size has been performed by Charters et al. (2015).

Previous sampling of street sediment with a sweeping machine found D50 equal to 250–700 µm (German 2003), and sampling with vacuum cleaner equipped with rotating brush presented D50 values varying between 100–400 µm (Lau et al. 2005). These results are closer to the D50 values found in this study, than the reported D50 values of particles in stormwater.

Analyzing the comparison of PSDs of *sediment from urban street surfaces* and *in rainfall-runoff* it can be noted that studies focused on street sediment have a slightly wider range of particle sizes and significantly higher D50 values (Kim et al. 2008). Sediment from urban street surfaces is much coarser than the particles found in road runoff samples (Vaze et al. 2002). This illustrates the limitations of the street sweeping practice for sampling smaller particles as well as the capacity of the rain and flow energy to transport finer particles.

Furthermore, the comparison of D50 values from the sieving analysis might not be an optimal way of evaluating characteristics of street sediments, due to the variation of sieving methods used. The lack of equipment capable of covering the wide range of particle sizes found in urban runoff may lead to inconsistent results (Selbig 2015). Another possible sources contributing to PSD variation of sampled road sediment is the sampling position across the road (Deletic et al. 2005; Gustafsson et al. 2016), the length of the antecedent dry weather period (Yuan et al. 2017) and the texture of the pavement (Gustafsson et al. 2016).

Figure 4.1 also illustrates that no apparent shift toward smaller particles size with time is observed. Lastly, it should be noted that the amount of sediment used for the sieving analysis is just a small fraction of the sediment collected by the street sweeping machine, which might influence the results. A visual assessment during sampling of sediment on 2018-03-26 revealed that the sediment was indeed not mixed properly in the machine, but rather was distributed in layers or chucks in the machine.

Though the finest particles in the by the street sweeping machine sampled sediment are missing, it is still possible that these may end up in the street-sweeping washwater. In this study a limited range (1 - 20 000 nm) of particles available in washwater was analyzed for PSD. Therefore in further studies the washwater samples may be filtrated and sieving curves determined on the solids trapped on the filter.

4.2.1 Particles size and concentrations of organic matter

Several LOI analyses (loss on ignition ≈ content of organic matter) were performed on sediment sampled by the street sweeping machine. The sampled street sediment consisted of 0.99–23 % organic material where the median values varied between 1.9 and 3.4 % (Table 4.2). The result in Table 4.2 show that organic matter is mostly associated with smaller particles and that the concentration of organic matter are negatively depended on the particle size. Previous research by Ha et al. (2012), Lorenzi et al. (2011) and Dong et al. (2009) showed that concentrations of OPs, such as PAHs, in the street sediment of finer fraction is higher than in road dust of coarser fractions.

The LOI values for the street sediment sampled with the street sweeping machine are below the mean value of organic material (5–15 %) in street sediment, reported by Gustafsson et al. (2016) and equal to the reported LOI values (1.4–2.9 %) in sediment sampled by street sweeping in Stockholm (Bjerking AB 2012).

Table 4.2: Loss of ignition [%] for street sediment sampled with the sweeping machine street. The amount of organic matter increases with decreasing particle diameter.

Size [mm]	2017-08-24	2017-08-31	2018-03-26
<25	3.4	7.5	4.5
25–35	3.2	5.4	23
35 - 45	1.9	4.9	3.9
45–60	1.9	3.6	3.3
60–80	1.6	3.1	2.8
80–120	2.0	2.1	2.3
120–170	1.4	1.7	3.4
170–230	1.4	1.2	2.2
> 230	1.1	0.99	n.a.[a]

[a] - not available

4.3 Organic pollutants in street sediments

In total, 16 specific PAHs, nine specific oxy-PAHs, 12 aromatics and six specific alkanes, 13 specific phthalates, eight specific phenols and five specific aldehydes were analyzed. A summary of performed analyses is presented in Table 3.3 and all the analyses results are available in Appendix C. The OPs found in highest concentrations in the street sediment sampled by the street sweeping machine were alkanes C_{16} - C_{35} and PAHs (Table 4.3). Oxy-PAHs and aromatics were however detected in lower concentrations. The sediments contained a moderate concentrations of phenols and aldehydes.

4.3.1 PAHs

Table 4.3 shows that concentrations of low molecular weight PAH-L, medium molecular weight PAH-M and high molecular weight PAH-H in the street sediment are far below the reference values (1, 3 and 3 mg/kg DS respectively) for sensitive soil given by the SEPA (2009). These concentrations are comparable to the PAH-L (0.49 mg/kg DS), PAH-M (0.52 mg/kg DS) and PAH-H (0.47 mg/kg DS) concentrations measured in the the street sediment also sampled by a street sweeping machine in Stockholm (Bjerking AB 2012).

Concentrations of PAH-16 in the street sediment particles with diameter 63–125 µm are slightly lower than concentrations in road dust (63–125 µm), sampled in a residential area (0.82 µg/g DS), and much lower than in a heavy-traffic area (6–9 µg/kg

DS) (Ha et al. 2012). Concentrations of PAH-16 in the street sediment (63–125 µm) sampled with the street sweeping machine were thought several times higher that the PAH-16 concentration found in urban street dust with the same diameter (Lorenzi et al. 2011).

Although it was expected that the concentrations of PAHs in street sediment samples of finer fraction (< 63 µm) would be higher than in samples of coarser fraction (63–125 µm), the results show that finer sediment contained much less PAHs. This assumption was based on that the finest fraction has the highest active sorption surface and also the highest organic content. Presumably, this result may be explained because the most PAHs are attached to the smaller street sediment particles sampled with the washwater.

Table 4.3: Concentrations [mg/kg DS] of 16 specific PAHs and sum of PAH-L, PAH-M, PAH-H and 16-PAHs in the street sediment sampled by the street sweeping machine.

	2017-08-17	**2017-08-24**	**2017-08-31**	**2017-08-17**		**2018-03-26**	
PAHs	**Total**			**<250 µm**		**63-125 µm**	**<63 µm**
	wet			**dry**[a]	**wet**	**dry**[b]	
Naphthalene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<1.0
Acenaphthylene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<1.0
Acenaphthene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<1.0
Fluorene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<1.0
Phenanthrene	<0.1	<0.1	<0.1	<0.1	<0.1	0.15	<1.0
Antracene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<1.0
Fluoranthene	<0.1	<0.1	<0.1	0.11	0.24	0.22	<1.0
Pyrene	<0.1	<0.1	<0.1	<0.1	0.19	0.28	<1.0
Benzo[a]anthracene	<0.08	<0.08	<0.08	<0.08	0.096	<0.080	<0.50
Chrysene	<0.08	<0.08	<0.08	0.10	0.14	<0.080	<0.50
Benzo[b]fluoranthen	<0.08	<0.08	<0.08	0.091	0.096	0.18	<0.50
Benzo[k]fluoranthen	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.50
Benzo[a]pyrene	<0.08	<0.08	<0.08	<0.08	<0.08	0.083	<0.50
Dibenzo[a,h]anthracen	<0.08	<0.08	<0.08	<0.08	<0.08	<0.080	<0.50
Benzo[g,h,i]perylene	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<1.0
Indeno[1,2,3-c,d]pyrene	<0.08	<0.08	<0.08	<0.08	<0.08	0.098	<0.50
PAH-16	<1.5	<1.5	<1.5	<1.5	<1.5	1.1	<13
PAH-L	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<1.5
PAH-M	<0.25	<0.25	<0.25	0.11	0.43	0.65	<2.5
PAH-H	<0.3	<0.3	<0.3	0.19	0.33	0.48	<2.5

[a] - dried at 105 °C
[b] - dried at room temp.

Figure 4.2 presents the proportional distribution of specific PAHs in the street sediment sampled by the street sweeper. For plotting the data, concentrations of the specific undetected PAHs were estimated to half of the detection limit, which may lead to missleading interpretations of the results. The dominating PAHs in the street sediment were pyrene, fluoranthene as well as benzo[b]fluoranthene, indicating the presence of tire wear material (Aatmeeyata et al. 2010), vehicle exhaust emissions (Ntziachristos et al. 2017) as well as residues of lubricant motor oils (Souza et al. 2016; Wong et al. 2001). Proportions of chrysene, phenanthrene and benzo[g,h,i]perylene in some samples were less dominant but still of importance. The presence of those substances also indicate the presence of lubricant motor oil (Souza et al. 2016; Wong et al. 2001), as well as bituminous binder in asphalt (Brandt et al. 2001) and brake wear particles (Rogge et al. 1993; Luhana et al. 2004) in the sampled street sediment.

The relative composition of the specific and dominating PAH in the finest fractions are in line with the measurements in road runoff sediment: pyrene > fluoranthene > phenanthrene > benzo[g,h,i]perylene ≈ benzo[b]fluoranthene ≈ chrysene (Markiewicz et al. 2017)
Phenanthrene, pyrene, chrysene, fluoraanthene also dominated among PAHs found in urban road dust (Wei et al. 2015; Franco et al. 2017). Also, Franco et al. (2017) noted the predominance of benzo[g,h,i]perylene and indeno[1,2,3-c,d]pyrene in street dust samples.

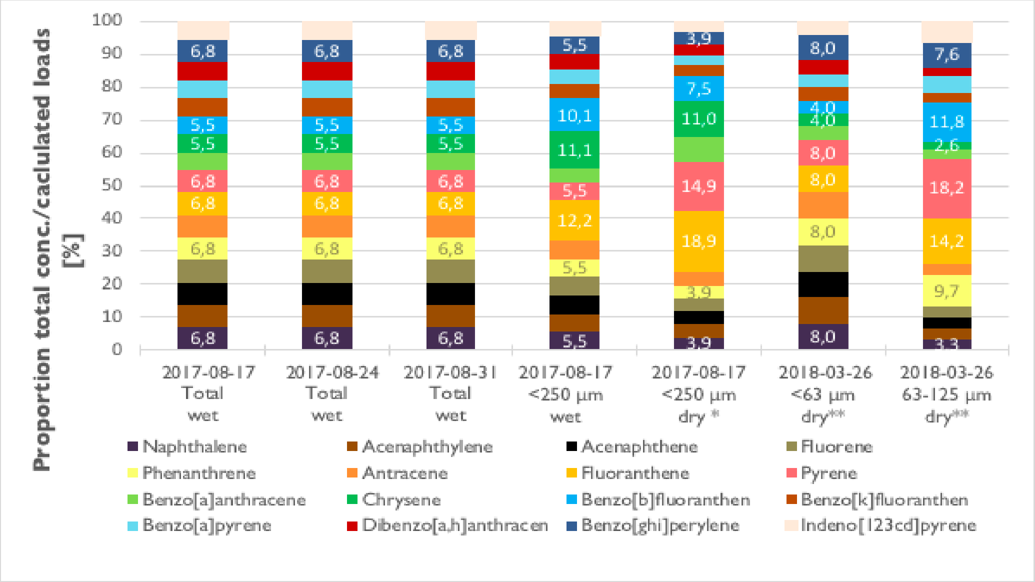


Figure 4.2: Proportion [%] of specific PAHs to total PAH concentrations measured in the street sediment sampled by the street sweeping machine.

4.3.2 Oxy-PAHs

The concentrations of oxy-PAHs in the street sediment (Table 4.4) are complicated to evaluate, because all concentrations of the specific oxy-PAHs analyzed were lower than detection limit for the analysis method. The detection limit for the oxy-PAHs used in this study was higher in some cases than the oxy-PAH concentration measured in road runoff in Gårda sedimentation facility 2015, see Table 4.4. Compared to concentrations of similar oxy-PAHs in stormwater sludge (4.5–200 ng/g DS) and urban soil (0.74–120 ng/g DS) reported by Brorström-Lundén et al. (2010), the concentrations of oxy-PAHs in the street sediment are low. This may imply that stormwater and urban soil are more important sinks than street sediment for the urban-based oxy-PAHs. Considering the low concentrations analyzed the relationship between the concentrations of the oxy-PAHs in the stormwater and in the street sediment can not be evaluated in this study. For future studies, analysis methods with lower detection limit for oxy-PAHs are highly requested as these compounds can cause endocrine disruption to mammalian and yeast cells already in very low ($7.7*10^{-7}$ µg/L) concentrations (Lampi et al. 2006). More information about the toxicity of oxy-PAHs is available in Lundstedt et al. (2007)

Table 4.4: Concentrations of oxy-PAHs [mg/kg DS] in the samples from the street sweeping machine sediment 2018-08-17 and 2018-03-26. The sediment from 2018-03-26 was prior to analysis, dried at room temperature and sieved (<63 µm).

Oxy-PAHs	**2017-08-17 Total**	**2018-03-26 <63 um**	**Road runoff sediment Gårda chamber 2015**[a]
9-fluorenone	<0.1	<0.2	0.14
9,10-Anthraquinone	<0.1	<0.2	0.18
2-methylanthracene-9 10-dione	<0.1	<0.1	0.15
7H-benz[de]anthracen-7-one	<0.1	<0.2	0.12
Benzo[a]anthracene-7,12-dione	<0.1	<0.2	0.26
6H-benzo[cd]pyren-6-one	<0.1	<0.2	0.11
Benzo[a]fluorenone	<0.1	<0.2	0.12
4H-cyklopenta[def]fenantrenon	<0.1	<0.2	<0.1
Naftacen-5,12-dione	<0.1	<0.2	0.13

[a] - meanvalues for conc. of oxy-PAHs [mg/kg DS] in road runoff sediment in the Gårda underground treatment facility chamber no 1, 3, 5 and 7 (Markiewicz et al. 2017)

4.3.3 Phthalates

Out of 13 analyzed phthalates, DEHP, DIDP DBP and DINP were found in significant concentrations in the street sediment (Table 4.5). These compounds were also the most dominant phthalates found in street dust and in soil samples collected around the world with wide ranges of occurrence (Škrbić et al. 2016).

The most frequently found phthalate was DEHP, which occurred in five samples: in three non-sieved (total) samples and two sieved samples from 2017-08-17 (wet and dry). DEHP was also the only detected phthalate in the street sediment sampled by the street sweeping machine in Stockholm (Bjerking AB 2012). Surprisingly, DEHP was detected in low concentrations in the sediment samples from the sampling occasion after the winter break in street sweeping. However, DEHPs concentration in the washwater collected at the same occasion, was high (see chapter 4.5.3), probably depending on sorption to the much smaller size and higher organic content of particles present in the washwater. DEHP concentrations in the sampled street sediment were below DEHP concentrations found in road dust (2.8–14 mg/Kg DS) and

Table 4.5: Concentrations of phthalates [mg/kg DS] in street sediments sampled by the street sweeping machine.

	2017-08-17	2017-08-24	2017-08-31	2017-08-17		2018-03-26	
Phthalates		**Total**		**<250 µm**		**63-125 µm**	**<63 µm**
		wet		**dry**^{a}	**wet**	**dry**^{b}	
Dimethyl phthalate (DMP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Diethyl phthalate (DEP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Di-n-propyl phthalate (DPP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Diisobutyl phthalate (DIBP)	<0.050	<0.050	<0.050	<0.060	<0.050	<0.0010	<0.0010
Di-n-butyl phthalate (DBP)	<0.050	<0.050	<0.050	0.052	0.17	<0.0010	<0.0010
Di-n-pentyl phthalate (DnPP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Di-n-octyl phthalate (DnOP)	<0.050	<0.050	<0.050	<0.10	<0.050	<0.0010	<0.0010
Di-2-ethylhexyl phthalate (DEHP)	0.33	0.23	0.21	0.82	0.60	<0.0010	<0.0010
Benzyl butyl phthalate (BBP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Dicyclohexyl phthalate (DCP)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0010	<0.0010
Diisodecyl phthalate (DIDP)	<2.5	<2.5	<2.5	<2.5	<2.5	<0.010	<0.010
Diisononyl phthalate (DINP)	<2.5	<2.5	<2.5	3.3	<2.5	<0.010	<0.010
Di-n-hexyl phthalate (DnHP)	<0.050	<0.050	<0.050	<0.050	<0.05	<0.001	<0.0010

^{a} - dried at 105 °C
^{b} - dried at room temp.

in road sediment (25–48 mg/kg DS) (Björklund 2011), and street sediment (0.58–2.2 mg/kg DS) sampled by the street sweeping machine in Stockholm (Bjerking AB 2012). Also, Škrbić et al. reported higher DEHP concentrations (1.22 mg/kg DS) in road dust. The street sediment analyzed by Bjerking AB (2012)for DEHP had a lower content of organic matter (1.4–1.5 %), was of a higher particle fraction (3–8 mm and 4–8 mm), and still had higher DEHP concentrations. However, since neither Björklund (2011) nor Škrbić et al. (2016) reported the particle sizes and the organic matter content in road dust and road sediment, the reason for the DEHPs deviant concentrations in the street sediment is complex to explain. This deviation was therefore likely a result of sample non-homogeneity. Furthermore, studies have shown that traffic intensity, as well as antecedent dry period, drainage area, maximum rain intensity, and land use, has an influence on pollutant concentrations in urban runoff (Kayhanian et al. 2003).

Despite of its low vapour pressure, the lower molecular weight DBP was detected in sieved < 250 µm samples from 2017-08-17 with concentrations 0.82 mg/kg (wet sample sent for analysis) and 0.6 mg/kg (dried sample sent for analysis). The fact that out of all LMW phthalates DBP was detected is thought not surprising since it has also been the most used LMW phthalate (KEMI 2018) and since it also has been detected in high concentration in surface waters (Vethaak et al. 2005). These values are however much higher than those reported by Björklund (2011) in road dust <0.10–0.16 mg/kg DS and in road sediment 0.30–0.40 mg/kg DS. Presented values are also above the DBP concentrations in road dust of 0.071 mg/kg DS reported by Škrbić et al. (2016).

DINP was detected in only one samples: wet sieved < 250 µm sediment from 2017-08-17 in concentration of 3.3 mg/kg DS, which is below the DINP values reported in road dust (<5.0–41 µg/g DS) and road sediment of 87–200 mg/kg DS (Björklund 2011). Though the detection frequency of DINPs in street sediment sampled by the sweeper was low, its concentrations are still the highest compare to other analyzed phthalates, which could be explained by the current consumption pattern of phthalates in Sweden (Björklund 2011).

4.3.4 Alkanes

Out of six analyzed groups of alkanes, only C_{16} - C_{35}, was found in high concentrations in the street sediment samples (Table 4.6). These compounds were found in: three total samples and a dry sieved < 250 µm sample from 2017-08-17 and in very high concentrations in samples from 2018-03-26: 658 mg/kg DS in fractions 63–125 µm and 780 mg/kg DS in fraction < 63 µm. These concentrations are far above the reference values of 100 mg/kg DS given for sensitive soil by the SEPA (2009). The alkane fraction of hydrocarbons C_{16} - C_{35} were also the only detected alkanes in the street sediment sampled by street sweeping in Stockholm (Bjerking AB 2012), where the concentrations varied between 18 and 1100 mg/kg DS, and the median value was 24.5 mg/kg DS.

Table 4.6: Concentrations of alkanes [mg/kg DS] in the street sediment sampled by the street sweeping machine.

	2017-08-17	2017-08-24	2017-08-31	2017-08-17		2018-03-26	
Alkanes		**Total**		**<250 µm**		**63-125 µm**	**<63 µm**
		wet		**dry**^{a}	**wet**	**dry**^{b}	
> C_5 - C_8	<10	<10	<10	<10	<10	<4.0	<10
> C_8 - C_{10}	<10	<10	<10	<10	<10	<4.0	<100
> C_{10} - C_{12}	<20	<20	<20	<20	<20	<20	<200
> C_{12} - C_{16}	<20	<20	<20	<20	<20	<20	<200
> C_5 - C_{16}	<30	<30	<30	<30	<30	<24	<260
> C_{16} - C_{35}	120	68	110	<20	120	658	780

^{a} - dried at 105 °C
^{b} - dried at room temp.

4.3.5 Volatile aromatics and alkylated PAHs

All the groups of volatile aromatic hydrocarbons and alkylated PAHs in the street sediment were lower than the detection limit of the methods for analysis (Table 4.7). The results in this study agrees with the analysis results of street sediment sampled with the street sweeping machine in Stockholm (Bjerking AB 2012). Since groups of volatile aromatics and alkylated PAHs were not detected in the street sediment, more studies are recommended but should focus on the washwater as aromatics are more water soluble than corresponding alkanes. This knowledge is crucial for evaluating how the street sediment should be treated and deposited in a sustainable way.

Table 4.7: Concentrations [mg/kg DS] of volatile aromatics and alkylated PAHs in the street sediment sampled by the street sweeping machine.

	2017-08-17	**2017-08-24**	**2017-08-31**	**2017-08-17**		**2018-03-26**	
Aromatics and alkylated PAHs	**Total**			**<250 μm**		**63-125 μm**	**<63 μm**
	wet			**dry^a**	**wet**	**dry^b**	
$> C_8$ - C_{10}	<1	<1	<1	<1	<1	<0.48	<10
$> C_{10}$ - C_{16}	<1	<1	<1	<1	<1.	<1.24	<10
Methylpyrene/methylfluoranthene	<1	<1	<1	<1	<1	<1.0	<10
Methylchrysene/1-methylbenz[a]anthracene	<1	<1	<1	<1	<1	<1.0	<10
$>C_{16}$ - C_{35}	<1	<1	<1	<1	<1	<1.0	<10
Benzene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01
Toluene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05
Ethylbenzene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05
M,p-xylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05
O-xylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05
Xylenes, sum	<0.05	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05
TEX, sum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.1

^{a} - dried at 105 °C
^{b} - dried at room temp.

4.3.6 Phenols and aldehydes

The analysis of the street sediment collected on 2018-03-26 (Table 4.8) show a high concentrations of 4-tert-octylphenol, which was also the most frequently detected AP in aqueous and road runoff sediment samples in a previous study (Björklund 2011). Furthermore, formaldehyde and acetaldehyde, which are among the most abundant OPs identified in vehicle exhausts, such as diesel (M.C. et al. 2012), were detected in the street sediment in high concentrations. The source apportionment of aldehydes showed on-road emissions, to be the most common sources (Markiewicz et al. 2017). Other important sources of aldehydes are brake linings and tire wear (Rogge et al. 1993). The concentrations of formaldehyde and acetaldehyde in this study are in the same range as the in sediment in Gårda (Markiewicz et al. 2017): 5.7 mg/kg DS and 1.7 mg/kg DS, respectively. The analysis of the source apportionment of aldehydes showed on-road emissions to be the most common sources.

The concentration of 4-tert-octylphenols (4-t-OPs) is close to previously reported in road dust (0.01–0.43 mg/kg) and in road sediment (0.36–0.96 mg/kg DS) (Björklund

Table 4.8: Concentrations [mg/kg DS] of aldehydes, alkylphenols and alkylphenol ethoxylates [mg/kg DS] in the street sediment sampled 2018-03-26. The sediment was dried in room temperature and sieved (<63 µm) prior the analysis.

Aldehydes	**Conc.**	**Phenols and its ethoxylates**	**Conc.**
Formaldehyde	5.1	Bisphenol A	<0.10
Acetaldehyde	7.6	4-tert-octylphenols	0.15
Propionaldehyde	<2.0	4-tert-OP-monoethoxylates	<0.10
Butyraldehyde	<2.0	4-tert-OP-di-ethoxylates	<0.040
Glutaraldehyde	<2.0	4-tert-OP-tri-ethoxylates	<0.020
		4-nonylphenols	<0.10
		4-NP-monoethoxylates	<0.10
		4-NP-di-ethoxylates	<0.15
		4-NP-tri-ethoxylates	<0.20

2011). Considering that 98 % of 4-t-OP in EU are used fore tire manufacturing (DEFRA 2008), 4-t-OP in the sediment may indicate the presence of tire wear particles. 4-nonylphenols previously detected in street sediment sampled by street sweeping in Stockholm (Bjerking AB 2012) were not detected in the street sediment analyzed in this study.

