REPORT

Screening 2013

Assessment of the occurrence of stormwater related substances in sewage sludge and effluent water

Katarina Hansson Magnus Rahmberg Lennart Kaj
Eva Brorström-Lundén

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John Munthe
Vice President, Research

IVL Swedish Environmental Research Institute

NATUR VÅRDS VERKET
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Telephone +46 (0)31-725 62 00	

Author

Katarina Hansson, Magnus Rahmberg, Lennart Kaj, Eva Brorström-Lundén

Title and subtitle of the report

Screening 2013 Assessment of the occurrence of stormwater related substances in sewage sludge and effluent water

Summary An assessment of the occurrence of stormwater related pollutants in effluents and sludge from municipal wastewater treatment plants (WWTPs) has been performed in order to assess how stormwater may affect the occurrence of various chemicals in sludge and effluent from WWTPs. Results from the Swedish EPA monitoring programme of sludge and effluent as well as results of chemical analyses of alkyl phenols, major phthalates, PAHs and metals in sediment sampled downstream of selected plants were analysed with multivariate methods to determine if any co-variation exist between share of stormwater inflow, for which additional water was used as an approximation, and measured concentrations of contaminants. Time trends at the different sites were observed but no correlation with the amount of additional water was seen. It is concluded that the use of "additional water" as an approximation for stormwater is not ideal. Better estimates of the stormwater share could perhaps reveal correlations in the data.

Keyword

stormwater, WWTP, sludge, effluent, multivariate modelling

Bibliographic data

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Summary

The total inflow of wastewater to a municipal waste water treatment plant (WWTP) may be divided in sanitary sewer and additional water. The additional water may further be divided into three compartments: groundwater or soil water that leaks or drains into the sewage system; runoff from roofs and paved surfaces connected to the sewage system due to direct impact of precipitation (stormwater); runoff from e.g. paved surfaces and green surfaces that infiltrates through soil and may leak to the sewage system or as leakage from stormwater system to the sewage system.

In order to determine the shares of stormwater in the load to the selected WWTPs, annual environmental reports from these plants were used together with information obtained by personal communication with the WWTPs. Generally, the level of knowledge concerning the proportion of stormwater in the influent varied among the different WWTPs. Some of the WWTPs had modelled data, other not. Estimates from WWTPs for which inflow of stormwater could be separated from the total inflow of additional water (Henriksdal, Gässlösa, Ryaverket and Borlänge WWTP) showed that the share varied between 9 and 30%. The highest shares were found in Henriksdal in Stockholm.

Results from the Swedish EPA monitoring programme of sludge and effluent were analysed with multivariate methods to determine if any co-variation exist between share of stormwater inflow, for which additional water was used as an approximation, and measured concentrations of metals and organic substances. Also the change over time was studied with this methodology.

The results from the multivariate analyses showed that there is a grouping according to when the monitoring was performed. The monitoring performed in 2006 and 2007 differed from the rest. The analyses with multivariate method also showed that it was hard to see any trends regarding the additional water and its influence on the concentrations of pollutants in sludge or water. New measurements at the inflow to the WWTP and on sludge samples together with additional parameters, such as antimony or other specific markers, which could contribute to the explanation of the load from additional waters, are needed. Time trends at the different sites were observed with the present data but no correlation with the amount of additional water was however seen. It is clear that the use of "additional water" as an approximation for stormwater is not ideal. Better estimates of the stormwater share could perhaps reveal correlations in the data that was now hidden.

Effluent and sludge from the WWTPs Henriksdal, Ryaverken, Gässlösa and Bollebygd, and also sediment sampled downstream of the plants were chemically analysed on alkyl phenols, major phthalates, PAHs and metals. Multivariate modelling did not reveal any correlation between any of the measured parameters and the share of additional water, which was used as an estimate for the share of stormwater. As above, a better estimate of the stormwater share than "additional water" would have been beneficial.

Sammanfattning

Förekomsten av dagvattenrelaterade föroreningar i utgående vatten och slam från kommunala reningsverk har satts i relation till andelen dagvatten i det inkommande vattnet.

Det totala flödet in till ett reningsverk kan delas upp i sanitärt vatten och tillskottsvatten. Tillskottsvattnet kan i sin tur delas upp i tre olika typer: läck- och dränvatten; den direkta nederbördspåverkan - avrinning från tak och gatumark kopplade till avloppsystem samt den indirekta nederbördspåverkan vars källa till stor del är hårdgjorda ytor, men dess väg till avloppssystemet är via markinfiltration och vidare läckage till avloppsnätet.

Andelen dagvatten av belastningen till reningsverken bedömdes med hjälp av information från de årliga miljörapporterna och genom kontakt med ansvariga på reningsverken. Kännedomen om andelen dagvatten in till reningsverken varierade mellan dessa. Vissa reningsverk hade modellerade data, andra inte. Uppskattningar från reningsverk där andelen dagvatten kunde separeras från det totala tillskottsvattnet (Henriksdal, Gässlösa, Ryaverket och Borlänge) varierade mellan 9 och 30%. Högsta andelen uppgavs från Henriksdal.

Resultat från Naturvårdsverkets program för övervakning av utgående vatten och slam från avloppsreningsverk analyserades med multivariata metoder för att för att utröna om det finns samvariation mellan andelen dagvatten, för vilken andelen tillskottsvatten användes som en approximation, och uppmätta halter av metaller och organiska ämnen. Förändring över tid studerades också.