All these OPs were previously analyzed in washwater from the first sampling occasion (2017-08-17), but were not detected. The presence of these substances in the sediment from 2018-03-26 can be explained by the 3.5 months build-up time and octylphenol´s low solubility in water.

4.4 Particle distribution in washwater

4.4.1 Nanoparticles by Litersizer$^{\text{TM}}$ 500

The particle size distribution in the washwater analyzed with the Litesizer is presented in Figure 4.3. The results show that the samples from the sweeping machine contain particles finer than 1 nm. The results are also presented as the 10th (D10), 50th (D50) and 90th (D90) percentile values. The mean D10 value for samples from 13 sampling occasions was calculated to 10 nm, implying that 10 % of the particles in the washwater were approximately 10 nm in diameter. The same procedure was applied for the calculation of the mean D50 and D90 values for the 13 sampling occasions. These values were estimated to 893 and 1582 nm, respectively. The PSD curves illustrated in Figure 4.3 show that particles < 40 nm are more randomly distributed than those from 91–300 nm, where six of 13 samples have the similar pattern. A similar unimodal distribution around 100 nm was also reported by Nielsen (2015) for stormwater, and by Munz (2018) for water from carwashing.

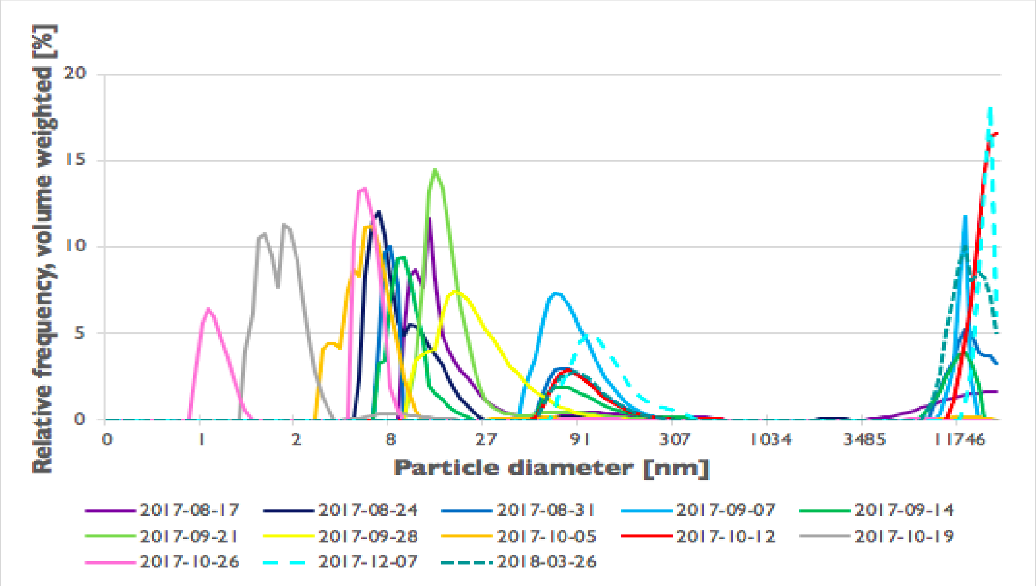


Figure 4.3: Particle size distribution in washwater sampled by a street sweeping machine at 13 different occasions around Sahlgrenska Hospital area. Analyzed by dynamic light scattering (Litesizer$^{\text{TM}}$500).

Several washwater samples contained particles > 0.45 µm in diameter, despite the filtration of the samples with a 0.45 µm filter (Figure 4.3). The occurrence of larger particles in the samples may be explained by a possible aggregation of particles after filtration. Therefore the zeta potential was measured in all washwater samples to determine if particles were stable or not. The results presented in Table 4.9 shows that the values of the zeta potential were in the range of > -30 mV, < +30 mV, which indicates an instability of particles because repulsive forces between the particles are low. Similar results with zeta potential varying between -1.5 mV and

-26 mV were observed in the water from carwashing (Munz 2018), -15.8–29.6 mV in stormwater (Nielsen 2015) and -22.6 ± 1.2 mV in stormwater particles from a highway bridge (Kim et al. 2008). However, zeta potential is dependent on the pH in the liquid surrounding the studied particles (Kim et al. 2008). The washwater samples used for the zeta potential analysis were also used for measurements of particle size distribution (PSD). However, the PSD and zeta potential analysis were performed at different occasions and samples could be oxygenated while working with the samples. This could lead to an uneven change of pH of the washwater samples, which in turn could cause the shifting flocculation ability of particles and therefore fluctuation in PSD.

Table 4.9: Zeta potential [mV] in the washwater sampled by the street sweeper. Measurements were performed by dynamic light scattering (Litesizer®500).

Sampling date	Zeta potential
2017-08-17	-11
2017-08-24	-24
2017-08-31	n.a.[a]
2017-09-07	-1.5
2017-09-14	-9.1
2017-09-21	-5.6
2017-09-28	-14
2017-10-05	n.a.[a]
2017-10-12	-5.2
2017-10-19	-3
2017-10-26	-4.8
2017-12-07	n.a.[a]
2018-03-26	-22
WDS Before	-10
WDS After	-4.3

[a] - not analyzed

Figure B.4 in Appendix B shows a PSD for a washwater with all particles < 450 nm. Each curve is based on the mean value for three replicates. To achieve these three replicates, the samples were analyzed up to 10 times in a row. Note that the shape and the distribution of the curves in Figure B.4 are similar to the results in Figure 4.3.

There are very few studies regarding PSD in stormwater (Nielsen 2015; Markiewicz et al. 2018). Particles in stormwater are distributed in a similar range (5 to approximately 300 nm) as the particles in washwater from street sweeping (between 1 and 307 nm). Analyzed water from carwashing shows a similar but narrower PSD distribution, 70–250 nm (Munz 2018), than the PSD in this study. The studies by Nielsen (2015) and Munz (2018) were performed with similar instruments, measuring particle volumes relative to each other, which makes the results easier to compare.

The origin of the nano particles are not possible to determine, but is worth to notice that particles presented in Figures 4.3 and 4.4 are in the same order of magnitude as aerosols (d_{mean} = 15–50 nm) generated by simulated interaction between tires and pavement (Dahl et al. 2006), and similar to particles with a mean value of 100 nm generated from simulated interaction between summer- and unstudded winter tires and pavement (Gustafsson et al. 2009). In this study it was assumed that various traffic related sources would show a characteristic distribution pattern of PSD, which would allow to draw conclusions about the most dominant source to studied street sediment. However, after reviewing an extensive work of non-exhaust-related traffic emissions by Grigoratos et al. (2014), as well as both exhaust and non-exhaust based road traffic emissions by Pant et al. (2013), it was concluded that the analysis of characteristic PSD from specific sources in sampled street sediment is too complex. The complexity depends on a high number of available exhaust-related and non-exhaust-related sources, such as particles from road- and tire wear, and factors affecting their build-up patterns, including speed, road surface, tire type (Gustafsson et al. 2009) as well as vehicle weight and ambient temperature (Johansson et al. 2008; Olivares et al. 2007). It should be noted that the same source as for example tire wear, showed a wide variance of the PSD in the literature reviewed by Grigoratos et al. (2014). In addition, the distribution of exhaust emission showed different distribution types as unimodal, bimodal and trimodal (Pant et al. 2013), which indicates that a broad spectrum of particles occurs on the roads.

4.4.2 Nanoparticles by Nanosight NS 300

The Nanosight analysis of the washwater samples showed that nanoparticles are present in all samples (Figure 4.4). The mean D10, D50 and D90 values of the total number of particles from the 13 sampling occasions were 124 nm, 177 nm and 250 nm respectively. This indicates that although smaller nanoparticles are present in the washwater samples, particles 90–300 nm in diameter occur in highest concentration in all samples. The PSD determined in the washwater samples from the street sweeping machine in this study is in the same range, approximately 25–300 nm, as the PSD in the water, also analyzed with Nanosight, from carwashing (Munz 2018).

The higher concentrations of nanoparticles in the sample collected 2017-09-28 may depend on the low precipitation load and intensity the week before sampling (see Figure 3.2 and Table 3.1). The Nanosight measure concentrations of all particle sizes on this date, less dilution had probably occurred due to dryer road surface.

A significant decrease of nanoparticles collected by the street sweeper could be observed when studying the change of D90 value over time (Figure B.3 in Appendix B). At the same time, a more constant value of D10 could be observed. These findings may indicate effects of the scrubbing motion of the machine brush, which with time cracks coarser particles to finer ones. Similar effect on the PSD after street sweeping were also reported by Vaze et al. (2002).

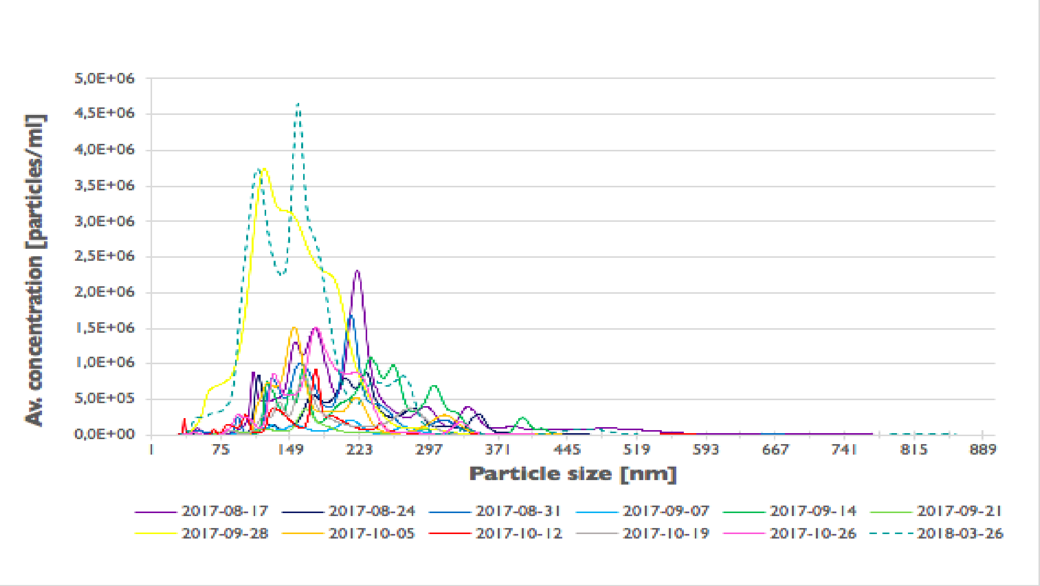


Figure 4.4: Particle size distribution in washwater sampled by a street sweeping machine at 11 different occasions around Sahlgrenska Hospital area. Analysis was performed by Nanosight NS 300.

One hypothesis was that the particle size would decrease the longer the sweeping period proceeds because the sweeping machine should manage to pick up more of the finer particles, once the layer of larger particles is removed. However, no general PSD shifting towards smaller particle size in the washwater sampled with more frequent street sweeping was observed (Figures 4.3 and 4.4). Results from the dynamic light scattering measurements (Litesizer and Nanosight) did neither show any apparent decreasing trend of the D10 values representing finer particles (Figures B.2 and B.3 in Appendix B). However, a slight decreasing trend of the D50 and D90 was observed when studying the results from the Nanosight measurement showed in Figure B.3.

Another hypothesis was that the number of nanoparticles would increase after the introduction of studded tires, because of increase of the wear of the road material (Gustafsson et al. 2008). This hypothesis was not proven: the number of particles from 2017-12-07 and 2018-03-26 (Figure 4.3), after an interruption in the weekly sweeping routine and introduction of compulsory usage of studded tires do not tend to increase.

4.4.3 Ranges and limitations of the Litesizer^{TM} and Nanosight

It is complex to compare the results for PSD between samples analyzed with different instruments. Some instruments, such as Zetasizer using DLS, used by Nielsen (2015), or Litesizer, measure occurrence of particles with different diameter relative to each other. The particle size is weighted by particle volume. Others, such as Nanosight NS 300 by Malvern Instruments Ltd. or Scanning Mobility Particle Sizer (SMPS) by TSI used by Gustafsson et al. (2009), count the particles in a certain volume, filled with either air or water. Not only the approach of the instrument is different, the range of the particle sizes they are capable of measuring varies. Furthermore, for examples studies about the PSD in air pollution, characterize the datasets with diverse parameters including mean-, median- and peak values as well as ranges and number of peaks.

The comparison of the Litesizer and Nanosight shows that the results can be complements to each other. The description of their ranges and limitations are as follows.

During PSD analysis, Litesizer^{TM} 500 measures particles ranges between 0.3 nm and 10 µm in diameter, while for the Zeta-potential analysis larger particles are detectable, 3.8 nm – 100 µm (Anton Paar 2018). One of the factors, which affect the quality of the particle-size measurements is the particle concentration. The ideal concentrations vary for different particles sizes. High concentration of particles may lead to multiparticle scattering of the light or distortion of the Brownian motion of the particles, which can lead to distortion of the measurements. Low concentrations may lead to a lack of scattering light, and no measurement is possible. The concentrations of particles were not measured before the analysis with Litesizer^{TM}. However, the detected light intensity for the analyzed samples ranges between 72 and 333 kcounts/s (Table B.2 in Appendix B), which is above the minimum value, recommended by the manufacturer Anton Paar. The filter optical density for the measured samples varied between 0 and 1.55, where the filter density of 0 suggests that the sampled concentration is too low. If count rate if sufficient, which it was in measured samples, the results may still be meaningful. Therefore, the concentrations of measured samples can be evaluated as sufficient, for achieving good quality PSD and Zeta-potential measurements.

The Nanosight NS300 Ltd. measures the concentration of particles by combining the light scattering microscopy with tracking the core of each particle using a charge-coupled device camera. The particle ranges it recognizes is 10 nm to 2000 nm (Malvern Panalytical 2018), which is low compared to the Litesizer´s measuring range. This implies that particles below 10 nm and above 2000 nm, undetected by Nanosight (Figure 4.4), but recognized by Litesizer (Figure B.4), should be considered. However, since the Nanosight is using two techniques for the particle detection the results it presents may be more reliable than the results from Litesizer measurements. Possible error source for the Nanosight results may be the imperfectly selected focus of the camera, which allows actual time visualization for identifying and tracking the core of each particle. However, the focus-related errors are here considered neglectable, because it was carefully adjusted for each measurement.

4.4.4 Organic matter in the washwater

The amount of total suspended solids (TSS) in sampled washwater (226–51 000 µg/L) is extremely high, compared to the guideline value (25 µg/L), formulated by the Environmental administration of the City of Gothenburg (Göteborgs Stad 2013). Considering that these particles may transport OPs and other pollutants, the geographical position of the site for temporal dumping of material sampled by the street sweeping machine, should be carefully chosen. Analysis of volatile suspended solids (VSI) in the washwater showed a presence of organic matter in the fine (<1.0 µm) street sediment sampled by the street sweeper (Figure 4.5). Organic matter in the suspended solids in the washwater ranges approximately between 50 and 86%.

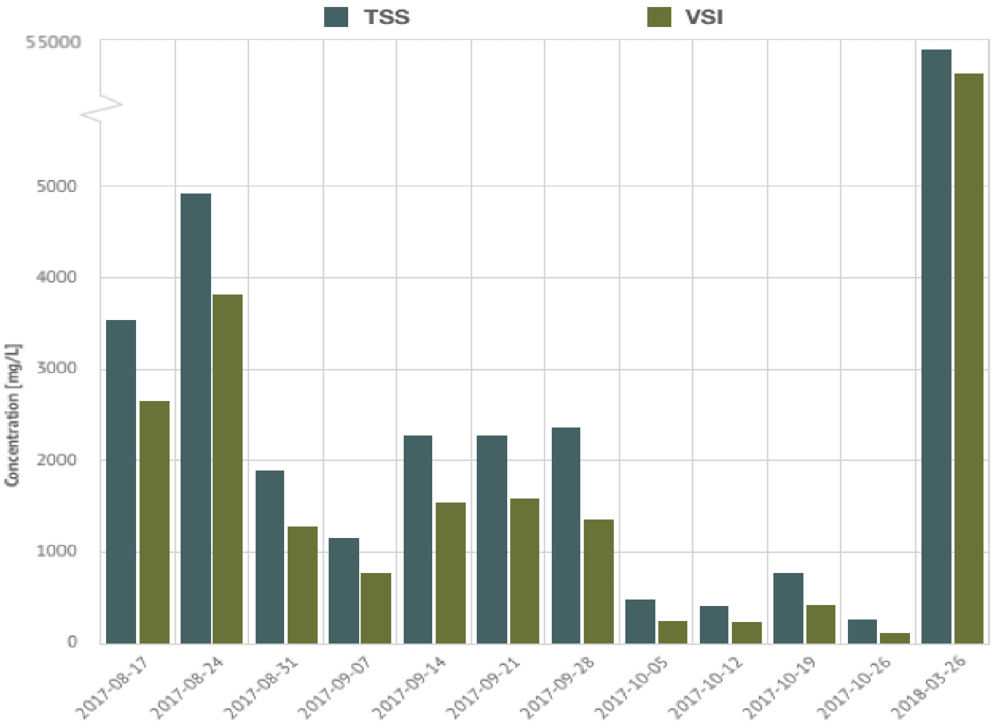


Figure 4.5: Total suspended solids (TSS) and volatile suspended solids (VSI) ≈ organic matter (both in mg/L) in the street sweeper washwater samples. The pore size of the used filter was 1.0 µm.

4.5 Organic pollutants in the washwater

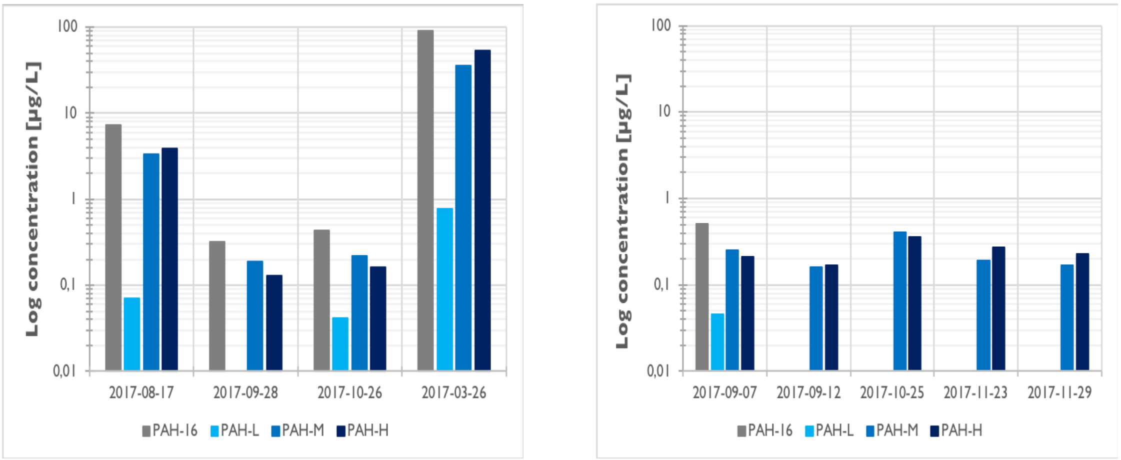
In total, 16 specific PAHs (Table 4.10), nine specific oxy-PAHs (Table 4.11), 13 specific phthalates (Table 4.12), 16 alkanes and aromatics (Tables 4.13 and 4.14), eight phenols and five specific aldehydes (Table 4.15) were analyzed in the washwater samples (Appendix C). All 16 PAHs as well as up to five oxy-PAHs, nine hydrocarbons, three phthalates were detected. The analysis of organic pollutants in the washwater also shows high concentrations of PAHs (Figure 4.6), phthalates (Table 4.12) and alkanes (Table 4.13). Analyzed phenols and aldehydes were not detected in the samples from the first sampling occasion of washwater, and therefore not included in further studies.

4.5.1 PAHs

Both washwater and stormwater samples had low concentrations of PAH-L (Figure 4.6). Due to their high volatility, PAH-L are readily released from the sediment, and therefore not found in street sediment washwater samples. Similar observation were made by Lau et al. (2005), studying PAHs in urban street sediment. Results for the stormwater quality, measured during the street sweeping for this study are reported by DHI Sverige (2017). The concentrations of PAH-16 in the washwater samples from 2017-08-17 were up to 16 higher than in the stormwater from 2017-09-07, and in stormwater from the same area measured in 2016 (DHI Sverige 2016). The concentrations of PAH-M and PAH-H in the washwater were from several times to several magnitudes higher than in the stormwater samples (Figure 4.6). This imply that the street sediment is an important sink for PAHs emitted in the traffic environment. Therefore, the importance of street sweeping for removal of PAHs should not be underestimated.

Although there is a decreasing trend in concentrations of PAH-M and PAH-H in stormwater and washwater after the first street sweeping event (2017-08-17), the concentrations are not further decreased with frequent street sweeping. These findings may depend on the constant additional flow of these pollutants or/and wind/rainfall transportation of pollutants. In addition, the pollutant may originate from the free load, which before the sweeping have been fixed in the pavement cracks and that become more available after the sweeping. These particles can then more easily be removed by wash-off by stormwater or by the sweeping machine (Vaze et al. 2002).

Due to lack of data it is not possible to compare concentrations of PAH-L, PAH-M and PAH-H in stormwater before the sweeping period and to concentrations measured during this study. However, the mean concentration of PAH-16 in stormwater (1.6 µg/L) (DHI Sverige 2016) before the sweeping period, have decreased to 0.51 µg/L (Figure 4.6) during the sweeping period. The concentration of specific PAHs, for example benzo[a]pyrene, in the stormwater have decreased by 58% with the weekly frequent sweeping during autumn 2017 (Göteborg Stad 2018).



(a) Washwater **(b)** Stormwater

Figure 4.6: Comparison of concentrations [µg/L] of PAHs in washwater from the street sweeping machine and stormwater (Göteborg Stad 2018) collected during rain events with flow-proportional sampling downstream of the swept area.

Table 4.10 shows that the number of detected specific PAHs in the washwater is higher than in the street sediment (Table 4.3). The street sediment from 2017-08-17 and 2018-03-26 contained up to three and seven specific PAHs respectively, while the washwater from the same sampling occasions contained nine and 13 specific PAHs. Therefore, in future studies it is recommended to extract, for instance by filtration and subsequent sieving, the washwater particles and focus the analysis on the presence of OPs such as PAHs, alkanes, phthalates and aromatics. The extraction of washwater particles is important also because it enables the estimation of their removal rate with different stormwater treatment techniques.

Since PAH concentrations in the washwater are expressed in mg/L it is complicated to compare these results to other studies about street sediment quality. An attempt to compare PAH concentrations in the washwater to the Canadian Environmental Quality Standards (CEQGs) for the protection of Aquatic Life and to the Environmental Quality Standards formulated by European Commission shows that these guideline values were exceeded in most of washwater samples. Furthermore, the concentrations (3.4 µg/L; 0.13 µg/L; 0.14 µg/L and 44 µg/L) of PAHs, previously labeled by as "carcinogenic", in the washwater from the street sweeping machine were occasionally above the guideline value of 0.2 µg/L for the pollution level of the groundwater at the gasoline polluted sites, given by the SEPA (1998). However, the dilution of the concentrations when released to the environment at temporary dump site were not considered here. It though should be noted that since several of PAHs are bioaccumulative these substance will accumulate in the environment. Therefore not only their concentrations in the washwater should be studied by also the frequency of their release into the environment, e.g. site for the temporal storage of collected street sediment.

Table 4.10: The concentrations in [µg/L] of 16 specific PAHs in the washwater samples by the street sweeping machine during autumn 2017 and spring 2018.

PAHs	**2017-08-17**	**2017-09-28**	**2017-10-26**	**2018-03-26**	**CEQG (for the Protection of Aquatic Life[a])**	**MAC_EQA Other surface water[b]**
Naphthalene	0.039	<0.030	<0.030	0.24	1.1	
Acenaphthylene	<0.010	<0.010	<0.010	0.31		
Acenaphthene	0.032	<0.010	0.041	0.22	5.8	
Fluorene	0.038	<0.010	0.013	0.64	3	
Phenanthrene	0.55	0.050	0.051	9.1	0.4	
Antracene	0.091	0.010	<0.010	0.95	0.012	0.1
Fluoranthene	1.4	0.056	0.065	11	0.04	0.12
Pyrene	1.3	0.075	0.094	14	0.025	
Benzo[a]anthracene	0.64	0.031	0.029	5.1	0.018	
Chrysene	0.67	0.04	0.031	6.0		
Benzo[b]fluoranthene	0.92	0.042	0.034	14		0.017
Benzo[k]fluoranthene	0.23	<0.010	0.014	3.2		0.017
Benzo[a]pyrene	0.59	0.02	0.021	5.5	0.015	0.027
Dibenzo[a,h]-anthracen	0.10	<0.010	<0.010	2.6		
Benzo[g,h,i]perylene	0.42	<0.010	0.021	10		0.00082
Indeno[1,2,3-c,d]pyrene	0.31	<0.010	0.013	7.6		

[a] - Canadian Environmental Quality Standards (CEQGs) for the protection of Aquatic Life

[b] - Environmental Quality Standards 2013 formulated by European Commission (MAC = Maximum Allowed Concentration).

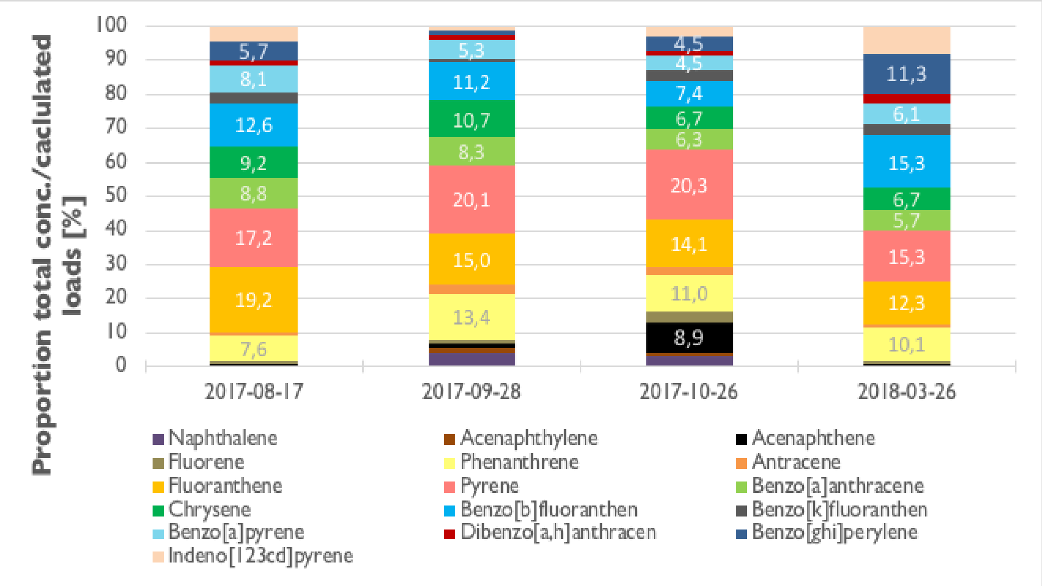


Figure 4.7: Proportion [%] of specific PAHs to total PAH concentrations measured in the washwater sampled by the street sweeping machine.

Considering the high TSS concentrations and the high abundance of PAHs in the washwater, as well as minor abundance of PAHs in the street sediment sampled by the street sweeping machine, future studies are recommended to focus on measuring PAH concentrations in fine street sediment particles following with the washwater during emptying of the street sweeping machine. This will make the results more comparable to other studies, since most of the studies about street sediment/dust quantify pollutants either per kilogram of the solid material or per square meter. Assuming that street sediment particles in the washwater are finer than in the settled street sediment, these studies will also widen the knowledge of PAH associated with smaller particles.

Figure 4.7 presents the proportional distribution of specific PAHs in the washwater sampled by the street sweeper. The dominating PAHs in the washwater, were pyrene, fluoranthene as well as benzo[b]fluoranthene. Proportions of chrysene, phenanthrene and benzo[g,h,i]perylene were less dominant but still significant. These six substances were also dominating in the street sediment sampled by the street sweeper. Since the concentrations of the undetected PAHs in the washwater were estimated to a half of the detection limit, the most reliable results are from 2018-03-26, when all PAHs were found in concentrations above the detection limit.

Phenanthrene, pyrene, chrysene and fluoraanthene also dominated among the PAHs found in the water from carwashing (Munz 2018). Significant concentrations of phenanthrene, pyrene, fluoroanthene and benzo[g,h,i]perylene were registered in tire wear particles (Gustafsson et al. 2009). Phenanthrene, pyrene and fluoroanthene was found dominating for gasoline profile (Spezzano et al. 2008). No apparent trends of higher concentrations of lighter weighted PAHs, such as phenanthrene, pyrene and fluoroanthene, in samples from 2018-08-17 and 2017-09-28 (period of summer tire usage) were observed. The dominance of heavy weighted PAHs, such as benzo[g,h,i]perylene and indeno[123cd]pyrene, were more apparent in the washwater samples from the period when winter tires were allowed (1/10 - 15/4). This result agrees with results of Gustafsson et al. (2009) comparing PAHs profiles for the wear of winter and summer tires. The concentrations of naphthalene, which otherwise is present in high concentrations in lubricant motor oils (Souza et al. 2016), diesel and petrol emissions (Ntziachristos et al. 2017), were much lower in the washwater than in the street sediment. These findings are strange as naphthalene is the most volatile and water soluble of the 16 specific PAHs.

4.5.2 Oxy-PAHs

Several high molecular weight oxy-PAHs were analyzed in high concentrations in the washwater sample from 2017-09-28 (Table 4.11), and in the same order of magnitudes PAH-H and PAH-M in the washwater from the same date and from 2017-10-26 (Figure 4.6). Furthermore, some of the individual oxy-PAHs, i.e. 6H-benzo[cd]pyren-6-one and naftacen-5,12-dione, were present in the washwater, in much higher concentrations than the compounds they originate from, which could depend on the oxidation of certain PAHs to oxy-PAHs (Cordeiro et al. 2009). It can also be explained by the fact that oxy-PAHs have higher solubility in water compare to PAHs (SEPA 2007). However, similar notification of the distribution oxy-PAHs and PAHs concentrations, and higher concentrations of several oxy-PAHs have also been noticed by Lundstedt et al. (2007), who studied these compounds in soils from contaminated cites. Surprisingly, the oxy-PAHs detected in the washwater are less soluble in water than the other oxy-PAHs analyzed.

A comparison of occurrence of oxy-PAH in the washwater and in the street sediment is not possible as no oxy-PAHs were detected in the street sediment. However, these compounds were analyzed in only one washwater and two street sediment samples, why oxy-PAHs may still be found in street sediment. Considering the toxicity of oxy-PAHs, including endocrine disruption (Machala et al. 2001; Kurihara et al. 2005), cytotoxic effects on mammals (Zhu et al. 1995) and mutagenicity (Chesis et al. 1984; Sakai et al. 1985), future studies are therefore recommended for screening of the presence of oxy-PAHs in street sediment samples.

Table 4.11: Concentrations [µg/L] of detected oxy-PAHs and their corresponding in the washwater from 2017-09-28 sampled by the street sweeping machine.

oxy-PAHs	**Conc.**	**PAHs**	**Conc.**
9-fluorenone	<0.1	Fluorene	<0.010
9,10-Anthraquinone	<0.1	Anthracene	0.010
2-methylanthracene-9 10-dione	<0.1	Methylanthracene	n.a.[a]
7H-benz[de]anthracen-7-one	0.17	Dibenzo[a,h]antracen	<0.010
Benzo[a]anthracene-7,12-dione	0.16	Dibenzo[a,h]antracen	<0.010
6H-benzo[cd]pyren-6-one	0.30	Benzo[a]pyrene	0.021
Benzo[a]fluorenone	0.28	Benzo[a]fluorene	n.a.[a]
4H-cyklopenta[def]fenantrenon	<0.1	Cyclopenta[d,e,f]phenanthrene	n.a.[a]
Naftacen-5,12-dione	0.11	Naphthalene	<0.030

[a] n.a. = not available

4.5.3 Phthalates

Two common high molecular phthalates, i.e. DINP and DEHP, were detected in the washwater in high concentrations (Table 4.12). Di-iso-butylftalat (DIBP) was detected (1.2 µ/L) in the washwater from 2018-03-26. The concentrations of DEHP were similar to the concentrations found in stormwater up 5 µg/L (Björklund 2011), 0.45–24 µg/L (Clara et al. 2010), 3–8.5 µg/L (Birch et al. 2011) and 3–58 µg/L (Zgheib et al. 2012). The results show that the concentrations of DEHP exceed the European environmental quality standard (Directive 2008/105/EC) in surface water (both AA and MAC 1.3 µg/L), and the Canadian freshwater quality guidelines protection of aquatic life of 19 µg/L in several of the washwater samples. Concentrations of DINP in washwater were up to twice as high as previously detected in stormwater <0.1–85 µg/L (Björklund 2011). The higher concentration of DINP compared to DEHP can be considered as reasonable. However, the fact that DEHP is still found and potentially being emitted in urban environments after restriction on use is of high concern. Considering DEHP´s toxicity and its occurrence in high concentrations in urban road environment, but also its replacement by other phthalates, future studies are highly recommended to focus on analysis of a range of both low and high molecular weight phthalates in stormwater and urban sediment.

Table 4.12: Concentration in [µg/L] of selected phthalates in the washwater sampled with the sweeping machine.

Phthalates	2017-08-17	2017-09-28	2017-10-26	2018-03-26
Dimethyl phthalate (DMP)	<1.0	<1.0	<1.0	<1.0
Diethyl phthalate (DEP)	<1.0	<1.0	<1.0	<1.0
Dipropyl phthalate (DPP)	<1.0	<1.0	<1.0	<1.0
Di-n-butylphthalate (DBP)	<1.0	<1.0	<1.0	<1.0
Diisobutyl phthalate (DIBP)	<1.0	<1.0	<1.0	1.2
Dipentylphthalat (DnPP)	<1.0	<1.0	<1.0	<1.0
Di-n-octyl phthalate (DnOP)	<1.5	<1.0	<1.0	<2.5
Di-2-ethylhexyl phthalate (DEHP)	22	<1.0	1.7	21
Benzyl butyl phthalate (BBP)	<1.0	<1.0	<1.0	<1.0
Dicyclohexyl phthalate (DCP)	<1.0	<1.0	<1.0	<1.0
Diisodecyl phthalate (DIDP)	<40	<20	<5.0	<40
Diisononyl phthalate (DINP)	150	<20	<11	<230
Di-n-hexyl phthalate (DnHP)	<1.0	<1.0	<1.0	<1.0

Among the low molecular weight (LMW) phthalates, DIBP, which is the main marketed all-round alternative to DBP (ECB 2009), was the only detected in the washwater. This was not surprising since it has a high water solubility (20 mg/L) (ECHA 2014b). The fact that di-isobutyl phthalate was detected in washwater while another LMW phthalate, DBP, was found in the street sediment sampled by the street sweeping machine can be explained by the higher solubility of DIBP (ECHA 2014a). Though DIBP has been detected only in the sample from 2018-03-26, more studies are recommended to quantify its occurrence in urban runoff, because of its high solubility and endocrine disrupting properties (ECHA 2014b).

4.5.4 Alkanes

The number of alkanes detected in high concentrations in washwater (Table 4.13) is much higher than in the road sediment, where only one alkane group of compounds i.e. C_{16} - C_{35} was detected. The Hydrocarbons with the highest number of carbons (C_{16} - C_{35}) were also found in the highest concentrations in the washwater. The presence of C_{16} - C_{35} in high concentrations was unexpected considering that heavier hydrocarbons tend to be the least soluble in water, but it was also expected because the more volatile alkanes have already been evaporated into air. However, a similar trend was identified in road runoff water sampled at the inlet into the Nogawa River (Yamane et al. 1990), with alkanes C_{11} - C_{30}.

The concentrations of all alkanes were several times higher in the sample from 2018-03-26 than in the other samples (Table 4.13). Meanwhile, the concentrations of DEHP, the only detected phthalate in the washwater, from 2018-03-26 is similar to the concentrations found in the washwater from 2017-08-17. Considering the build-up time for the first sampling occasion (2017-08-17) was one month, and three months during winter for the last sampling occasion (2018-03-26) the alkanes are the

Table 4.13: Concentrations [µg/L] of selected alkanes in washwater sampled with the street sweeping machine.

Alkanes	**2017-08-17**	**2017-09-28**	**2017-10-26**	**2018 -03-26**
$>C_5$ - C_8	<10	16	<10	<10
$>C_8$ - C_{10}	<10	<10	10	<10
$>C_{10}$ - C_{12}	12	21	18	96
$>C_{12}$ - C_{16}	24	13	16	250
$>C_5$ - C_{16}	36	50	34	350
$>C_{16}$ - C_{35}	1720	185	1420	37500

most dominant of the measured pollutants in urban traffic environments. The nonlinear relationship between build-up time and concentrations of fuelrelated pollutant such as alkanes and PAHs could depend on the lower ambient air temperature and the cold-start conditions, which have been shown to cause higher PAHs emission for diesel vehicles (Alves et al. 2015), as well as higher PAHs and oxy-PAHs emission for ethanol/gasoline fuelled vehicles (Trifa et al. 2018).

4.5.5 Volatile aromatics and alkylated PAHs

Volatile aromatic hydrocarbons and alkylated PAHs were detected in two washwater samples, i.e. from 2017-08-17 and 2018-03-26 (Table 4.14). The aromatic fraction of C_{16} - C_{35} hydrocarbons is several times lower than the alkane fraction, which is reasonable due to the higher volatility of the aromatics.

As oxy-PAHs and aromatics were found in higher concentrations in the washwater than in the street sediment, it is considered that these substances rather dissolve or become attached to colloids than bond to road sediment. For this reason, it is of high importance to investigate these groups of compounds in stormwater in future studies.

4.5.6 Phenols and aldehydes

Only the washwater from one sampling occasion (2017-08-17) was analyzed for presence of aldehydes, alkylphenols and alkylphenol ethoxylates. Non of these substances were detected in concentrations higher than the limit of detection (Table 4.15).

The absence of alkylphenols in the washwater and their presence in the street sediment (Table 4.8) could be explained by alkylphenol´s tendency to stick onto particles when released in natural waters (Ferguson et al. 2001). Furthermore the detection limit for the applied analyzing method is high. The substances are therefore recommended to be analyzed with another technique, which may have a lower detection limit.

Table 4.14: Concentrations [µg/L] of selected valatile aromatics and alkylated PAHs in washwater sampled with the street sweeping machine.

Aromatics and alkylated PAHs	2017-08-17	2017-09-28	2017-10-26	2018-03-26
>C_8 - C_{10}	<0.30	0.68	0.060	1.4
>C_{10} - C_{16}	0.39	<0.79	<0.93	10
Methylpyrene/ methylfluoranthene	<1.0	<1.0	<1.0	11
Methylchrysene/ 1-methylbenz[a]anthracene	1.1	<1.0	<1.0	46
>C_{16} - C_{35}	1.1	<1.0	<1.0	58
Benzene	<0.20	<0.20	<0.20	<0.20
Toluene	<0.20	<0.20	<0.20	<0.20
Ethylbenzene	<0.20	<0.20	<0.20	<0.20
M,p-xylene	<0.20	<0.20	<0.20	<0.20
O-xylene	<0.2	<0.20	<0.20	<0.20
Xyleners, sum	<0.20	<0.20	<0.20	<0.20
TEX, sum	<0.40	<0.40	<0.40	<0.40

Since aldehydes are the alkane derivatives, their absence in the washwater could be explained by the stability of the detected in the washwater alkanes. The conditions for the formation of aldehydes could also be unfavorable.

Table 4.15: Concentrations [µg/L] of detected aldehydes as well as alkylphenols and alkylphenol ethoxylates [µg/L] in the washwater sampled 2017-08-17.

Aldehydes	Conc.	Phenols and its ethoxylates	Conc.
Formaldehyde	<100	Bisphenol A	n.a.
Acetaldehyde	<100	4-tert-octylphenols	<0.26
Propionaldehyde	<100	4-tert-OP-monoethoxylates	<0.040
Butyraldehyde	<100	4-tert-OP-di-ethoxylates	<0.14
Glutaraldehyde	<100	4-tert-OP-tri-ethoxylates	<0.10
		4-nonylphenols	<2.3
		4-NP-monoethoxylates	<1.1
		4-NP-di-ethoxylates	<0.90
		4-NP-tri-ethoxylates	<3.7

n.a. - not analyzed

4.5.7 Chemical parameters

Other parameters, such as conductivity, turbidity, pH of the washwater sampled by the street sweeping machine, and the street sediment sampled by the WDS are available in Table B.1 in Appendix B. These values will however not be evaluated in this report.

4.6 Wet dust sampling before and after the street sweeping

4.6.1 PSD of the street sediment sampled with the WDS

The PSDs for the street sediment sampled with WDS and analyzed with Litesizer and Nanosight are presented in Figures 4.8 and 4.9.The results from both instruments suggest that the street sweeper, though it has an obvious ability to sample a wide range of nanoparticles, also leaves out particles. This can be concluded noticing that both the relative frequency and the concentration of particles before and after the street sweeping is similar. Alternatively, the street sweeping may also marginally contribute to the increase of the sediment particles which are not fixed to the street surface and can easily be removed (free load). The increase of the free load and decrease of the fixed load by the scrubbing motion of the brush associated with street sweeping was also discussed by Vaze et al. (2002). In addition, German et al. (2002) recognized an increase in the fine-grained street sediment load, after the street sweeping event.

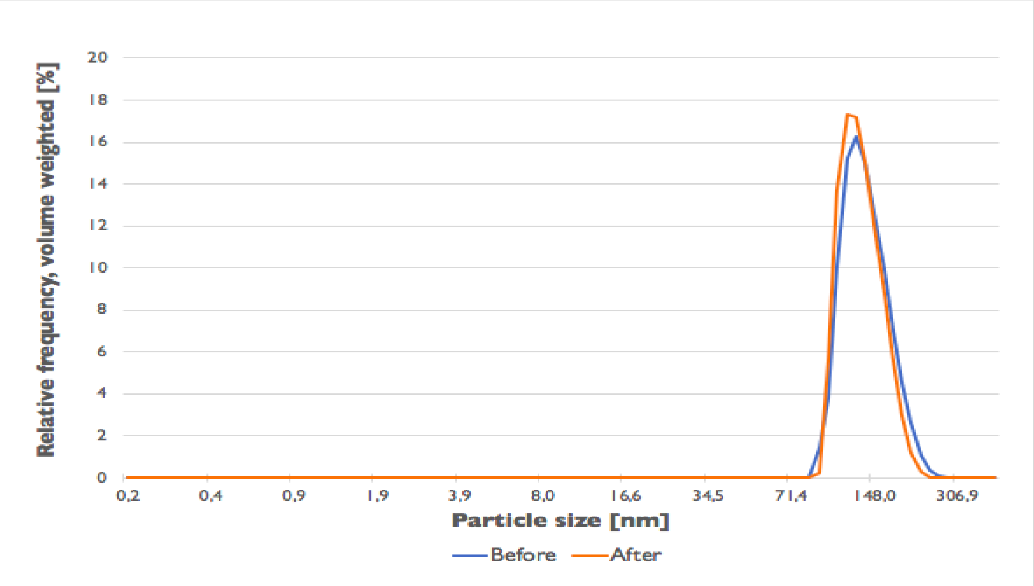


Figure 4.8: Particle size distribution in street sediment sampled at Sahlgrenska by WDS before and after the street sweeping. Analysis is performed by dynamic light scattering with Litesizer Litesizer$^{\text{TM}}$ 500.

Nevertheless, an illustrated removal of larger particles by the street sweeping machine (see section 4.2), may also give long term beneficial effects for the quality of stormwater and ambient air. That is because the large particles may be grinded into finer particles by traffic (Kuhns et al. 2003). The significance of this process versus the significance of the resuspension of the finer particles by the brushing of the sweeping machine should be studied further.

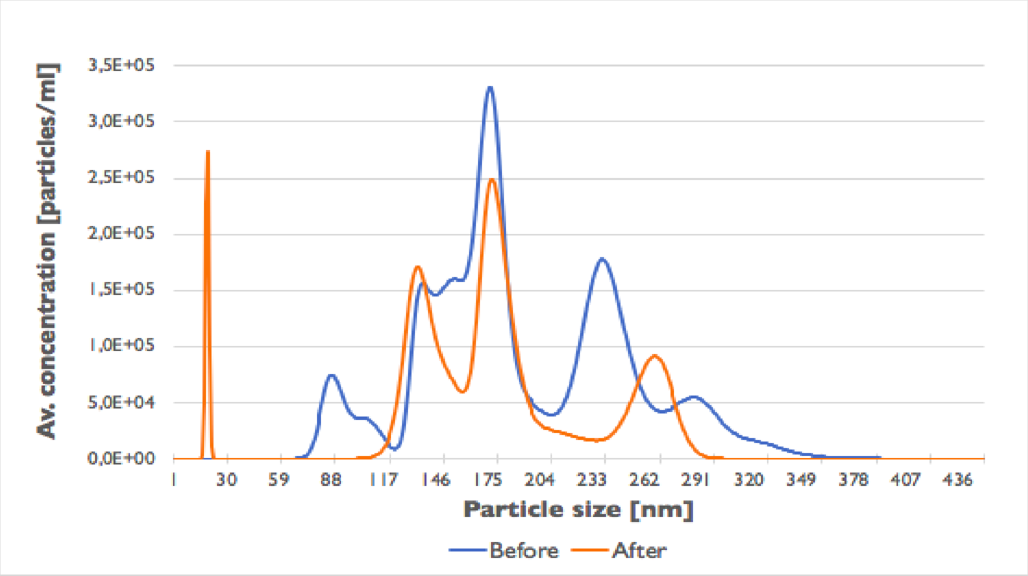


Figure 4.9: Particle size distribution in runoff sediment sampled at Sahlgrenska by WDS before and after the street sweeping. Analysis is performed by dynamic light scattering with Nanosight.

4.6.2 Concentrations of OPs in the street sediment sampled by the WDS

The street sediment sampled by the WDS was analyzed for 16 PAHs (Figure 4.10 and 4.11), 13 phthalates (Figure 4.12), six alkane groups of compounds (Figure 4.13) and 11 groups of aromatics (Figure 4.14). The compounds detected were: DEHP, alkanes (C_{16} - C_{35}), several aromatics and PAHs, however the general trend is that all studied OPs were present in higher concentrations in samples after the street sweeping. This can be because small particles to which OPs were attached were trapped by the larger particles. The brushing motion of the sweeping machine can also contribute to wear of the road material, which includes OPs. These small particles become available for the WDS when the street sweeping machine with its brushes and presumably powerful suction removes the larger particles. However, the collected samples may not be representative of the actual distribution of OPs in the sediment, since the sampling area of WDS is small.

4.6.2.1 PAHs

Results from the analysis of PAH-16, PAH-L, PAH-M, PAH-H as well as for 16 specific PAHs are presented in Figures 4.10 and 4.11. Though most of the specific PAHs were detected in the WDS sampled street sediment, three to four of the LMW PAHs (napthalene, acenaphthylene, acenaphthene and flourene) were below the detection limit. The concentrations of these substances were estimated to half the detection limit.

In both Figures 4.10 and 4.11 it is shown that concentrations of PAHs are higher in the sample taken after the street sweeping. This phenomenon was also reported by German et al. (2002) studying the heavy metal concentration in street sediment sampled before and after the street sweeping. Furthermore, the number of detected PAHs in the street sediment sampled by the WDS after street sweeping, was lower than in the sediment sampled by the street sweeping machine during the same sampling occasion (2018-03-26).

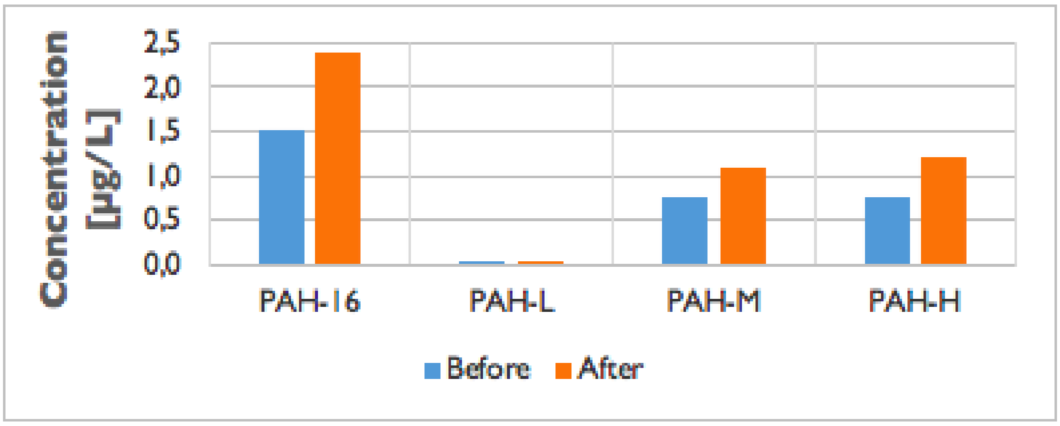


Figure 4.10: Concentrations [µg/L] of PAH-16, PAH-H, PAH-M and PAH-L detected in the street sediment sampled by the WDS before and after the street sweeping. Samples were taken 2018-03-26.

The most frequently detected PAHs in the sediment sampled by the WDS were phenanthene, flouranthene, pyrene, benzo[a]anthracene, benzo[b]flourene, benzo[a]pyrene and benzo[g,h,i]perylene (Figure 4.11), which were also the most dominant PAHs in street sediment and washwater sampled by the street sweeping machine.

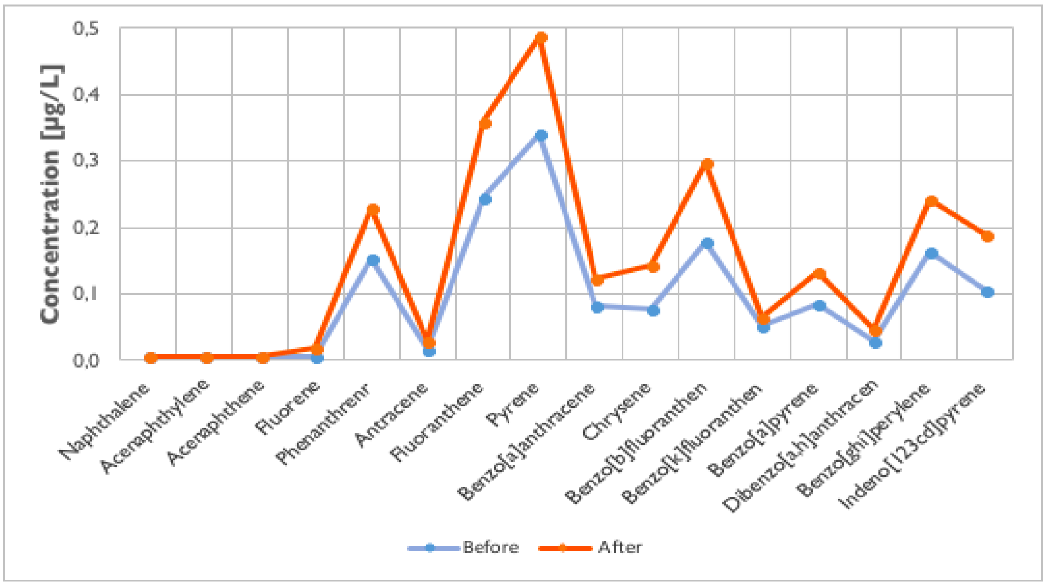


Figure 4.11: Concentrations [µg/L] of 16 specific PAHs detected in the street sediment sampled by the WDS before and after street sweeping. Samples were taken 2018-03-26. The concentrations of napthalene, acenaphthylene, acenaphthene and flourene in the "before" sample were estimated to half the detection limit. The concentrations of napthalene, acenaphthylene and acenaphthene in the "after" sample were also estimated to half the detection limit.

4.6.2.2 Phthalates

Only one of the phthalates i.e. DEHP was detected in the WDS sampled street sediment (Figure 4.12). The number of detected phthalates is lower in the sediment sampled by the WDS after the street sweeping event than in the washwater and the street sediment sampled by the street sweeping machine. This can depend on the fact that the WDS sampling area was much smaller than the sampling area of the street sweeping machine. Other possible explanations for the sweepers higher ability to collect OPs is the presence of brushes or a more powerful suction ability.

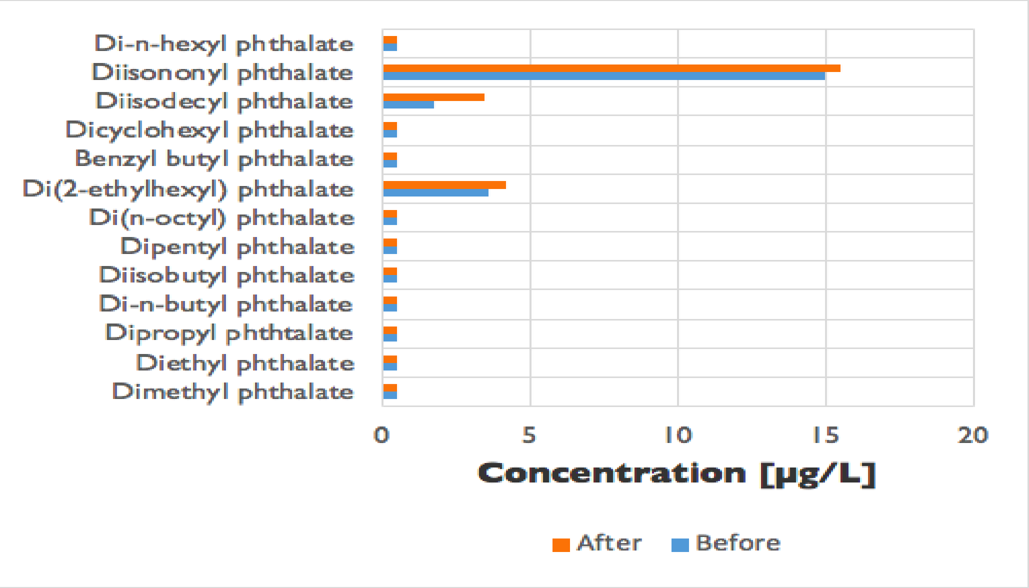


Figure 4.12: Concentrations [µg/L] of 13 phthalates analyzed in the street sediment sampled by the WDS before and after the street sweeping. Since only DEHP was detected, the concentrations of other phthalates were estimated to the half of the detection limit. Samples were taken 2018-03-26.

4.6.2.3 Alkanes

Alkanes C_{16} - C_{35} were detected in the street sediment sampled by the WDS (Figure 4.13). These alkanes were also the dominating alkane group of compounds in the street sediment and in the washwater from the street sweeping machine. The concentrations of other analyzed but not detected alkanes were estimated to half the detection limit.

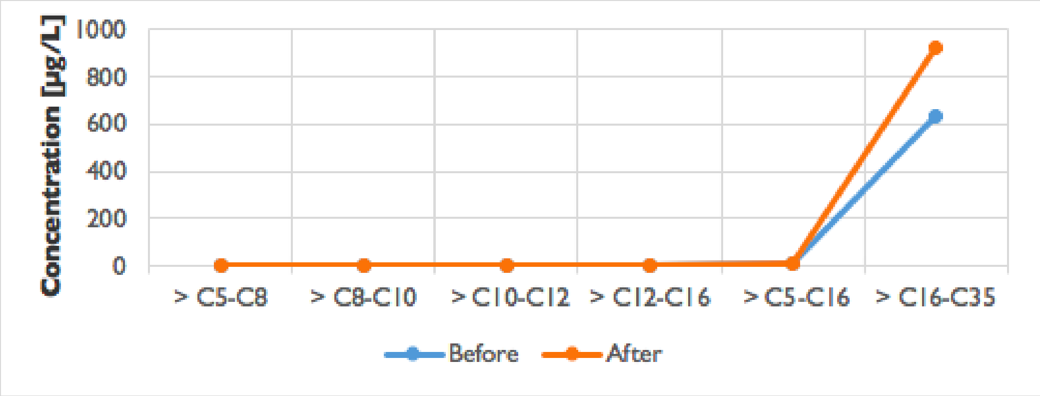


Figure 4.13: Concentrations [µg/L] of alkanes detected in the street sediment sampled by the WDS before and after the street sweeping. Since only C_{16} - C_{35} were detected, the concentrations of other alkanes were estimated to half the detection limit. Samples were taken 2018-03-26.

4.6.2.4 Volatile aromatics and alkylated PAHs

No aromatics were detected in the sediment sampled by the WDS before the street sweeping. The WDS-sampled sediment after the street sweeping contained aromatics C_{10} - C_{16} and C_{16} - C_{35} and methylchrysene/1-methylbenz[a]anthracene, which was also detected in the street sediment sampled by the street sweeping machine. The concentrations of undetected aromatics were estimated to half of their detection limits (Figure 4.14).

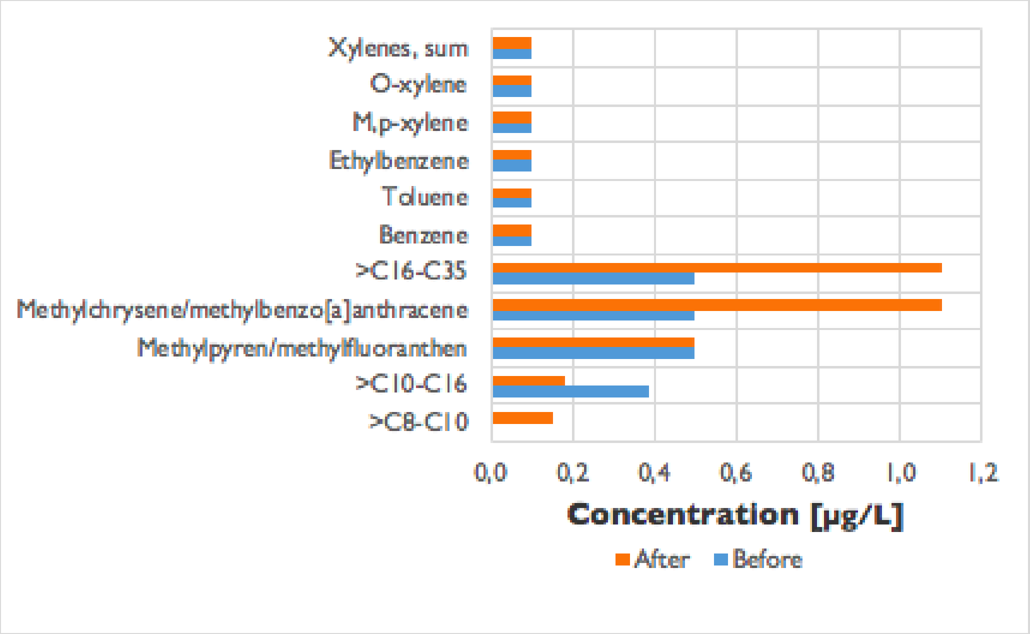


Figure 4.14: Concentrations [µg/l] of the volatile aromatics and alkylated PAHs detected in the street sediment sampled by the WDS before and after the street sweeping. Since the only detected aromatics were C_{10} - C_{16} and C_{16} - C_{35} and methylchrysene/1-methylbenz[a]anthracene found in street sediment sampled after the street sweeping, the concentrations of other aromatics were estimated to the half of the detection limit. Samples were taken 2018-03-26.

4.6.2.5 TSS, VSI and turbidity

The suspended solids (TSS) in the water buffering the street sediment sampled by WDS before and after the street sweeping was determined to 600 mg/l versus 1044 mg/l, and volatile suspended solids (VSI ≈ organic matter) to 541 mg/l versus 897 mg/l. The turbidity was 155 and 200 FTU before and after the sweeping, while the conductivity varied between 63 and 54 µS/cm before and after the sweeping, see Table B.1 in Appendix B.

4.7 Further studies

In addition to studies about sampling, temporal storage and recycling of the material from the street sweeping machine, future research is also recommended on:

- How the defoliation affects the stormwater quality, and if the leaf abrasion products carry traffic-related pollutants.

- Investigate the phase distribution of the organic matter in the washwater. Is it dissolved? What is the amount of DOC and TOC in the washwater and the street sediment sampled by the street sweeping machine and the WDS? This is knowledge is important to improve existing and improve new stormwater techniques.

- In which concentration OPs can be analyzed in the TSS of the washwater.

- The change in PSD when stormwater and washwater samples are frozen and thawed. Does the PSD of the fresh and frozen samples coincide? If the PSD differs between the states, stormwater treatment techniques might have to be adjusted in respect to seasonal changes.

5

Conclusions

- The street sediment sampled by the street sweeping machine consists of up to 70 % sand.

- The organic matter is mostly associated with smaller particles of the street sediment and the concentration of organic matter is negatively correlated with particle size. The sampled street sediment consisted to 0.99–23 % of organic material, where the median values varied between 1.9 and 3.4 %.

- OPs found in the most significant concentrations in the street sediment were C_{16} - C_{35} and the phthalate DEHP. However, a number of specific PAHs, 4-tert-octylphenols, formaldehyde and acetaldehyde were also detected in the street sediment.

- The concentrations of C_{16} - C_{35} alkanes in the street sediment were far above the reference values (100 mg/kg DS) for sensitive soil given by the SEPA.

- The concentrations of PAH-L, PAH-M and PAH-H in the street sediment are far below the guideline values (1, 3 and 3 mg/kg DS respectively) for the sensitive soil given by the SEPA.

- The dominating PAHs in the street sediment were pyrene, fluoranthene as well as benzo[b]fluoranthene, indicating the presence of tire wear material, vehicle exhaust emissions, as well as residues from lubricant motor oils. Proportions of chrysene, phenanthrene, and benzo[g,h,i]perylene in some samples were less dominant, but still significant. The sources of these substances also may be lubricant motor oil spillage, as well as bituminous binder in asphalt and brake wear particles in the sampled street sediment.

- A PSD analysis of the washwater showed the presence of a wide range of fine particles, including nanoparticles of sizes down to 1 nm in diameter.

- The organic matter in the suspended solids in the washwater ranges approximately between 50 and 86 %.

- Far more OPs, such as specific PAHs and alkanes, were detected in the washwater compared to the street sediment sampled by the street sweeping machine. The concentrations of these substances in the washwater were high comparing to the guidelines given by....

- Oxy-PAHs and aromatics, which were not detected in the analyzed street sediment, were present in the washwater. Some of the individual oxy-PAHs, i.e. 6H-benzo[c,d]pyren-6-one and naftacen-5,12-dione, were present in the washwater; in much higher concentrations than the compounds they originate from.

- However, the street sediment contained a higher number of specific phthalates.

- Considering the high TSS concentration and the abundance of PAHs in the washwater, as well as the low abundance of PAHs in the street sediment sampled by the street sweeping machine, future studies are recommended to focus on measuring the PAH concentrations in the street sediment particles floating in the washwater. This can be achieved for example through filtration, and will make the results comparable to other studies on OPs in the street sediment. Assuming the street sediment particles in the washwater are finer than in the settled street sediment, these studies will also widen the knowledge of PAH associated with smaller particles.

- The street sediment sampled by the WDS contained a lower number of specific PAHs, alkanes, and aromatics than the washwater. This implies a positive contribution from the street sweeping to the removal of OPs from urban runoff.

- The street sweeping is suspected to contribute to the resuspension of finer particles. That is because the concentrations of OPs in the street sediment sampled were higher after the street sweeping than before. The turbidity and the TSS were higher in the street sediment sampled by the WDS after the street sweeping, compared to the sediment sampled before the street sweeping.

- Since the evaluation of the efficiency of street sweeping for removal of OPs and fine particles with the WDS sampling before and after the sweeping was only based on a single sampling occasion´s result, its reliability should be statistically tested.

- Since a higher number of OPs in much higher concentrations were detected in the washwater than in the street sediment, the temporary location of the dumping site of the material sampled by the street sweeping machine should be reevaluated. To separate OPs and fine particles from the washwater, implementation of a granular filter on the dumping site is recommended. Also, the sampling method of this material should be investigated. Eventually, analysis of the surrounding soil at the dumping cite is necessary.

- Lastly, for complete evaluation of street sweeping as a method to reduce OPs and fine particles in urban runoff, the problem of routinized recycling of street sediment should be addressed and investigated further.

- Future research is also recommended on defoliation effects on the stormwater quality, phase distribution of the organic matter in the washwater and the change of eventual PSD when stormwater and washwater samples are frozen and thawed. This knowledge is important to improve existing and develop new stormwater techniques.

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Appendix 1

Parameter	**Setting**
Laser type	Blue488
Software Version	NTA 3.2 Dev Build 3.2.16
Camera level	10
Slider Shutter	600
Slider Gain	250
Detection Threshold	5 particles/mL
Focus	varied depending on the sample
Screen gain	10

Table A.1: Settings for measuring the particle size distribution with dynamic light scattering using the Nanosight NS3000.

Figure A.1: 1. The regenerative sweeper uses a power air jet, created by a blower wheel. 2. Air blasts down and across onto the pavement and loosens the street sediment. 3. The debris-laden air stream is pulled into the large hopper. There, the larger particles settle on the bottom, while larger objects, such as leaves, paper, cans and rocks are screened, preventing them from entering the centrifugal dust separator. 4. Fine particle are separated because of the centrifugal motion of the air along the curved wall of the chamber. These particles are later transported into the hopper, while the clean air is recycled further (Tymco® 2018).

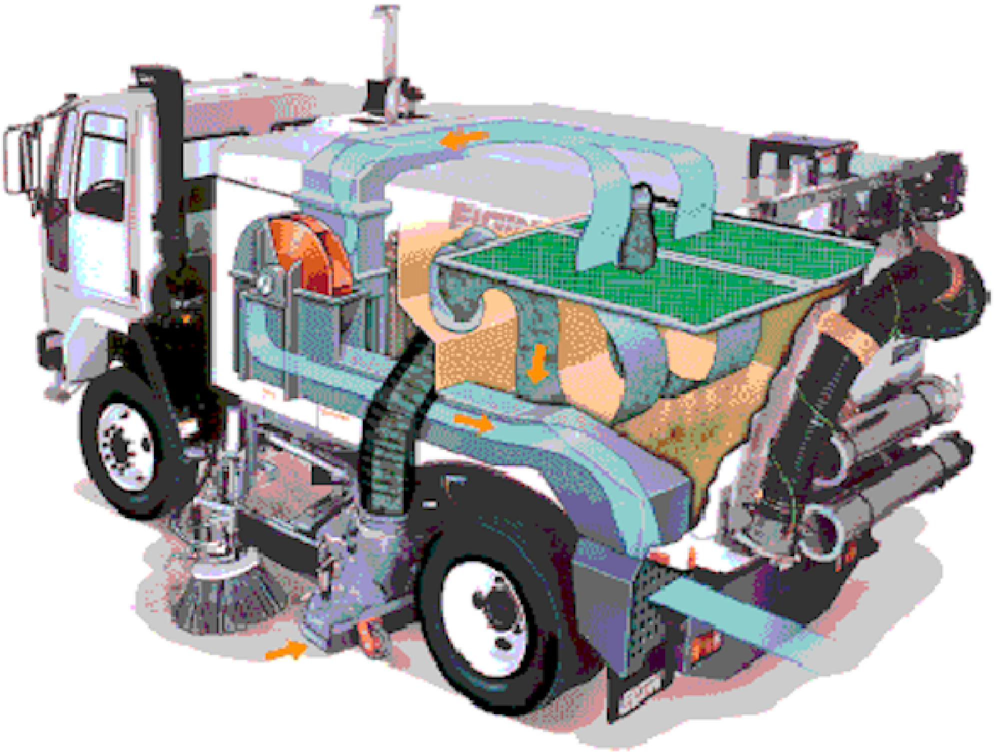

Figure A.2: Vacuum street sweeper uses air jets and brushes to resuspend the street sediment, which is then suck up in the hopper. Filter is separating collected street sediment and air, which released outside (Sweepers 2018).

Figure A.3: The sampling of street sediment at the Sahlgrenska catchment area with the WDS during 2018-03-26.

B

Appendix 2

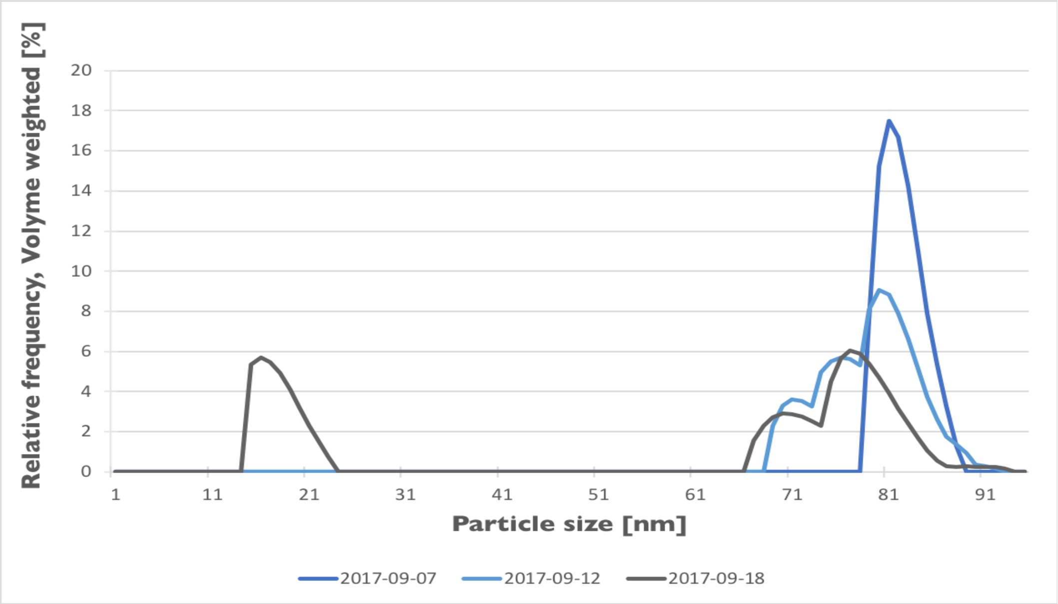

Figure B.1: Particle size distribution in stormwater, collected during Autumn 2017 by DHI Sverige using automatic sampling. The water sampling device was situated at Blå Stråket. Analyses were performed by Litesizer^{TM} 500, which measures the occurrence of particles with different volumes relative to each other. Note that this PSD is for particles 0–19 000 nm and that particles larger than 450 nm are absent.

Table B.1: pH, conductivity, temperature, turbidity and oxygen level measured in the washwater samples collected by the street sweeping machine, in street sediment collected by the WDS, and in stormwater. The stormwater was collected during Autumn 2017 by DHI Sverige using automatic sampling. The water sampling device was situated at Blå Stråket.

	pH	**Conductivity [µm/cm]**	**Temperature [°C]**	**Turbidity [FTU]**	**Oxygen**
Washwater					
2017-08-17	6.146	255	18		
2017-08-24	6.068	859	19		
2017-08-31	6.078	360			
2017-09-07					
2017-09-14	6.015	525	12		
2017-09-21	5.608	565	18		
2017-09-28	4.950	906	11		
2017-10-05	5.620	478	22		
2017-10-12	5.418	850	11	166	
2017-10-19		948	16	287	
2017-10-26		416		125	
2017-12-07		580		2.66	
2018-03-26		2	16	<0.01	
Stormwater					
2017-09-07	6.243	34	12		
2017-09-12	6.167	48	12		
2017-09-18	6.148	59	12		
2017-10-25		46	11	34	
2017-11-29		271	12	38	
WDS					
2018-03-26, Before	7.703	63	20	155	8.46
2018-03-26, After	7.220	54	17.	200	8.67

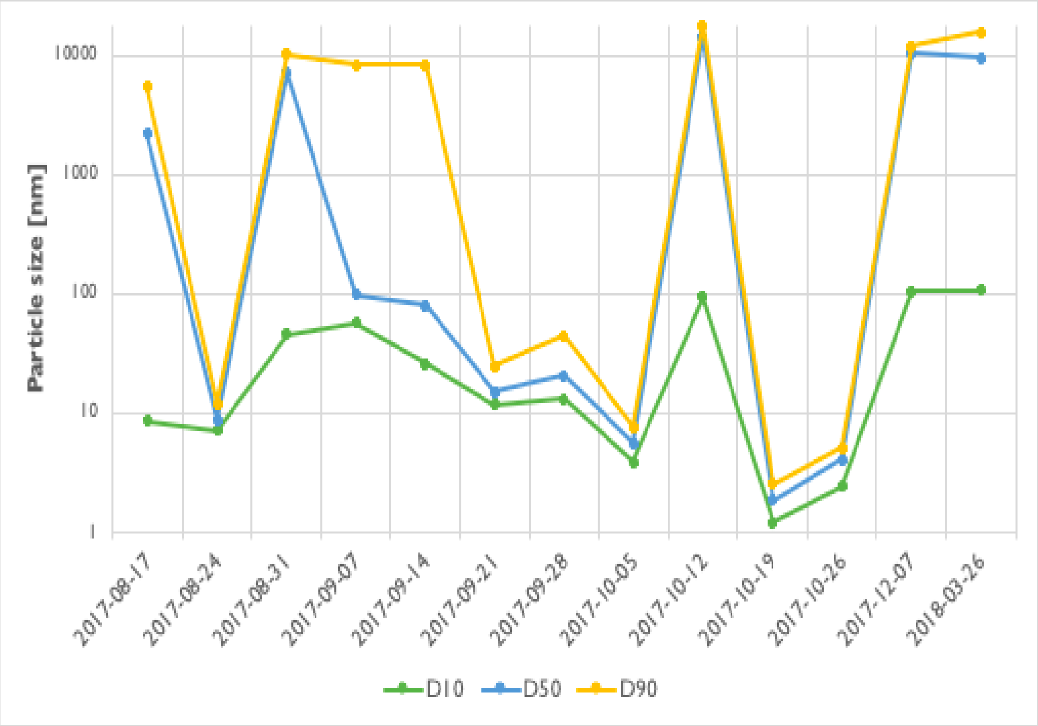

Figure B.2: The change in D10, D50 and D90 values for PSD in the washwater sampled by the street sweeping machine and analyzed by Litesizer^{TM}.

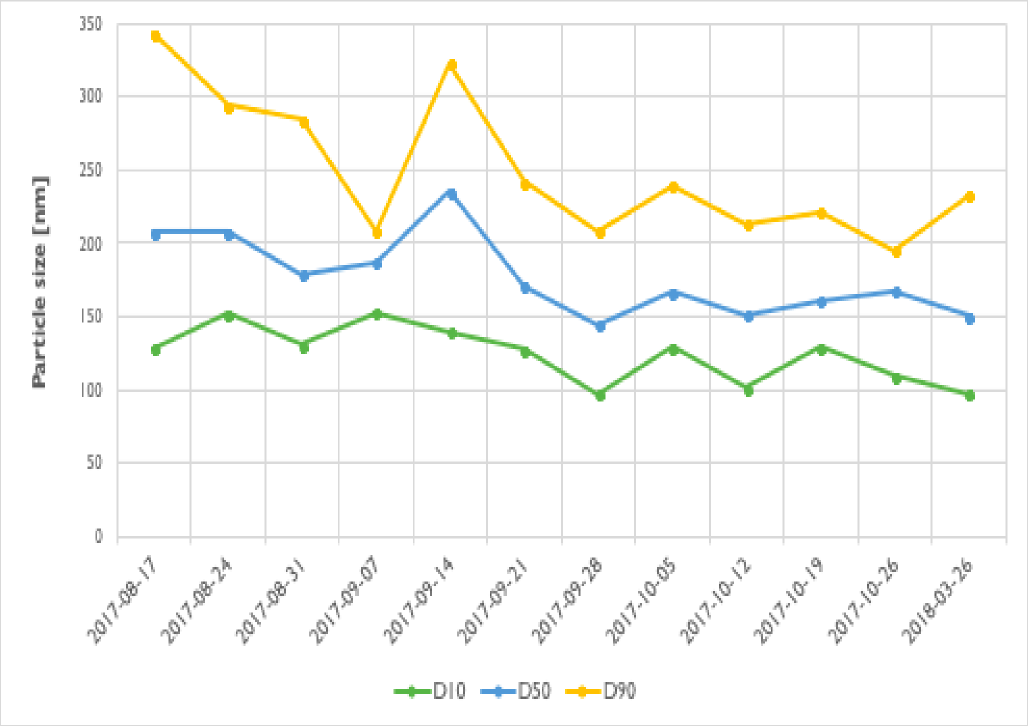

Figure B.3: The change of D10, D50 and D90 values for PSD in the washwater sampled by the street sweeping machine and analyzed with Nanosight NS300.

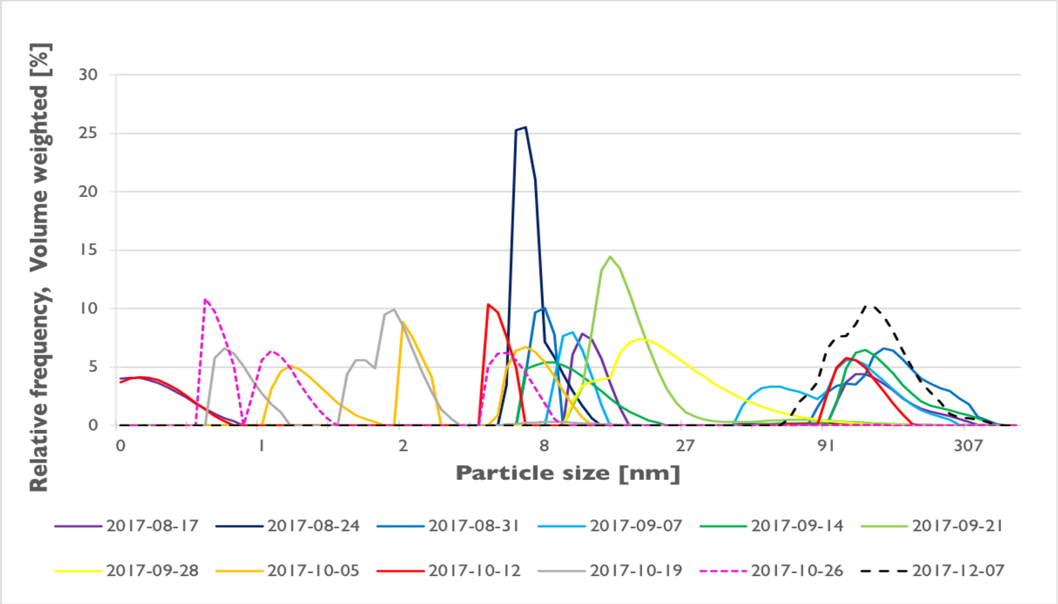

Figure B.4: Particle size distribution in washwater sampled by a street sweeping machine at 12 different occasions around the Sahlgrenska Hospital area. Analyses are performed with Litesizer$^{\text{TM}}$ 500, which measures the occurrence of particles with different volumes relative to each other. Note that particles larger than 450 nm is absent.

Table B.2: Mean intensity of the scattered light and the filter optical density during PSD measurements with Litesizer^{TM}.

Sampling date	**Sample ID**	**Mean intensity [kcps]**	**Filter optical density**
2017-08-17	Prov 1	96,8	0,5
2017-08-17	Prov 2	100,6	0,5
2017-08-17	Prov 3	89,1	0,5
2017-08-24	Prov 1	104,8	0,0
2017-08-24	Prov 2	96,8	0,0
2017-08-24	Prov 3	110,1	0,0
2017-08-31	Prov 1 färsk	314,2	0,7
2017-08-31	Prov 2 färsk	292,5	0,9
2017-08-31	Prov 3 färsk	315,3	0,9
2017-09-07	Prov 1 färsk	289,1	0,7
2017-09-07	Prov 2 färsk	316,3	0,6
2017-09-07	Prov 3 färsk	322,8	0,7
2017-09-14	Prov 1 färsk	287,0	0,9
2017-09-14	Prov 2	159,4	0,0
2017-09-14	Prov 3	129,3	0,0
2017-09-21	Prov 1 färsk	308,4	1,5
2017-09-21	Prov 2 färsk	293,4	1,5
2017-09-21	Prov 3 färskt	298,5	1,3
2017-09-28	Prov 1	294,1	1,4
2017-09-28	Prov 2	301,8	1,4
2017-09-28	Prov 3	310,0	1,5
2017-10-05	Prov 1 fryst	74,5	0,0
2017-10-05	Prov 2 fryst	125,2	0,0
2017-10-05	Prov 3 fryst	74,6	0,0
2017-10-12	Prov 1 färskt	304,7	0,7
2017-10-12	Prov 2 färskt	320,0	0,6
2017-10-12	Prov 3 färskt	308,5	0,5
2017-10-19	Prov 1 fryst	90,6	0,0
2017-10-19	Prov 2 fryst	71,7	0,0
2017-10-19	Prov 3 fryst	82,7	0,0
2017-10-26	Prov 1 fryst	83,1	0,0
2017-10-26	Prov 2 fryst	146,4	0,0
2017-10-26	Prov 3 fryst	74,0	0,5
2017-12-07	Prov 1 färskt	280,7	1,0
2017-12-07	Prov 2 färskt	259,4	1,1
2017-12-07	Prov 3 färskt	272,9	1,0
2018-03-26	prov 1 färskt	92,4	0,5
2018-03-26	Prov 5	168,6	0,5
2018-03-26	Prov 8	100,1	0,5
WDS Before 2018-03-26	Försök 3	121,2	0,5
WDS Before 2018-03-26	Försök 5	113,7	0,5
WDS Before 2018-03-26	Försök 7	98,3	0,5
Minimin:		**71,7**	**0,0**
Maximum:		**322,8**	**1,5**

C

Appendix 3

Rapport

T1721909

57Z4LMP910

Ankomstdatum **2017-08-23**
Utfärdad **2017-09-13**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning **Sopvatten 170817**

Provtagare **Maria Polukararova**
Provtagningsdatum **2017-08-17**

Labnummer O10913404

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
9-fluorenon*	**----------**		µg/l	1	1	JECE
9,10-antrakinon*	**----------**		µg/l	1	1	JECE
2-metylantracen-9,10-dion*	**----------**		µg/l	1	1	JECE
7H-bens(de)antracen-7-on*	**----------**		µg/l	1	1	JECE
bens(a)antracen-7,12-dion*	**----------**		µg/l	1	1	JECE
6H-bens(cd)pyren-6-on*	**----------**		µg/l	1	1	JECE
bens(a)fluorenon*	**----------**		µg/l	1	1	JECE
4H-cyklopenta(def)fenantrenon*	**----------**		µg/l	1	1	JECE
naftacen-5,12-dion*	**----------**		µg/l	1	1	JECE
naftalen	**0.039**	0.013	µg/l	2	2	ULKA
acenaftylen	**<0.010**		µg/l	2	2	ULKA
acenaften	**0.032**	0.010	µg/l	2	2	ULKA
fluoren	**0.038**	0.009	µg/l	2	2	ULKA
fenantren	**0.548**	0.142	µg/l	2	2	ULKA
antracen	**0.091**	0.023	µg/l	2	2	ULKA
fluoranten	**1.39**	0.432	µg/l	2	2	ULKA
pyren	**1.25**	0.388	µg/l	2	2	ULKA
bens(a)antracen	**0.635**	0.172	µg/l	2	2	ULKA
krysen	**0.666**	0.193	µg/l	2	2	ULKA
bens(b)fluoranten	**0.915**	0.338	µg/l	2	2	ULKA
bens(k)fluoranten	**0.230**	0.083	µg/l	2	2	ULKA
bens(a)pyren	**0.588**	0.147	µg/l	2	2	ULKA
dibenso(ah)antracen	**0.102**	0.033	µg/l	2	2	ULKA
benso(ghi)perylen	**0.415**	0.166	µg/l	2	2	ULKA
indeno(123cd)pyren	**0.313**	0.110	µg/l	2	2	ULKA
PAH, summa 16*	**7.3**		µg/l	2	2	ULKA
PAH, summa cancerogena*	**3.4**		µg/l	2	2	ULKA
PAH, summa övriga*	**3.8**		µg/l	2	2	ULKA
PAH, summa L*	**0.071**		µg/l	2	2	ULKA
PAH, summa M*	**3.3**		µg/l	2	2	ULKA
PAH, summa H*	**3.9**		µg/l	2	2	ULKA

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Bestämning av oxy-PAHer (9 föreningar). Mätningen utförs med GCMS. Rev 2011-06-09
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

	Godkännare
JECE	Jeanna Cederström
ULKA	Ulrika Karlsson

	Utf[1]
1	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
2	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.

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

Ankomstdatum **2017-08-23**
Utfärdad **2017-09-05**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning **Sopvatten 170817**

Provtagare **Maria Polukararova**
Provtagningsdatum **2017-08-17**

Labnummer O10913405

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	ULKA
alifater >C8-C10	**<10**		µg/l	1	1	ULKA
alifater >C10-C12	**12**	4	µg/l	1	1	ULKA
alifater >C12-C16	**24**	7	µg/l	1	1	ULKA
alifater >C5-C16*	**36**		µg/l	1	1	ULKA
alifater >C16-C35	**1720**	517	µg/l	1	1	ULKA
aromater >C8-C10	**<0.30**		µg/l	1	1	ULKA
aromater >C10-C16	**0.386**	0.116	µg/l	1	1	ULKA
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	ULKA
metylkrysener/metylbens(a)antracener	**1.1**	0.3	µg/l	1	1	ULKA
aromater >C16-C35	**1.1**	0.3	µg/l	1	1	ULKA
bensen	**<0.20**		µg/l	1	1	ULKA
toluen	**<0.20**		µg/l	1	1	ULKA
etylbensen	**<0.20**		µg/l	1	1	ULKA
m,p-xylen	**<0.20**		µg/l	1	1	ULKA
o-xylen	**<0.20**		µg/l	1	1	ULKA
xylener, summa*	**<0.20**		µg/l	1	1	ULKA
TEX, summa*	**<0.40**		µg/l	1	1	ULKA
4-tert-oktylfenol	**<0.260**		µg/l	2	1	ULKA
4-tert-OF-monoetoxilat	**<0.040**		µg/l	2	1	ULKA
4-tert-OF-dietoxilat	**<0.140**		µg/l	2	1	ULKA
4-tert-OF-trietoxilat	**<0.100**		µg/l	2	1	ULKA
4-nonylfenoler (tekn blandning)	**<2.30**		µg/l	2	1	ULKA
4-NF-monoetoxilat	**<1.10**		µg/l	2	1	ULKA
4-NF-dietoxilat	**<0.900**		µg/l	2	1	ULKA
4-NF-trietoxilat	**<3.70**		µg/l	2	1	ULKA
dimetylftalat	**<1.0**		µg/l	3	2	CL
dietylftalat	**<1.0**		µg/l	3	2	CL
di-n-propylftalat	**<1.0**		µg/l	3	2	CL
di-n-butylftalat	**<1.0**		µg/l	3	2	CL
di-iso-butylftalat	**<1.0**		µg/l	3	2	CL
di-pentylftalat	**<1.0**		µg/l	3	2	CL
di-n-oktylftalat (DNOP)	**<1.5**		µg/l	3	2	CL
di-(2-etylhexyl)ftalat (DEHP)	**22**	3.5	µg/l	3	2	CL
butylbensylftalat	**<1.0**		µg/l	3	2	CL
di-cyklohexylftalat	**<1.0**		µg/l	3	2	CL
di-iso-decylftalat (DIDP)	**<40**		µg/l	3	2	CL
di-iso-nonylftalat (DINP)	**150**	24	µg/l	3	2	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	3	2	CL

Er beteckning	**Sopvatten 170817**
Provtagare	**Maria Polukararova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10913405

Parameter	**Resultat**	**Osäkerhet (±)**	**Enhet**	**Metod**	**Utf**	**Sign**
formaldehyd	**<100**		µg/l	4	2	CL
acetaldehyd	**<100**		µg/l	4	2	CL
propionaldehyd	**<100**		µg/l	4	2	CL
butyraldehyd	**<100**		µg/l	4	2	CL
glutaraldehyd	**<100**		µg/l	4	2	CL

* 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-18E. Bestämning av nonylfenol, oktylfenol och -etoxilater enligt metod baserad på ISO 18857-2. Mätning utförs med GC-MS. Rev 2016-04-25
3	Paket OV-4B. Bestämning av 13st ftalater. Bestämning enligt metod DIN EN ISO 18856. Rev 2017-05-22
4	Paket OV-33 Bestämning av aldehyder med HPLC-DAD efter derivatisering med DNPH. Filtrering av grumliga prover ingår i metoden. Rev 2014-11-27

	Godkännare
CL	Camilla Lundeborg
ULKA	Ulrika Karlsson

	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.
2	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

---

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

	Utf[1]
	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.

Rapport

T1727260

8PU081ZM9H

Ankomstdatum **2017-10-03**
Utfärdad **2017-10-24**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning	**Sopvatten** **170928**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-09-28**
Labnummer	O10929871

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**16**	6	µg/l	1	1	AKR
alifater >C8-C10	**<10**		µg/l	1	1	AKR
alifater >C10-C12	**21**	6	µg/l	1	1	AKR
alifater >C12-C16	**13**	4	µg/l	1	1	AKR
alifater >C5-C16*	**50**		µg/l	1	1	AKR
alifater >C16-C35	**185**	55	µg/l	1	1	AKR
aromater >C8-C10	**0.68**	0.20	µg/l	1	1	AKR
aromater >C10-C16	**<0.788**		µg/l	1	1	AKR
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	AKR
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	AKR
aromater >C16-C35	**<1.0**		µg/l	1	1	AKR
bensen	**<0.20**		µg/l	1	1	AKR
toluen	**<0.20**		µg/l	1	1	AKR
etylbensen	**<0.20**		µg/l	1	1	AKR
m,p-xylen	**<0.20**		µg/l	1	1	AKR
o-xylen	**<0.20**		µg/l	1	1	AKR
xylener, summa*	**<0.20**		µg/l	1	1	AKR
TEX, summa*	**<0.40**		µg/l	1	1	AKR
naftalen	**<0.030**		µg/l	2	1	AKR
acenaftylen	**<0.010**		µg/l	2	1	AKR
acenaften	**<0.010**		µg/l	2	1	AKR
fluoren	**<0.010**		µg/l	2	1	AKR
fenantren	**0.050**	0.013	µg/l	2	1	AKR
antracen	**0.010**	0.002	µg/l	2	1	AKR
fluoranten	**0.056**	0.017	µg/l	2	1	AKR
pyren	**0.075**	0.023	µg/l	2	1	AKR
bens(a)antracen	**0.031**	0.008	µg/l	2	1	AKR
krysen	**0.040**	0.012	µg/l	2	1	AKR
bens(b)fluoranten	**0.042**	0.015	µg/l	2	1	AKR
bens(k)fluoranten	**<0.010**		µg/l	2	1	AKR
bens(a)pyren	**0.020**	0.005	µg/l	2	1	AKR
dibenso(ah)antracen	**<0.010**		µg/l	2	1	AKR
benso(ghi)perylen	**<0.010**		µg/l	2	1	AKR
indeno(123cd)pyren	**<0.010**		µg/l	2	1	AKR
PAH, summa 16*	**0.32**		µg/l	2	1	AKR
PAH, summa cancerogena*	**0.13**		µg/l	2	1	AKR
PAH, summa övriga*	**0.19**		µg/l	2	1	AKR
PAH, summa L*	**<0.030**		µg/l	2	1	AKR
PAH, summa M*	**0.19**		µg/l	2	1	AKR

Er beteckning	**Sopvatten** **170928**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-09-28**
Labnummer	O10929871

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
PAH, summa H*	**0.13**		µg/l	2	1	AKR
dimetylftalat	**<1.0**		µg/l	3	2	AKR
dietylftalat	**<1.0**		µg/l	3	2	AKR
di-n-propylftalat	**<1.0**		µg/l	3	2	AKR
di-n-butylftalat	**<1.0**		µg/l	3	2	AKR
di-iso-butylftalat	**<1.0**		µg/l	3	2	AKR
di-pentylftalat	**<1.0**		µg/l	3	2	AKR
di-n-oktylftalat (DNOP)	**<1.0**		µg/l	3	2	AKR
di-(2-etylhexyl)ftalat (DEHP)	**<1.0**		µg/l	3	2	AKR
butylbensylftalat	**<1.0**		µg/l	3	2	AKR
di-cyklohexylftalat	**<1.0**		µg/l	3	2	AKR
di-iso-decylftalat (DIDP)	**<20**		µg/l	3	2	AKR
di-iso-nonylftalat (DINP)	**<20**		µg/l	3	2	AKR
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	3	2	AKR
9-fluorenon*	**<0.1**		µg/l	4	3	LISO
9,10-antrakinon*	**<0.1**		µg/l	4	3	LISO
2-metylantracen-9,10-dion*	**<0.1**		µg/l	4	3	LISO
7H-bens(de)antracen-7-on*	**0.17**		µg/l	4	3	LISO
bens(a)antracen-7,12-dion*	**0.16**		µg/l	4	3	LISO
6H-bens(cd)pyren-6-on*	**0.30**		µg/l	4	3	LISO
bens(a)fluorenon*	**0.28**		µg/l	4	3	LISO
4H-cyklopenta(def)fenantrenon*	**<0.1**		µg/l	4	3	LISO
naftacen-5,12-dion*	**0.11**		µg/l	4	3	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	Paket OV-4B. Bestämning av 13st ftalater. Bestämning enligt metod DIN EN ISO 18856. Rev 2017-05-22
4	Bestämning av oxy-PAHer (9 föreningar). Mätningen utförs med GCMS. Rev 2011-06-09

	Godkännare
AKR	Anna-Karin Revell
LISO	Linda Söderberg

	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.

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

	Utf[1]
	Kontakta ALS Stockholm för ytterligare information.
2	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.
3	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).

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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Rapport

Ackred. nr 2030
Provning
ISO/IEC 17025

Ankomstdatum	**2017-11-10**
Utfärdad	**2017-12-04**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av vatten

Er beteckning	**Sopvatten** **171026**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-11-10**
Labnummer	O10946179

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
alifater >C5-C8	**<10**		µg/l	1	1	AKR
alifater >C8-C10	**<10**		µg/l	1	1	AKR
alifater >C10-C12	**18**	6	µg/l	1	1	AKR
alifater >C12-C16	**16**	5	µg/l	1	1	AKR
alifater >C5-C16*	**34**		µg/l	1	1	AKR
alifater >C16-C35	**1420**	426	µg/l	1	1	AKR
aromater >C8-C10	**0.06**	0.02	µg/l	1	1	AKR
aromater >C10-C16	**<0.932**		µg/l	1	1	AKR
metylpyrener/metylfluorantener	**<1.0**		µg/l	1	1	AKR
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	1	1	AKR
aromater >C16-C35	**<1.0**		µg/l	1	1	AKR
bensen	**<0.20**		µg/l	1	1	AKR
toluen	**<0.20**		µg/l	1	1	AKR
etylbensen	**<0.20**		µg/l	1	1	AKR
m,p-xylen	**<0.20**		µg/l	1	1	AKR
o-xylen	**<0.20**		µg/l	1	1	AKR
xylener, summa*	**<0.20**		µg/l	1	1	AKR
TEX, summa*	**<0.40**		µg/l	1	1	AKR
naftalen	**<0.030**		µg/l	2	1	AKR
acenaftylen	**<0.010**		µg/l	2	1	AKR
acenaften	**0.041**	0.012	µg/l	2	1	AKR
fluoren	**0.013**	0.003	µg/l	2	1	AKR
fenantren	**0.051**	0.013	µg/l	2	1	AKR
antracen	**<0.010**		µg/l	2	1	AKR
fluoranten	**0.065**	0.020	µg/l	2	1	AKR
pyren	**0.094**	0.029	µg/l	2	1	AKR
bens(a)antracen	**0.029**	0.008	µg/l	2	1	AKR
krysen	**0.031**	0.009	µg/l	2	1	AKR
bens(b)fluoranten	**0.034**	0.013	µg/l	2	1	AKR
bens(k)fluoranten	**0.014**	0.005	µg/l	2	1	AKR
bens(a)pyren	**0.021**	0.005	µg/l	2	1	AKR
dibenso(ah)antracen	**<0.010**		µg/l	2	1	AKR
benso(ghi)perylen	**0.021**	0.008	µg/l	2	1	AKR
indeno(123cd)pyren	**0.013**	0.004	µg/l	2	1	AKR
PAH, summa 16*	**0.43**		µg/l	2	1	AKR
PAH, summa cancerogena*	**0.14**		µg/l	2	1	AKR
PAH, summa övriga*	**0.29**		µg/l	2	1	AKR
PAH, summa L*	**0.041**		µg/l	2	1	AKR
PAH, summa M*	**0.22**		µg/l	2	1	AKR
PAH, summa H*	**0.16**		µg/l	2	1	AKR

Er beteckning	**Sopvatten** **171026**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-11-10**
Labnummer	O10946179

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
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
dimetylftalat	**<1.0**		µg/l	4	3	CL
dietylftalat	**<1.0**		µg/l	4	3	CL
di-n-propylftalat	**<1.0**		µg/l	4	3	CL
di-n-butylftalat	**<1.0**		µg/l	4	3	CL
di-iso-butylftalat	**<1.0**		µg/l	4	3	CL
di-pentylftalat	**<1.0**		µg/l	4	3	CL
di-n-oktylftalat (DNOP)	**<1.0**		µg/l	4	3	CL
di-(2-etylhexyl)ftalat (DEHP)	**1.7**	0.27	µg/l	4	3	CL
butylbensylftalat	**<1.0**		µg/l	4	3	CL
di-cyklohexylftalat	**<1.0**		µg/l	4	3	CL
di-iso-decylftalat (DIDP)	**<5.0**		µg/l	4	3	CL
di-iso-nonylftalat (DINP)	**<11**		µg/l	4	3	CL
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	4	3	CL

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

	Godkännare
AKR	Anna-Karin Revell
CL	Camilla Lundeborg
LISO	Linda Söderberg

	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,

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

	Utf[1]
	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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Ankomstdatum	**2018-04-09**
Utfärdad	**2018-04-20**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt	
Bestnr	**Ref Ann-Margret Strömvall**

Analys av vatten

Er beteckning	**1. Sopvatten 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992287

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	INRO
dietylftalat	**<1.0**		µg/l	1	1	INRO
di-n-propylftalat	**<1.0**		µg/l	1	1	INRO
di-n-butylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-butylftalat	**1.2**	0.19	µg/l	1	1	INRO
di-pentylftalat	**<1.0**		µg/l	1	1	INRO
di-n-oktylftalat (DNOP)	**<2.5**		µg/l	1	1	INRO
di-(2-etylhexyl)ftalat (DEHP)	**21**	3.3	µg/l	1	1	INRO
butylbensylftalat	**<1.0**		µg/l	1	1	INRO
di-cyklohexylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-decylftalat (DIDP)	**<40**		µg/l	1	1	INRO
di-iso-nonylftalat (DINP)	**<230**		µg/l	1	1	INRO
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	INRO
alifater >C5-C8	**<10**		µg/l	2	2	HESE
alifater >C8-C10	**<10**		µg/l	2	2	HESE
alifater >C10-C12	**96**	29	µg/l	2	2	HESE
alifater >C12-C16	**250**	75	µg/l	2	2	HESE
alifater >C5-C16 *	**350**		µg/l	2	2	HESE
alifater >C16-C35	**37500**	11200	µg/l	2	2	HESE
aromater >C8-C10	**1.41**	0.42	µg/l	2	2	HESE
aromater >C10-C16	**10.2**	3.08	µg/l	2	2	HESE
metylpyrener/metylfluorantener	**11.4**	3.4	µg/l	2	2	HESE
metylkrysener/metylbens(a)antracener	**46.4**	13.9	µg/l	2	2	HESE
aromater >C16-C35	**57.8**	17.3	µg/l	2	2	HESE
bensen	**<0.20**		µg/l	2	2	HESE
toluen	**<0.20**		µg/l	2	2	HESE
etylbensen	**<0.20**		µg/l	2	2	HESE
m,p-xylen	**<0.20**		µg/l	2	2	HESE
o-xylen	**<0.20**		µg/l	2	2	HESE
xylener, summa *	**<0.20**		µg/l	2	2	HESE
naftalen	**0.244**	0.073	µg/l	2	2	HESE
acenaftylen	**0.307**	0.092	µg/l	2	2	HESE
acenaften	**0.221**	0.066	µg/l	2	2	HESE
fluoren	**0.640**	0.192	µg/l	2	2	HESE

Er beteckning	**1. Sopvatten 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992287

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
fenantren	**9.10**	2.73	µg/l	2	2	HESE
antracen	**0.950**	0.285	µg/l	2	2	HESE
fluoranten	**11.1**	3.32	µg/l	2	2	HESE
pyren	**13.8**	4.13	µg/l	2	2	HESE
bens(a)antracen	**5.14**	1.54	µg/l	2	2	HESE
krysen	**6.04**	1.81	µg/l	2	2	HESE
bens(b)fluoranten	**13.8**	4.14	µg/l	2	2	HESE
bens(k)fluoranten	**3.22**	0.966	µg/l	2	2	HESE
bens(a)pyren	**5.49**	1.65	µg/l	2	2	HESE
dibenso(ah)antracen	**2.62**	0.788	µg/l	2	2	HESE
benso(ghi)perylen	**10.2**	3.06	µg/l	2	2	HESE
indeno(123cd)pyren	**7.59**	2.28	µg/l	2	2	HESE
PAH, summa 16 *	**90**		µg/l	2	2	HESE
PAH, summa cancerogena *	**44**		µg/l	2	2	HESE
PAH, summa övriga *	**47**		µg/l	2	2	HESE
PAH, summa L *	**0.77**		µg/l	2	2	HESE
PAH, summa M *	**36**		µg/l	2	2	HESE
PAH, summa H *	**54**		µg/l	2	2	HESE

Er beteckning **2. WSD Före 180326**

Provtagare **Maria Polukarova**
Provtagningsdatum **2018-03-26**

Labnummer O10992288

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	INRO
dietylftalat	**<1.0**		µg/l	1	1	INRO
di-n-propylftalat	**<1.0**		µg/l	1	1	INRO
di-n-butylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-butylftalat	**<1.0**		µg/l	1	1	INRO
di-pentylftalat	**<1.0**		µg/l	1	1	INRO
di-n-oktylftalat (DNOP)	**<1.0**		µg/l	1	1	INRO
di-(2-etylhexyl)ftalat (DEHP)	**3.6**	0.57	µg/l	1	1	INRO
butylbensylftalat	**<1.0**		µg/l	1	1	INRO
di-cyklohexylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-decylftalat (DIDP)	**<3.5**		µg/l	1	1	INRO
di-iso-nonylftalat (DINP)	**<30**		µg/l	1	1	INRO
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	INRO
alifater >C5-C8	**<10**		µg/l	2	2	HESE
alifater >C8-C10	**<10**		µg/l	2	2	HESE
alifater >C10-C12	**<10**		µg/l	2	2	HESE
alifater >C12-C16	**<10**		µg/l	2	2	HESE
alifater >C5-C16*	**<20**		µg/l	2	2	HESE
alifater >C16-C35	**633**	190	µg/l	2	2	HESE
aromater >C8-C10	**<0.30**		µg/l	2	2	HESE
aromater >C10-C16	**<0.775**		µg/l	2	2	HESE
metylpyrener/metylfluorantener	**<1.0**		µg/l	2	2	HESE
metylkrysener/metylbens(a)antracener	**<1.0**		µg/l	2	2	HESE
aromater >C16-C35	**<1.0**		µg/l	2	2	HESE
bensen	**<0.20**		µg/l	2	2	HESE
toluen	**<0.20**		µg/l	2	2	HESE
etylbensen	**<0.20**		µg/l	2	2	HESE
m,p-xylen	**<0.20**		µg/l	2	2	HESE
o-xylen	**<0.20**		µg/l	2	2	HESE
xylener, summa*	**<0.20**		µg/l	2	2	HESE
naftalen	**<0.014**		µg/l	2	2	HESE
acenaftylen	**<0.014**		µg/l	2	2	HESE
acenaften	**<0.014**		µg/l	2	2	HESE
fluoren	**<0.014**		µg/l	2	2	HESE
fenantren	**0.154**	0.046	µg/l	2	2	HESE
antracen	**0.017**	0.005	µg/l	2	2	HESE
fluoranten	**0.245**	0.073	µg/l	2	2	HESE
pyren	**0.342**	0.103	µg/l	2	2	HESE
bens(a)antracen	**0.081**	0.024	µg/l	2	2	HESE
krysen	**0.078**	0.023	µg/l	2	2	HESE
bens(b)fluoranten	**0.178**	0.053	µg/l	2	2	HESE
bens(k)fluoranten	**0.052**	0.016	µg/l	2	2	HESE
bens(a)pyren	**0.084**	0.025	µg/l	2	2	HESE
dibenso(ah)antracen	**0.028**	0.008	µg/l	2	2	HESE
benso(ghi)perylen	**0.164**	0.049	µg/l	2	2	HESE
indeno(123cd)pyren	**0.104**	0.031	µg/l	2	2	HESE

Er beteckning	**2. WSD Före 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992288

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
PAH, summa 16 *	**1.5**		µg/l	2	2	HESE
PAH, summa cancerogena *	**0.61**		µg/l	2	2	HESE
PAH, summa övriga *	**0.92**		µg/l	2	2	HESE
PAH, summa L *	**<0.021**		µg/l	2	2	HESE
PAH, summa M *	**0.76**		µg/l	2	2	HESE
PAH, summa H *	**0.77**		µg/l	2	2	HESE

Er beteckning **3. WSD Efter 180326**

Provtagare **Maria Polukarova**
Provtagningsdatum **2018-03-26**

Labnummer O10992289

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<1.0**		µg/l	1	1	INRO
dietylftalat	**<1.0**		µg/l	1	1	INRO
di-n-propylftalat	**<1.0**		µg/l	1	1	INRO
di-n-butylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-butylftalat	**<1.0**		µg/l	1	1	INRO
di-pentylftalat	**<1.0**		µg/l	1	1	INRO
di-n-oktylftalat (DNOP)	**<1.0**		µg/l	1	1	INRO
di-(2-etylhexyl)ftalat (DEHP)	**4.2**	0.66	µg/l	1	1	INRO
butylbensylftalat	**<1.0**		µg/l	1	1	INRO
di-cyklohexylftalat	**<1.0**		µg/l	1	1	INRO
di-iso-decylftalat (DIDP)	**<7.0**		µg/l	1	1	INRO
di-iso-nonylftalat (DINP)	**<31**		µg/l	1	1	INRO
di-n-hexylftalat (DNHP)	**<1.0**		µg/l	1	1	INRO
alifater >C5-C8	**<10**		µg/l	2	2	HESE
alifater >C8-C10	**<10**		µg/l	2	2	HESE
alifater >C10-C12	**<10**		µg/l	2	2	HESE
alifater >C12-C16	**<10**		µg/l	2	2	HESE
alifater >C5-C16 *	**<20**		µg/l	2	2	HESE
alifater >C16-C35	**924**	277	µg/l	2	2	HESE
aromater >C8-C10	**<0.30**		µg/l	2	2	HESE
aromater >C10-C16	**0.180**	0.054	µg/l	2	2	HESE
metylpyrener/metylfluorantener	**<1.0**		µg/l	2	2	HESE
metylkrysener/metylbens(a)antracener	**1.1**	0.3	µg/l	2	2	HESE
aromater >C16-C35	**1.1**	0.3	µg/l	2	2	HESE
bensen	**<0.20**		µg/l	2	2	HESE
toluen	**<0.20**		µg/l	2	2	HESE
etylbensen	**<0.20**		µg/l	2	2	HESE
m,p-xylen	**<0.20**		µg/l	2	2	HESE
o-xylen	**<0.20**		µg/l	2	2	HESE
xylener, summa *	**<0.20**		µg/l	2	2	HESE
naftalen	**<0.014**		µg/l	2	2	HESE
acenaftylen	**<0.014**		µg/l	2	2	HESE
acenaften	**<0.014**		µg/l	2	2	HESE
fluoren	**0.019**	0.006	µg/l	2	2	HESE
fenantren	**0.230**	0.069	µg/l	2	2	HESE
antracen	**0.028**	0.008	µg/l	2	2	HESE
fluoranten	**0.359**	0.108	µg/l	2	2	HESE
pyren	**0.489**	0.146	µg/l	2	2	HESE
bens(a)antracen	**0.122**	0.036	µg/l	2	2	HESE
krysen	**0.142**	0.042	µg/l	2	2	HESE
bens(b)fluoranten	**0.299**	0.090	µg/l	2	2	HESE
bens(k)fluoranten	**0.064**	0.019	µg/l	2	2	HESE
bens(a)pyren	**0.133**	0.040	µg/l	2	2	HESE
dibenso(ah)antracen	**0.047**	0.014	µg/l	2	2	HESE
benso(ghi)perylen	**0.241**	0.072	µg/l	2	2	HESE
indeno(123cd)pyren	**0.188**	0.056	µg/l	2	2	HESE

Er beteckning	**3. WSD Efter 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992289

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
PAH, summa 16 *	**2.4**		µg/l	2	2	HESE
PAH, summa cancerogena *	**1.0**		µg/l	2	2	HESE
PAH, summa övriga *	**1.4**		µg/l	2	2	HESE
PAH, summa L *	**<0.021**		µg/l	2	2	HESE
PAH, summa M *	**1.1**		µg/l	2	2	HESE
PAH, summa H *	**1.2**		µg/l	2	2	HESE

* 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
2	Paket OV-21A. Bestämning av alifatfraktioner och aromatfraktioner. Bestämning av metylpyrener/metylfluorantener och metylkrysener/metylbens(a)antracener. Bestämning av bensen, toluen, etylbensen och xylen (BTEX). Bestämning av polycykliska aromatiska kolväten, PAH (16 föreningar enligt EPA) Metod baserad på SPIMFABs kvalitetsmanual. Mätning utförs med GCMS. PAH cancerogena utgörs av benso(a)antracen, krysen, benso(b)fluoranten, benso(k)fluoranten, benso(a)pyren, dibenso(ah)antracen och indeno(123cd)pyren. 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 direktiv från Naturvårdsverket oktober 2008. Rev 2017-08-18

	Godkännare
HESE	Hedvig von Seth
INRO	Ingalill Rosén

	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.
2	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.

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

	Utf[1]
	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

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Rapport

Ackred. nr 2030
Provning
ISO/IEC 17025

T1725011

76MFYJBCSI

Ankomstdatum **2017-09-14**
Utfärdad **2017-10-06**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr **Saknas**

Analys av fast prov

Er beteckning **Total**
170817
Provtagare **Maria Polukarova**
Provtagningsdatum **2017-08-17**

Labnummer O10922943

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**85.5**		%	1	O	KASO
9-fluorenon	**<0.1**		mg/kg TS	2	1	LISO
9,10-antrakinon	**<0.1**		mg/kg TS	2	1	LISO
2-metylantracen-9,10-dion	**<0.1**		mg/kg TS	2	1	LISO
7H-bens(de)antracen-7-on	**<0.1**		mg/kg TS	2	1	LISO
bens(a)antracen-7,12-dion	**<0.1**		mg/kg TS	2	1	LISO
6H-bens(cd)pyren-6-on	**<0.1**		mg/kg TS	2	1	LISO
bens(a)fluorenon	**<0.1**		mg/kg TS	2	1	LISO
4H-cyklopenta(def)fenantrenon	**<0.1**		mg/kg TS	2	1	LISO
naftacen-5,12-dion	**<0.1**		mg/kg TS	2	1	LISO
alifater >C5-C8	**<10**		mg/kg TS	3	J	MISW
alifater >C8-C10	**<10**		mg/kg TS	3	J	LISO
alifater >C10-C12	**<20**		mg/kg TS	3	J	LISO
alifater >C12-C16	**<20**		mg/kg TS	3	J	LISO
alifater >C5-C16*	**<30**		mg/kg TS	3	N	LISO
alifater >C16-C35	**120**		mg/kg TS	3	J	LISO
aromater >C8-C10	**<1**		mg/kg TS	3	J	LISO
aromater >C10-C16	**<1**		mg/kg TS	3	J	LISO
metylpyrener/metylfluorantener*	**<1**		mg/kg TS	3	N	LISO
metylkrysener/metylbens(a)antracener*	**<1**		mg/kg TS	3	N	LISO
aromater >C16-C35	**<1**		mg/kg TS	3	J	LISO
bensen	**<0.01**		mg/kg TS	3	J	MISW
toluen	**<0.05**		mg/kg TS	3	J	MISW
etylbensen	**<0.05**		mg/kg TS	3	J	MISW
m,p-xylen	**<0.05**		mg/kg TS	3	J	MISW
o-xylen	**<0.05**		mg/kg TS	3	J	MISW
xylener, summa*	**<0.05**		mg/kg TS	3	N	MISW
TEX, summa*	**<0.1**		mg/kg TS	3	N	MISW
naftalen	**<0.1**		mg/kg TS	3	J	LISO
acenaftylen	**<0.1**		mg/kg TS	3	J	LISO
acenaften	**<0.1**		mg/kg TS	3	J	LISO
fluoren	**<0.1**		mg/kg TS	3	J	LISO
fenantren	**<0.1**		mg/kg TS	3	J	LISO
antracen	**<0.1**		mg/kg TS	3	J	LISO
fluoranten	**<0.1**		mg/kg TS	3	J	LISO
pyren	**<0.1**		mg/kg TS	3	J	LISO
bens(a)antracen	**<0.08**		mg/kg TS	3	J	LISO
krysen	**<0.08**		mg/kg TS	3	J	LISO
bens(b)fluoranten	**<0.08**		mg/kg TS	3	J	LISO

Er beteckning	**Total** **170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922943

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
bens(k)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(a)pyren	**<0.08**		mg/kg TS	3	J	LISO
dibens(ah)antracen	**<0.08**		mg/kg TS	3	J	LISO
benso(ghi)perylen	**<0.1**		mg/kg TS	3	J	LISO
indeno(123cd)pyren	**<0.08**		mg/kg TS	3	J	LISO
PAH, summa 16	**<1.5**		mg/kg TS	3	D	LISO
PAH, summa cancerogena*	**<0.3**		mg/kg TS	3	N	LISO
PAH, summa övriga*	**<0.5**		mg/kg TS	3	N	LISO
PAH, summa L*	**<0.15**		mg/kg TS	3	N	LISO
PAH, summa M*	**<0.25**		mg/kg TS	3	N	LISO
PAH, summa H*	**<0.3**		mg/kg TS	3	N	LISO
TS_105°C	**86.8**	1.7	%	4	2	MB
dimetylftalat	**<0.050**		mg/kg TS	4	2	MB
dietylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-propylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-pentylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-oktylftalat	**<0.050**		mg/kg TS	4	2	MB
di-(2-etylhexyl)ftalat (DEHP)	**0.33**	0.049	mg/kg TS	4	2	MB
butylbensylftalat	**<0.050**		mg/kg TS	4	2	MB
di-cyklohexylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-decylftalat (DIDP)	**<2.5**		mg/kg TS	4	2	MB
di-iso-nonylftalat (DINP)	**<2.5**		mg/kg TS	4	2	MB
di-n-hexylftalat (DNHP)	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**Total** **240824**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-24**
Labnummer	O10922944

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**84.3**		%	1	O	KASO
alifater >C5-C8	**<10**		mg/kg TS	3	J	MISW
alifater >C8-C10	**<10**		mg/kg TS	3	J	LISO
alifater >C10-C12	**<20**		mg/kg TS	3	J	LISO
alifater >C12-C16	**<20**		mg/kg TS	3	J	LISO
alifater >C5-C16*	**<30**		mg/kg TS	3	N	LISO
alifater >C16-C35	**68**		mg/kg TS	3	J	LISO
aromater >C8-C10	**<1**		mg/kg TS	3	J	LISO
aromater >C10-C16	**<1**		mg/kg TS	3	J	LISO
metylpyrener/metylfluorantener*	**<1**		mg/kg TS	3	N	LISO
metylkrysener/metylbens(a)antracener*	**<1**		mg/kg TS	3	N	LISO
aromater >C16-C35	**<1**		mg/kg TS	3	J	LISO
bensen	**<0.01**		mg/kg TS	3	J	MISW
toluen	**<0.05**		mg/kg TS	3	J	MISW
etylbensen	**<0.05**		mg/kg TS	3	J	MISW
m,p-xylen	**<0.05**		mg/kg TS	3	J	MISW
o-xylen	**<0.05**		mg/kg TS	3	J	MISW
xylener, summa*	**<0.05**		mg/kg TS	3	N	MISW
TEX, summa*	**<0.1**		mg/kg TS	3	N	MISW
naftalen	**<0.1**		mg/kg TS	3	J	LISO
acenaftylen	**<0.1**		mg/kg TS	3	J	LISO
acenaften	**<0.1**		mg/kg TS	3	J	LISO
fluoren	**<0.1**		mg/kg TS	3	J	LISO
fenantren	**<0.1**		mg/kg TS	3	J	LISO
antracen	**<0.1**		mg/kg TS	3	J	LISO
fluoranten	**<0.1**		mg/kg TS	3	J	LISO
pyren	**<0.1**		mg/kg TS	3	J	LISO
bens(a)antracen	**<0.08**		mg/kg TS	3	J	LISO
krysen	**<0.08**		mg/kg TS	3	J	LISO
bens(b)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(k)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(a)pyren	**<0.08**		mg/kg TS	3	J	LISO
dibens(ah)antracen	**<0.08**		mg/kg TS	3	J	LISO
benso(ghi)perylen	**<0.1**		mg/kg TS	3	J	LISO
indeno(123cd)pyren	**<0.08**		mg/kg TS	3	J	LISO
PAH, summa 16	**<1.5**		mg/kg TS	3	D	LISO
PAH, summa cancerogena*	**<0.3**		mg/kg TS	3	N	LISO
PAH, summa övriga*	**<0.5**		mg/kg TS	3	N	LISO
PAH, summa L*	**<0.15**		mg/kg TS	3	N	LISO
PAH, summa M*	**<0.25**		mg/kg TS	3	N	LISO
PAH, summa H*	**<0.3**		mg/kg TS	3	N	LISO
TS_105°C	**83.6**	1.7	%	4	2	MB
dimetylftalat	**<0.050**		mg/kg TS	4	2	MB
dietylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-propylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-pentylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-oktylftalat	**<0.050**		mg/kg TS	4	2	MB
di-(2-etylhexyl)ftalat (DEHP)	**0.23**	0.034	mg/kg TS	4	2	MB
butylbensylftalat	**<0.050**		mg/kg TS	4	2	MB
di-cyklohexylftalat	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**Total** **240824**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-24**
Labnummer	O10922944

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
di-iso-decylftalat (DIDP)	**<2.5**		mg/kg TS	4	2	MB
di-iso-nonylftalat (DINP)	**<2.5**		mg/kg TS	4	2	MB
di-n-hexylftalat (DNHP)	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**Total** **310831**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-31**
Labnummer	O10922945

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**78.0**		%	1	O	KASO
alifater >C5-C8	**<10**		mg/kg TS	3	J	MISW
alifater >C8-C10	**<10**		mg/kg TS	3	J	LISO
alifater >C10-C12	**<20**		mg/kg TS	3	J	LISO
alifater >C12-C16	**<20**		mg/kg TS	3	J	LISO
alifater >C5-C16*	**<30**		mg/kg TS	3	N	LISO
alifater >C16-C35	**110**		mg/kg TS	3	J	LISO
aromater >C8-C10	**<1**		mg/kg TS	3	J	LISO
aromater >C10-C16	**<1**		mg/kg TS	3	J	LISO
metylpyrener/metylfluorantener*	**<1**		mg/kg TS	3	N	LISO
metylkrysener/metylbens(a)antracener*	**<1**		mg/kg TS	3	N	LISO
aromater >C16-C35	**<1**		mg/kg TS	3	J	LISO
bensen	**<0.01**		mg/kg TS	3	J	MISW
toluen	**<0.05**		mg/kg TS	3	J	MISW
etylbensen	**<0.05**		mg/kg TS	3	J	MISW
m,p-xylen	**<0.05**		mg/kg TS	3	J	MISW
o-xylen	**<0.05**		mg/kg TS	3	J	MISW
xylener, summa*	**<0.05**		mg/kg TS	3	N	MISW
TEX, summa*	**<0.1**		mg/kg TS	3	N	MISW
naftalen	**<0.1**		mg/kg TS	3	J	LISO
acenaftylen	**<0.1**		mg/kg TS	3	J	LISO
acenaften	**<0.1**		mg/kg TS	3	J	LISO
fluoren	**<0.1**		mg/kg TS	3	J	LISO
fenantren	**<0.1**		mg/kg TS	3	J	LISO
antracen	**<0.1**		mg/kg TS	3	J	LISO
fluoranten	**<0.1**		mg/kg TS	3	J	LISO
pyren	**<0.1**		mg/kg TS	3	J	LISO
bens(a)antracen	**<0.08**		mg/kg TS	3	J	LISO
krysen	**<0.08**		mg/kg TS	3	J	LISO
bens(b)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(k)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(a)pyren	**<0.08**		mg/kg TS	3	J	LISO
dibens(ah)antracen	**<0.08**		mg/kg TS	3	J	LISO
benso(ghi)perylen	**<0.1**		mg/kg TS	3	J	LISO
indeno(123cd)pyren	**<0.08**		mg/kg TS	3	J	LISO
PAH, summa 16	**<1.5**		mg/kg TS	3	D	LISO
PAH, summa cancerogena*	**<0.3**		mg/kg TS	3	N	LISO
PAH, summa övriga*	**<0.5**		mg/kg TS	3	N	LISO
PAH, summa L*	**<0.15**		mg/kg TS	3	N	LISO
PAH, summa M*	**<0.25**		mg/kg TS	3	N	LISO
PAH, summa H*	**<0.3**		mg/kg TS	3	N	LISO
TS_105°C	**81.8**	1.6	%	4	2	MB
dimetylftalat	**<0.050**		mg/kg TS	4	2	MB
dietylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-propylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-pentylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-oktylftalat	**<0.050**		mg/kg TS	4	2	MB
di-(2-etylhexyl)ftalat (DEHP)	**0.21**	0.031	mg/kg TS	4	2	MB
butylbensylftalat	**<0.050**		mg/kg TS	4	2	MB
di-cyklohexylftalat	**<0.050**		mg/kg TS	4	2	MB

Ackred. nr 2030
Provning
ISO/IEC 17025

Er beteckning	**Total** **310831**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-31**
Labnummer	O10922945

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
di-iso-decylftalat (DIDP)	**<2.5**		mg/kg TS	4	2	MB
di-iso-nonylftalat (DINP)	**<2.5**		mg/kg TS	4	2	MB
di-n-hexylftalat (DNHP)	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**<250um vått170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922946

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**66.1**		%	1	O	KASO
alifater >C5-C8	**<10**		mg/kg TS	3	J	MISW
alifater >C8-C10	**<10**		mg/kg TS	3	J	LISO
alifater >C10-C12	**<20**		mg/kg TS	3	J	LISO
alifater >C12-C16	**<20**		mg/kg TS	3	J	LISO
alifater >C5-C16*	**<30**		mg/kg TS	3	N	LISO
alifater >C16-C35	**<20**		mg/kg TS	3	J	LISO
aromater >C8-C10	**<1**		mg/kg TS	3	J	LISO
aromater >C10-C16	**<1**		mg/kg TS	3	J	LISO
metylpyrener/metylfluorantener*	**<1**		mg/kg TS	3	N	LISO
metylkrysener/metylbens(a)antracener*	**<1**		mg/kg TS	3	N	LISO
aromater >C16-C35	**<1**		mg/kg TS	3	J	LISO
bensen	**<0.01**		mg/kg TS	3	J	MISW
toluen	**<0.05**		mg/kg TS	3	J	MISW
etylbensen	**<0.05**		mg/kg TS	3	J	MISW
m,p-xylen	**<0.05**		mg/kg TS	3	J	MISW
o-xylen	**<0.05**		mg/kg TS	3	J	MISW
xylener, summa*	**<0.05**		mg/kg TS	3	N	MISW
TEX, summa*	**<0.1**		mg/kg TS	3	N	MISW
naftalen	**<0.1**		mg/kg TS	3	J	LISO
acenaftylen	**<0.1**		mg/kg TS	3	J	LISO
acenaften	**<0.1**		mg/kg TS	3	J	LISO
fluoren	**<0.1**		mg/kg TS	3	J	LISO
fenantren	**<0.1**		mg/kg TS	3	J	LISO
antracen	**<0.1**		mg/kg TS	3	J	LISO
fluoranten	**0.11**	0.028	mg/kg TS	3	J	LISO
pyren	**<0.1**		mg/kg TS	3	J	LISO
bens(a)antracen	**<0.08**		mg/kg TS	3	J	LISO
krysen	**0.10**	0.024	mg/kg TS	3	J	LISO
bens(b)fluoranten	**0.091**	0.023	mg/kg TS	3	J	LISO
bens(k)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(a)pyren	**<0.08**		mg/kg TS	3	J	LISO
dibens(ah)antracen	**<0.08**		mg/kg TS	3	J	LISO
benso(ghi)perylen	**<0.1**		mg/kg TS	3	J	LISO
indeno(123cd)pyren	**<0.08**		mg/kg TS	3	J	LISO
PAH, summa 16	**<1.5**		mg/kg TS	3	D	LISO
PAH, summa cancerogena*	**0.19**		mg/kg TS	3	N	LISO
PAH, summa övriga*	**0.11**		mg/kg TS	3	N	LISO
PAH, summa L*	**<0.15**		mg/kg TS	3	N	LISO
PAH, summa M*	**0.11**		mg/kg TS	3	N	LISO
PAH, summa H*	**0.19**		mg/kg TS	3	N	LISO
TS_105°C	**63.2**	1.3	%	4	2	MB
dimetylftalat	**<0.050**		mg/kg TS	4	2	MB
dietylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-propylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-butylftalat	**<0.060**		mg/kg TS	4	2	MB
di-n-butylftalat	**0.052**	0.0077	mg/kg TS	4	2	MB
di-pentylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-oktylftalat	**<0.10**		mg/kg TS	4	2	MB
di-(2-etylhexyl)ftalat (DEHP)	**0.82**	0.12	mg/kg TS	4	2	MB
butylbensylftalat	**<0.050**		mg/kg TS	4	2	MB
di-cyklohexylftalat	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**<250um vått170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922946

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
di-iso-decylftalat (DIDP)	**<2.5**		mg/kg TS	4	2	MB
di-iso-nonylftalat (DINP)	**3.3**	0.49	mg/kg TS	4	2	MB
di-n-hexylftalat (DNHP)	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**<250um** **torrt170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922947

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**99.7**		%	1	O	KASO
alifater >C5-C8	**<10**		mg/kg TS	3	J	MISW
alifater >C8-C10	**<10**		mg/kg TS	3	J	LISO
alifater >C10-C12	**<20**		mg/kg TS	3	J	LISO
alifater >C12-C16	**<20**		mg/kg TS	3	J	LISO
alifater >C5-C16*	**<30**		mg/kg TS	3	N	MISW
alifater >C16-C35	**120**		mg/kg TS	3	J	LISO
aromater >C8-C10	**<1**		mg/kg TS	3	J	LISO
aromater >C10-C16	**<1**		mg/kg TS	3	J	LISO
metylpyrener/metylfluorantener*	**<1**		mg/kg TS	3	N	LISO
metylkrysener/metylbens(a)antracener*	**<1**		mg/kg TS	3	N	LISO
aromater >C16-C35	**<1**		mg/kg TS	3	J	LISO
bensen	**<0.01**		mg/kg TS	3	J	MISW
toluen	**<0.05**		mg/kg TS	3	J	MISW
etylbensen	**<0.05**		mg/kg TS	3	J	MISW
m,p-xylen	**<0.05**		mg/kg TS	3	J	MISW
o-xylen	**<0.05**		mg/kg TS	3	J	MISW
xylener, summa*	**<0.05**		mg/kg TS	3	N	MISW
TEX, summa*	**<0.1**		mg/kg TS	3	N	MISW
naftalen	**<0.1**		mg/kg TS	3	J	LISO
acenaftylen	**<0.1**		mg/kg TS	3	J	LISO
acenaften	**<0.1**		mg/kg TS	3	J	LISO
fluoren	**<0.1**		mg/kg TS	3	J	LISO
fenantren	**<0.1**		mg/kg TS	3	J	LISO
antracen	**<0.1**		mg/kg TS	3	J	LISO
fluoranten	**0.24**	0.060	mg/kg TS	3	J	LISO
pyren	**0.19**	0.048	mg/kg TS	3	J	LISO
bens(a)antracen	**0.096**	0.023	mg/kg TS	3	J	LISO
krysen	**0.14**	0.034	mg/kg TS	3	J	LISO
bens(b)fluoranten	**0.096**	0.024	mg/kg TS	3	J	LISO
bens(k)fluoranten	**<0.08**		mg/kg TS	3	J	LISO
bens(a)pyren	**<0.08**		mg/kg TS	3	J	LISO
dibens(ah)antracen	**<0.08**		mg/kg TS	3	J	LISO
benso(ghi)perylen	**<0.1**		mg/kg TS	3	J	LISO
indeno(123cd)pyren	**<0.08**		mg/kg TS	3	J	LISO
PAH, summa 16	**<1.5**		mg/kg TS	3	D	LISO
PAH, summa cancerogena*	**0.33**		mg/kg TS	3	N	LISO
PAH, summa övriga*	**0.43**		mg/kg TS	3	N	LISO
PAH, summa L*	**<0.15**		mg/kg TS	3	N	LISO
PAH, summa M*	**0.43**		mg/kg TS	3	N	LISO
PAH, summa H*	**0.33**		mg/kg TS	3	N	LISO
TS_105°C	**99.8**	2.0	%	4	2	MB
dimetylftalat	**<0.050**		mg/kg TS	4	2	MB
dietylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-propylftalat	**<0.050**		mg/kg TS	4	2	MB
di-iso-butylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-butylftalat	**0.17**	0.025	mg/kg TS	4	2	MB
di-pentylftalat	**<0.050**		mg/kg TS	4	2	MB
di-n-oktylftalat	**<0.050**		mg/kg TS	4	2	MB
di-(2-etylhexyl)ftalat (DEHP)	**0.60**	0.089	mg/kg TS	4	2	MB
butylbensylftalat	**<0.050**		mg/kg TS	4	2	MB
di-cyklohexylftalat	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**<250um** **torrt170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922947

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
di-iso-decylftalat (DIDP)	**<2.5**		mg/kg TS	4	2	MB
di-iso-nonylftalat (DINP)	**<2.5**		mg/kg TS	4	2	MB
di-n-hexylftalat (DNHP)	**<0.050**		mg/kg TS	4	2	MB

Er beteckning	**Total** **170817**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-17**
Labnummer	O10922948

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
fraktion >2 mm	**51.5**	5.15	%	5	3	AKR
fraktion 1-2 mm	**19.4**	1.94	%	5	3	AKR
fraktion 0,5-1 mm	**9.61**	0.96	%	5	3	AKR
fraktion 0,25-0,5 mm	**7.80**	0.78	%	5	3	AKR
fraktion 0,125-0,25 mm	**5.64**	0.56	%	5	3	AKR
fraktion 0,063-0,125 mm	**3.69**	0.37	%	5	3	AKR
fraktion 0,032-0,063 mm	**0.49**	0.05	%	5	3	AKR
fraktion 0,016-0,032 mm	**0.59**	0.06	%	5	3	AKR
fraktion 0,008-0,016 mm	**0.60**	0.06	%	5	3	AKR
fraktion 0,004-0,008 mm	**0.33**	0.03	%	5	3	AKR
fraktion 0,002-0,004 mm	**0.22**	0.02	%	5	3	AKR
fraktion <0,002 mm	**0.14**	0.01	%	5	3	AKR
se bilaga till rapport	**ja**			5	3	AKR

Er beteckning	**Total** **170824**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-24**
Labnummer	O10922949

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
fraktion >2 mm	**43.0**	4.30	%	5	3	AKR
fraktion 1-2 mm	**19.2**	1.92	%	5	3	AKR
fraktion 0,5-1 mm	**14.5**	1.45	%	5	3	AKR
fraktion 0,25-0,5 mm	**9.22**	0.92	%	5	3	AKR
fraktion 0,125-0,25 mm	**7.38**	0.74	%	5	3	AKR
fraktion 0,063-0,125 mm	**4.58**	0.46	%	5	3	AKR
fraktion 0,032-0,063 mm	**0.70**	0.07	%	5	3	AKR
fraktion 0,016-0,032 mm	**0.62**	0.06	%	5	3	AKR
fraktion 0,008-0,016 mm	**0.42**	0.04	%	5	3	AKR
fraktion 0,004-0,008 mm	**0.17**	0.02	%	5	3	AKR
fraktion 0,002-0,004 mm	**0.10**	0.01	%	5	3	AKR
fraktion <0,002 mm	**0.07**	0.007	%	5	3	AKR
se bilaga till rapport	**ja**			5	3	AKR

Er beteckning	**Total** **170831**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2017-08-31**
Labnummer	O10922950

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
fraktion >2 mm	**54.6**	5.46	%	5	3	AKR
fraktion 1-2 mm	**22.4**	2.24	%	5	3	AKR
fraktion 0,5-1 mm	**12.8**	1.28	%	5	3	AKR
fraktion 0,25-0,5 mm	**6.53**	0.65	%	5	3	AKR
fraktion 0,125-0,25 mm	**2.18**	0.22	%	5	3	AKR
fraktion 0,063-0,125 mm	**1.12**	0.11	%	5	3	AKR
fraktion 0,032-0,063 mm	**0.07**	0.007	%	5	3	AKR
fraktion 0,016-0,032 mm	**0.08**	0.008	%	5	3	AKR
fraktion 0,008-0,016 mm	**0.06**	0.006	%	5	3	AKR
fraktion 0,004-0,008 mm	**0.02**	0.002	%	5	3	AKR
fraktion 0,002-0,004 mm	**0.01**	0.001	%	5	3	AKR
fraktion <0,002 mm	**<0.01**		%	5	3	AKR
se bilaga till rapport	**ja**			5	3	AKR

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Bestämning av torrsubstans enligt SS 028113/1 Provet torkas vid 105°C. Mätosäkerhet (k=2): ±6% Rev 2013-05-15
2	Bestämning av oxy-PAHer (9 föreningar). Mätningen utförs med GCMS. Rev 2011-10-13
3	Paket OJ-21A Bestämning av alifatfraktioner och aromatfraktioner Bestämning av bensen, toluen, etylbensen och xylen (BTEX). Bestämning av polycykliska aromatiska kolväten, PAH (16 föreningar enligt EPA) * summa metylpyrener/metylfluorantener och summa metylkrysener/metylbens(a)antracener. Mätning utförs med GCMS enligt interna instruktioner TKI45a och TKI42a som är baserade på SPIMFABs kvalitetsmanual. PAH cancerogena utgörs av benso(a)antracen, krysen, benso(b)fluoranten, benso(k)fluoranten, benso(a)pyren, dibenso(ah)antracen och indeno(123cd)pyren. 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 direktiv från Naturvårdsverket oktober 2008. Mätosäkerhet (k=2): Alifatfraktioner: ±29-44% Aromatfraktioner: ±27-28% Enskilda PAH: ±24-27% Bensen ±31% vid 0,1 mg/kg Toluen ±23% vid 0,1 mg/kg Etylbensen ±24% vid 0,1 mg/kg m+p-Xylen ±25% vid 0,1 mg/kg o-Xylen ±25% vid 0,1 mg/kg Summorna för metylpyrener/metylfluorantener, metylkrysener/metylbens(a)antracener och alifatfraktionen >C5-C16 är inte ackrediterade. Rev 2017-02-28
4	Paket OJ-4B Bestämning av ftalater enligt E DIN 19742 (2012-04). Mätning utförs med GC-MS. Rev 2014-06-26
5	Bestämning av total siktkurva, bas. Mätning utförs med våtsiktning och laserdiffraktion enligt ISO 11277:2009. Rev 2014-03-05

	Godkännare
AKR	Anna-Karin Revell

	Godkännare
KASO	Katia Soza
LISO	Linda Söderberg
MB	Maria Bigner
MISW	Miryam Swartling

	Utf[1]
D	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
J	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
N	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
O	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
1	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
2	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.
3	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.

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

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.

Attachment no. 1 to the certificate of analysis for work order PR1758477

RESULTS OF GRAIN SIZE ANALYSIS

Sample label:				**922948**	**922949**	**922950**
Lab. ID:				001	002	003
Total weight of sample:			[g]	117.15	203.88	125.71
FW	**< 0.063**	mm	[g]	2.79	4.26	0.32
FW	**0.063-0.125**	mm	[g]	4.32	9.33	1.41
FW	**0.125-0.250**	mm	[g]	6.61	15.04	2.74
FW	**0.250-0.500**	mm	[g]	9.14	18.81	8.21
FW	**0.500-1.000**	mm	[g]	11.26	29.52	16.14
FW	**1.000-2.000**	mm	[g]	22.73	39.20	28.21
FW	**> 2.000**	mm	[g]	60.30	87.72	68.68
q	**< 0,002**	mm	[%]	0.14	0.07	0.01
q	**0.002-0.004**	mm	[%]	0.22	0.11	0.01
q	**0.004-0.008**	mm	[%]	0.33	0.17	0.02
q	**0.008-0.016**	mm	[%]	0.60	0.42	0.06
q	**0.016-0.032**	mm	[%]	0.59	0.62	0.08
q	**0.032-0.063**	mm	[%]	0.49	0.70	0.07
q	**0.063-0.125**	mm	[%]	3.69	4.58	1.12
q	**0.125-0.250**	mm	[%]	5.64	7.38	2.18
q	**0.250-0.500**	mm	[%]	7.80	9.23	6.53
q	**0.500-1.000**	mm	[%]	9.61	14.48	12.84
q	**1.000-2.000**	mm	[%]	19.40	19.23	22.44
q	**> 2.000**	mm	[%]	51.47	43.02	54.64
Q	**< 0,002**	mm	[%]	0.14	0.07	0.01
Q	**< 0.004**	mm	[%]	0.36	0.18	0.02
Q	**< 0.008**	mm	[%]	0.70	0.35	0.04
Q	**< 0.016**	mm	[%]	1.30	0.76	0.10
Q	**< 0.032**	mm	[%]	1.89	1.39	0.18
Q	**< 0.063**	mm	[%]	2.38	2.09	0.26
Q	**< 0.125**	mm	[%]	6.07	6.66	1.37
Q	**< 0.250**	mm	[%]	11.71	14.04	3.55
Q	**< 0.500**	mm	[%]	19.51	23.27	10.08
Q	**< 1.000**	mm	[%]	29.12	37.75	22.92
Q	**< 2.000**	mm	[%]	48.53	56.98	45.36

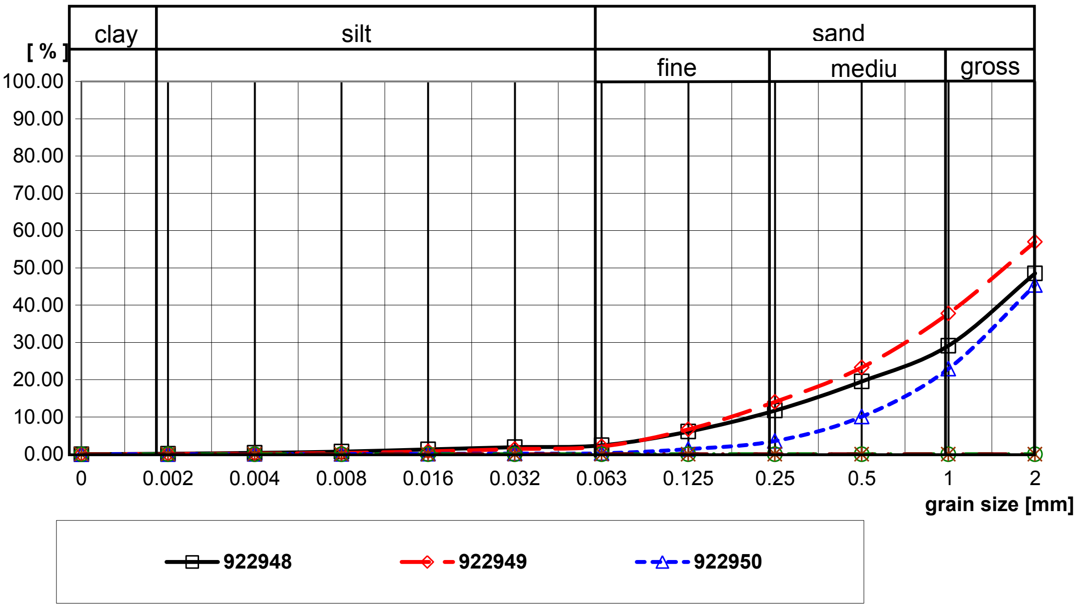
FW - fraction weight, **q** -fraction percentage part, **Q** - fraction cumulative part.

Test method specification: CZ_SOP_D06_07_120 Grain size analysis using the wet sieve analysis using laser diffraction (fraction from 2 µm to 63 mm). Fractions > 2 mm, 1-2 mm, 0.5-1 mm, 0.25-0.50 mm, 0.125-0.25 mm and 0.063-0.125 mm were determined by wet sieving method, other fractions were determined from the fraction "<0.063 mm" by laser particle size analyzer using liquid dispersion mode.

Test specification, deviations, additions to or exclusions from the test specification:

Attachment no. 1 to the certificate of analysis for work order PR1758477

RESULTS OF GRAIN SIZE ANALYSIS



Rapport

T1734532

CVUEACSQ4G

Ankomstdatum **2017-11-28**
Utfärdad **2017-12-12**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr **Ann-Margret Strömvall**

Analys av fast prov

Er beteckning **Vägdamm 171012**

Provtagare **Maria Polukarova**
Provtagningsdatum **2017-10-12**

Labnummer O10953290

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
fraktion >2 mm	**35.5**	3.55	%	1	1	MB
fraktion 1-2 mm	**16.8**	1.68	%	1	1	MB
fraktion 0,5-1 mm	**14.9**	1.49	%	1	1	MB
fraktion 0,25-0,5 mm	**11.6**	1.16	%	1	1	MB
fraktion 0,125-0,25 mm	**12.3**	1.23	%	1	1	MB
fraktion 0,063-0,125 mm	**6.78**	0.68	%	1	1	MB
fraktion 0,032-0,063 mm	**0.86**	0.08	%	1	1	MB
fraktion 0,016-0,032 mm	**0.62**	0.06	%	1	1	MB
fraktion 0,008-0,016 mm	**0.35**	0.03	%	1	1	MB
fraktion 0,004-0,008 mm	**0.14**	0.01	%	1	1	MB
fraktion 0,002-0,004 mm	**0.08**	0.008	%	1	1	MB
fraktion <0,002 mm	**0.06**	0.006	%	1	1	MB
se bilaga till rapport	**----------**			1	1	MB

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Bestämning av total siktkurva, bas. Mätning utförs med våtsiktning och laserdiffraktion enligt ISO 11277:2009. Rev 2014-03-05

	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.

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

Attachment no. 1 to the certificate of analysis for work order PR1784932

RESULTS OF GRAIN SIZE ANALYSIS

Sample label:				**953290**
Lab. ID:				001
Total weight of sample:			[g]	96.01
FW	**< 0.063**	mm	[g]	2.03
FW	**0.063-0.125**	mm	[g]	6.51
FW	**0.125-0.250**	mm	[g]	11.81
FW	**0.250-0.500**	mm	[g]	11.15
FW	**0.500-1.000**	mm	[g]	14.31
FW	**1.000-2.000**	mm	[g]	16.15
FW	**> 2.000**	mm	[g]	34.06
q	**< 0,002**	mm	[%]	0.06
q	**0.002-0.004**	mm	[%]	0.09
q	**0.004-0.008**	mm	[%]	0.14
q	**0.008-0.016**	mm	[%]	0.35
q	**0.016-0.032**	mm	[%]	0.62
q	**0.032-0.063**	mm	[%]	0.86
q	**0.063-0.125**	mm	[%]	6.78
q	**0.125-0.250**	mm	[%]	12.30
q	**0.250-0.500**	mm	[%]	11.61
q	**0.500-1.000**	mm	[%]	14.90
q	**1.000-2.000**	mm	[%]	16.82
q	**> 2.000**	mm	[%]	35.47
Q	**< 0,002**	mm	[%]	0.06
Q	**< 0.004**	mm	[%]	0.15
Q	**< 0.008**	mm	[%]	0.28
Q	**< 0.016**	mm	[%]	0.63
Q	**< 0.032**	mm	[%]	1.25
Q	**< 0.063**	mm	[%]	2.11
Q	**< 0.125**	mm	[%]	8.89
Q	**< 0.250**	mm	[%]	21.19
Q	**< 0.500**	mm	[%]	32.80
Q	**< 1.000**	mm	[%]	47.70
Q	**< 2.000**	mm	[%]	64.53

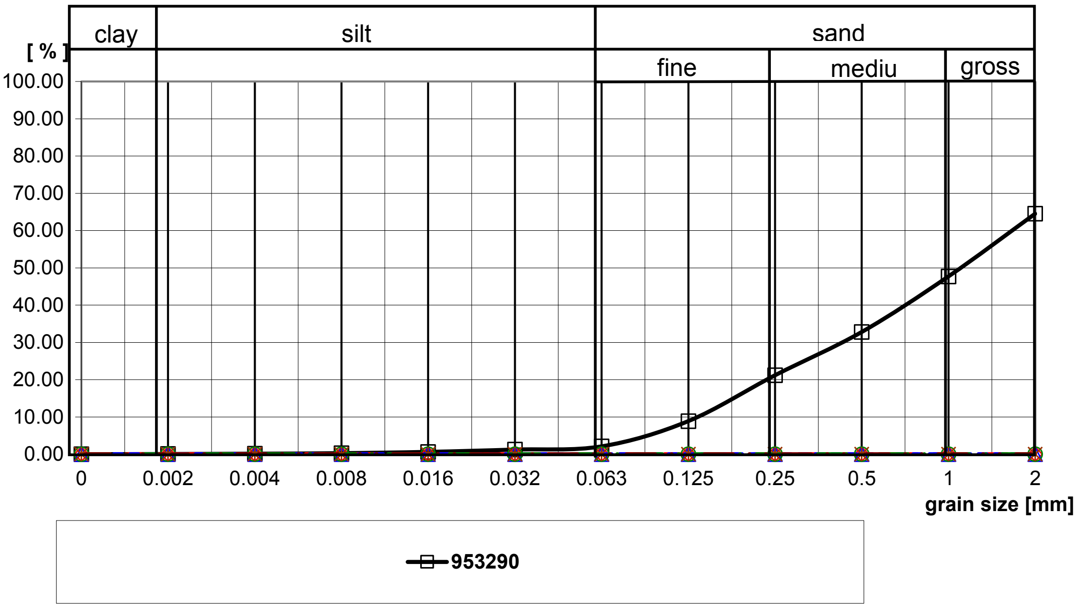
FW – fraction weight, **q** –fraction percentage part, **Q** – fraction cumulative part.

Test method specification: CZ_SOP_D06_07_120 Grain size analysis using the wet sieve analysis using laser diffraction (fraction from 2 µm to 63 mm). Fractions > 2 mm, 1-2 mm, 0.5-1 mm, 0.25-0.50 mm, 0.125-0.25 mm and 0.063-0.125 mm were determined by wet sieving method, other fractions were determined from the fraction "<0.063 mm" by laser particle size analyzer using liquid dispersion mode.

Test specification, deviations, additions to or exclusions from the test specification:

Attachment no. 1 to the certificate of analysis for work order PR1784932

RESULTS OF GRAIN SIZE ANALYSIS



Rapport

Ackred. nr 2030
Provning
ISO/IEC 17025

T1810063

OPJTO4M7F2

Ankomstdatum **2018-04-06**
Utfärdad **2018-04-30**

Chalmers Tekniska Högskola
Ann-Margret Strömvall
Vatten Miljö Teknik

412 96 Göteborg
Sweden

Projekt
Bestnr

Analys av fast prov

Er beteckning **Sopsand <63um 180326**

Provtagare **Maria Polukarova**
Provtagningsdatum **2018-03-26**

Labnummer O10992994

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
TS_105°C	**99.4**	2.0	%	1	1	INRO
formaldehyd	**5.1**	1.0	mg/kg TS	1	1	INRO
acetaldehyd	**7.6**	1.5	mg/kg TS	1	1	INRO
propionaldehyd	**<2.0**		mg/kg TS	1	1	INRO
butyraldehyd	**<2.0**		mg/kg TS	1	1	INRO
glutaraldehyd	**<2.0**		mg/kg TS	1	1	INRO
dimetylftalat	**<0.0010**		vikt-%	2	1	INRO
dietylftalat	**<0.0010**		vikt-%	2	1	INRO
di-n-propylftalat	**<0.0010**		vikt-%	2	1	INRO
di-n-butylftalat (DBP)	**<0.0010**		vikt-%	2	1	INRO
di-iso-butylftalat (DIBP)	**<0.0010**		vikt-%	2	1	INRO
di-pentylftalat (DPP)	**<0.0010**		vikt-%	2	1	INRO
di-n-oktylftalat (DNOP)	**<0.0010**		vikt-%	2	1	INRO
di-(2-etylhexyl)ftalat (DEHP)	**<0.0010**		vikt-%	2	1	INRO
butylbensylftalat (BBP)	**<0.0010**		vikt-%	2	1	INRO
di-cyklohexylftalat	**<0.0010**		vikt-%	2	1	INRO
di-iso-decylftalat (DIDP)	**<0.010**		vikt-%	2	1	INRO
di-iso-nonylftalat (DINP)	**<0.010**		vikt-%	2	1	INRO
di-n-hexylftalat (DnHP)	**<0.0010**		vikt-%	2	1	INRO
bisfenol A	**<0.10**		mg/kg TS	3	1	INRO
TS_105°C	**99.4**	5.99	%	4	2	VITA
4-tert-oktylfenol	**0.146**	0.058	mg/kg TS	4	2	VITA
4-tert-OF-monoetoxilat	**<0.010**		mg/kg TS	4	2	VITA
4-tert-OF-dietoxilat	**<0.040**		mg/kg TS	4	2	VITA
4-tert-OF-trietoxilat	**<0.020**		mg/kg TS	4	2	VITA
4-nonylfenoler (tekn blandning)	**<0.10**		mg/kg TS	4	2	VITA
4-NF-monoetoxilat	**<0.10**		mg/kg TS	4	2	VITA
4-NF-dietoxilat	**<0.15**		mg/kg TS	4	2	VITA
4-NF-trietoxilat	**<0.20**		mg/kg TS	4	2	VITA
TOC	**3.69**		% av TS	5	2	VITA
glödförlust	**5.49**	0.28	% av TS	6	2	VITA
TS_105°C	**99.2**		%	7	O	JOHE
naftalen	**<1.0**		mg/kg TS	8	J	MASU

Er beteckning	**Sopsand <63um 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992994

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
acenaftylen	**<1.0**		mg/kg TS	8	J	MASU
acenaften	**<1.0**		mg/kg TS	8	J	MASU
fluoren	**<1.0**		mg/kg TS	8	J	MASU
fenantren	**<1.0**		mg/kg TS	8	J	MASU
antracen	**<1.0**		mg/kg TS	8	J	MASU
fluoranten	**<1.0**		mg/kg TS	8	J	MASU
pyren	**<1.0**		mg/kg TS	8	J	MASU
bens(a)antracen	**<0.50**		mg/kg TS	8	J	MASU
krysen	**<0.50**		mg/kg TS	8	J	MASU
bens(b)fluoranten	**<0.50**		mg/kg TS	8	J	MASU
bens(k)fluoranten	**<0.50**		mg/kg TS	8	J	MASU
bens(a)pyren	**<0.50**		mg/kg TS	8	J	MASU
dibens(ah)antracen	**<0.50**		mg/kg TS	8	J	MASU
benso(ghi)perylen	**<1.0**		mg/kg TS	8	J	MASU
indeno(123cd)pyren	**<0.50**		mg/kg TS	8	J	MASU
PAH, summa 16	**<13**		mg/kg TS	8	D	MASU
PAH, summa cancerogena*	**<2.0**		mg/kg TS	8	N	MASU
PAH, summa övriga*	**<5.0**		mg/kg TS	8	N	MASU
PAH, summa L*	**<1.5**		mg/kg TS	8	N	MASU
PAH, summa M*	**<2.5**		mg/kg TS	8	N	MASU
PAH, summa H*	**<2.5**		mg/kg TS	8	N	MASU
9-fluorenon	**<0.20**		mg/kg TS	9	3	LISO
9,10-antrakinon	**<0.20**		mg/kg TS	9	3	LISO
2-metylantracen-9,10-dion	**<0.20**		mg/kg TS	9	3	LISO
7H-bens(de)antracen-7-on	**<0.20**		mg/kg TS	9	3	LISO
bens(a)antracen-7,12-dion	**<0.20**		mg/kg TS	9	3	LISO
6H-bens(cd)pyren-6-on	**<0.20**		mg/kg TS	9	3	LISO
bens(a)fluorenon	**<0.20**		mg/kg TS	9	3	LISO
4H-cyklopenta(def)fenantrenon	**<0.20**		mg/kg TS	9	3	LISO
naftacen-5,12-dion	**<0.20**		mg/kg TS	9	3	LISO
alifater >C5-C8	**<10**		mg/kg TS	10	J	MASU
alifater >C8-C10	**<100**		mg/kg TS	10	J	LISO
alifater >C10-C12	**<200**		mg/kg TS	10	J	LISO
alifater >C12-C16	**<200**		mg/kg TS	10	J	LISO
alifater >C5-C16*	**<260**		mg/kg TS	10	N	MASU
alifater >C16-C35	**780**		mg/kg TS	10	J	LISO
aromater >C8-C10	**<10**		mg/kg TS	10	J	LISO
aromater >C10-C16	**<10**		mg/kg TS	10	J	LISO
metylpyrener/metylfluorantener*	**<10**		mg/kg TS	10	N	LISO
metylkrysener/metylbens(a)antracener*	**<10**		mg/kg TS	10	N	LISO
aromater >C16-C35	**<10**		mg/kg TS	10	J	LISO
bensen	**<0.01**		mg/kg TS	10	J	MASU
toluen	**<0.05**		mg/kg TS	10	J	MASU
etylbensen	**<0.05**		mg/kg TS	10	J	MASU
m,p-xylen	**<0.05**		mg/kg TS	10	J	MASU
o-xylen	**<0.05**		mg/kg TS	10	J	MASU
xylener, summa*	**<0.05**		mg/kg TS	10	N	MASU
TEX, summa*	**<0.1**		mg/kg TS	10	N	MASU

Er beteckning **Sopsand 63-125 um 180326**

Provtagare **Maria Polukarova**
Provtagningsdatum **2018-03-26**

Labnummer O10992995

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dimetylftalat	**<0.0010**		vikt-%	2	1	CL
dietylftalat	**<0.0010**		vikt-%	2	1	CL
di-n-propylftalat	**<0.0010**		vikt-%	2	1	CL
di-n-butylftalat (DBP)	**<0.0010**		vikt-%	2	1	CL
di-iso-butylftalat (DIBP)	**<0.0010**		vikt-%	2	1	CL
di-pentylftalat (DPP)	**<0.0010**		vikt-%	2	1	CL
di-n-oktylftalat (DNOP)	**<0.0010**		vikt-%	2	1	CL
di-(2-etylhexyl)ftalat (DEHP)	**<0.0010**		vikt-%	2	1	CL
butylbensylftalat (BBP)	**<0.0010**		vikt-%	2	1	CL
di-cyklohexylftalat	**<0.0010**		vikt-%	2	1	CL
di-iso-decylftalat (DIDP)	**<0.010**		vikt-%	2	1	CL
di-iso-nonylftalat (DINP)	**<0.010**		vikt-%	2	1	CL
di-n-hexylftalat (DnHP)	**<0.0010**		vikt-%	2	1	CL
TS_105°C	**99.6**	6.01	%	11	2	VITA
alifater >C5-C8	**<4.0**		mg/kg TS	11	2	VITA
alifater >C8-C10	**<4.0**		mg/kg TS	11	2	VITA
alifater >C10-C12	**<20**		mg/kg TS	11	2	VITA
alifater >C12-C16	**<20**		mg/kg TS	11	2	VITA
alifater >C5-C16 *	**<24**		mg/kg TS	11	2	VITA
alifater >C16-C35	**658**	132	mg/kg TS	11	2	VITA
aromater >C8-C10	**<0.480**		mg/kg TS	11	2	VITA
aromater >C10-C16	**<1.24**		mg/kg TS	11	2	VITA
metylpyrener/metylfluorantener	**<1.0**		mg/kg TS	11	2	VITA
metylkrysener/metylbens(a)antracener	**<1.0**		mg/kg TS	11	2	VITA
aromater >C16-C35	**<1.0**		mg/kg TS	11	2	VITA
bensen	**<0.010**		mg/kg TS	11	2	VITA
toluen	**<0.050**		mg/kg TS	11	2	VITA
etylbensen	**<0.050**		mg/kg TS	11	2	VITA
m,p-xylen	**<0.050**		mg/kg TS	11	2	VITA
o-xylen	**<0.050**		mg/kg TS	11	2	VITA
xylener, summa	**<0.050**		mg/kg TS	11	2	VITA
TEX, summa *	**<0.10**		mg/kg TS	11	2	VITA
naftalen	**<0.100**		mg/kg TS	11	2	VITA
acenaftylen	**<0.100**		mg/kg TS	11	2	VITA
acenaften	**<0.100**		mg/kg TS	11	2	VITA
fluoren	**<0.100**		mg/kg TS	11	2	VITA
fenantren	**0.149**	0.037	mg/kg TS	11	2	VITA
antracen	**<0.100**		mg/kg TS	11	2	VITA
fluoranten	**0.218**	0.054	mg/kg TS	11	2	VITA
pyren	**0.279**	0.070	mg/kg TS	11	2	VITA
bens(a)antracen	**<0.080**		mg/kg TS	11	2	VITA
krysen	**<0.080**		mg/kg TS	11	2	VITA
bens(b)fluoranten	**0.181**	0.045	mg/kg TS	11	2	VITA
bens(k)fluoranten	**<0.080**		mg/kg TS	11	2	VITA
bens(a)pyren	**0.083**	0.021	mg/kg TS	11	2	VITA

Er beteckning	**Sopsand 63-125 um 180326**
Provtagare	**Maria Polukarova**
Provtagningsdatum	**2018-03-26**
Labnummer	O10992995

Parameter	Resultat	Osäkerhet (±)	Enhet	Metod	Utf	Sign
dibens(ah)antracen	**<0.080**		mg/kg TS	11	2	VITA
benso(ghi)perylen	**0.117**	0.029	mg/kg TS	11	2	VITA
indeno(123cd)pyren	**0.098**	0.024	mg/kg TS	11	2	VITA
PAH, summa 16 *	**1.1**		mg/kg TS	11	2	VITA
PAH, summa cancerogena *	**0.36**		mg/kg TS	11	2	VITA
PAH, summa övriga *	**0.76**		mg/kg TS	11	2	VITA
PAH, summa L *	**<0.15**		mg/kg TS	11	2	VITA
PAH, summa M *	**0.65**		mg/kg TS	11	2	VITA
PAH, summa H *	**0.48**		mg/kg TS	11	2	VITA
TOC	**2.19**		% av TS	5	2	VITA
glödförlust	**3.29**	0.18	% av TS	6	2	VITA

* efter parameternamn indikerar icke ackrediterad analys.

	Metod
1	Paket OJ-33 Bestämning av aldehyder. Mätning utförs med HPLC. Rev 2014-10-27
2	Paket OJ-4B Bestämning av ftalater enligt E DIN 19742 (2012-04). Mätning utförs med GC-MS. Rev 2014-06-26
3	Bestämning av Bisfenol-A. Mätning utförs med GC-MS. Rev 2014-03-17
4	Paket OJ-18E. Bestämning av 4-nonylfenol, 4-t-oktylfenol samt mono- ,di- och trietoxilater. Mätning utförs med GC-MS. Rev 2013-01-11
5	Bestämning av TOC. TOC är beräknad från TC och TIC-bestämningen enligt metod baserad på CSN ISO 10694 , CSN EN 13137 och 15936 (coulometri). Rev 2017-02-15
6	Bestämning av glödförlust med gravimetri enligt metod baserad på CSN EN 12879, CSN 72 0103 och CSN 46 5735. Rev 2013-09-19
7	Bestämning av torrsubstans enligt SS 028113 utg. 1 Provet torkas vid 105°C. Mätosäkerhet (k=2): ±6% Rev 2018-03-28
8	Paket OJ-1 Bestämning av polycykliska aromatiska kolväten, PAH (16 föreningar enligt EPA) Mätning utförs med GCMS enligt metod baserad på SS EN ISO 18287:2008 utg. 1 mod. och intern instruktion TKI38. PAH cancerogena utgörs av benso(a)antracen, krysen, benso(b)fluoranten, benso(k)fluoranten, benso(a)pyren, dibenso(ah)antracen och indeno(123cd)pyren. 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 direktiv från Naturvårdsverket oktober 2008. Mätosäkerhet k=2 Enskilda PAH: ±27-37% Rev 2017-02-27
9	Bestämning av oxy-PAHer (9 föreningar).

	Metod
	Mätningen utförs med GCMS. Rev 2011-10-13
10	Paket OJ-21C Bestämning av alifatfraktioner och aromatfraktioner. Bestämning av bensen, toluen, etylbensen och xylen (BTEX). * summa metylpyrener/metylfluorantener och summa metylkrysener/metylbens(a)antracener. Mätning utförs med GCMS enligt interna instruktioner TKI45a och TKI42a som är baserade på SPIMFABs kvalitetsmanual. Mätosäkerhet (k=2): Alifatfraktioner: ±29-44% Aromatfraktioner: ±27-28% Bensen ±31% vid 0,1 mg/kg Toluen ±23% vid 0,1 mg/kg Etylbensen ±24% vid 0,1 mg/kg m+p-Xylen ±25% vid 0,1 mg/kg o-Xylen ±25% vid 0,1 mg/kg Summorna för metylpyrener/metylfluorantener, metylkrysener/metylbens(a)antracener och alifatfraktionen >C5-C16 är inte ackrediterade. Rev 2017-02-28
11	Paket OJ-21A Bestämning av alifatfraktioner och aromatfraktioner. Bestämning av metylpyrener/metylfluorantener och metylkrysener/metylbens(a)antracener. Bestämning av bensen, toluen, etylbensen och xylen (BTEX). Bestämning av polycykliska aromatiska kolväten, PAH (16 föreningar enligt EPA) Metod baserad på SPIMFABs kvalitetsmanual. 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. 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 direktiv från Naturvårdsverket oktober 2008. Rev 2016-01-26

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	Utf[1]
D	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
J	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
N	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
O	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).
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.
2	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.
3	För mätningen svarar ALS Scandinavia AB, Box 700, 182 17 Danderyd som är av det svenska ackrediteringsorganet SWEDAC ackrediterat laboratorium (Reg.nr. 2030).

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).