Resultatet från den multivariata analysen visade en gruppering av data efter när provtagningen var gjord. Prover från 2006 och 2007 avvek från övriga år. Analysen kunde inte påvisa några samband mellan andelen tillskottsvatten och koncentration av föroreningar i slam eller vatten. Nya mätningar i inkommande vatten och slam också av ytterligare parametrar som antimon eller andra specifika markörer för dagvatten behövs. Tidstrender vid de olika verken kunde ses i de befintliga data men samvariation med andelen tillskottsvatten kunde inte påvisas. Att använda andelen tillskottsvatten som en approximation för andelen dagvatten är inte optimalt. En bättre uppskattning av den verkliga dagvattenadelen kan kanske avslöja samband i data som ny döljs.

Utgående vatten och slam från reningsverken Henriksdal, Ryaverken, Gässlösa och Bollebygd, och även sediment nedströms dessa, analyserades kemiskt på med avseende på alkylfenoler, de dominerande ftalaterna, PAHer och metaller. Multivariat modellering visade inte någon korrelation mellan någon eller några mätta parametrar och andelen tillskottsvatten som användes som en uppskattning av andelen dagvatten. Även här skulle ett bättre mått på den verkliga dagvattenandelen varit värdefullt.

Contents

Introduction and aim

As an assignment from the Swedish Environmental Protection Agency, an assessment of the occurrence of stormwater related pollutants in effluents and sludge from municipal wastewater treatment plants (WWTPs) has been performed by IVL Swedish Environmental Research Institute.

The first part of the study was to assess how stormwater may affect the occurrence of various chemicals in sludge and effluent from WWTPs using data from the WWTPs included in the Swedish EPA monitoring programme of sludge and effluent (Haglund and Olofsson, 2012).

In the second part of the study new measurements were performed of organic substances and metals in effluent water and sludge from four of these WWTPs. Sediments from near the discharge points of the respective WWTPS were also analysed. The results were evaluated in relation to the share of “additional water” using multivariate methods.

Background

Sources of wastewater to WWTPs

Sweden has more than 2000 WWTPs, which processes water from a variety of sources e.g. households, hospitals and industrial sites as well as stormwater, which is included in the term “additional water”. The following three components contribute to additional water (Lundblad and Backö, 2012):

- Impact of leaked and drainage water - groundwater or soil water that leak or drain into the sewage system
- Direct impact of precipitation such as runoff from roofs and paved surfaces connected to sewage system. This part corresponds to approximately less than 10% of the additional water supplements.
- Indirect impact of precipitation such as runoff from e.g. paved surfaces (stormwater surfaces) and green surfaces that infiltrate thought soil and further may leak to sewage system or as leakage from stormwater system to the sewage system.

A schematic picture showing the different compartments of additional water that enter the WWTP is presented in Figure 1. The direct impact of precipitation corresponds to the flow of stormwater and the other two compartments to total flow of leak and drain water.

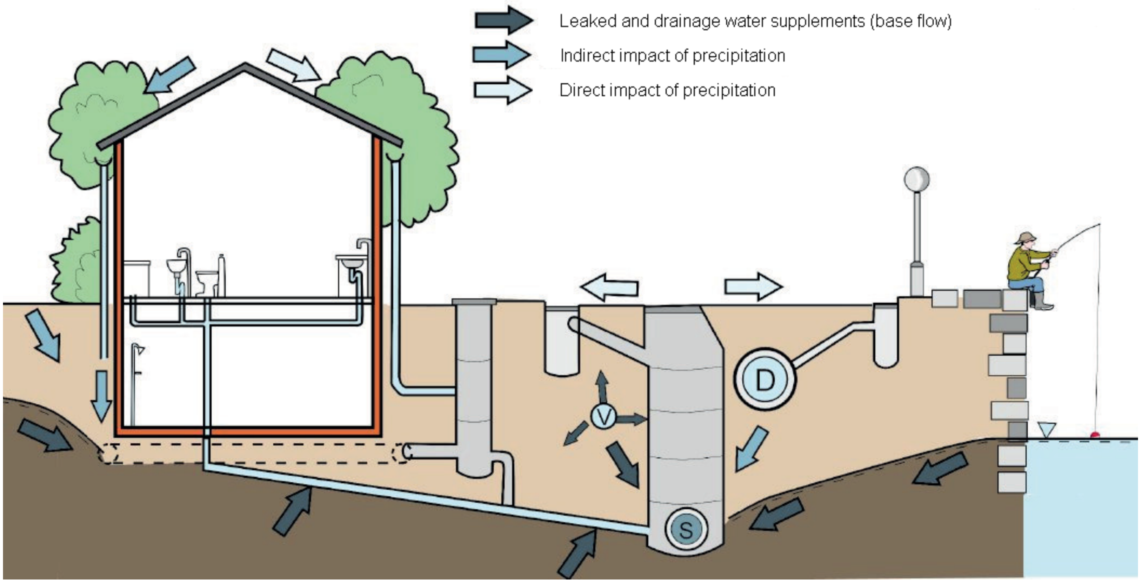

Figure 1. Schematic picture showing the different compartments of additional water that enter a WWTP. D-stormwater conduit, S-sewage conduit, V-water (Lundblad and Backö, 2012, text translated from Swedish).

National monitoring of sludge and effluent from WWTPs

The monitoring program for contaminants in WWTPs sludge run by the Swedish Environmental Protection Agency started in 2004. It included seven WWTPs of varying sizes and with different loads and treatment technologies. In 2010, monitoring of effluent was added to the programme. The measurements cover both metals and organic substances. Approximately 120 substances in sludge and 90 in effluent from nine WWTPs were determined in 2010 and 2011 (Haglund and Olofsson, 2012).

An overview of the WWTPs from which monitoring data is available is shown in Table 1. More information about the WWTPs, the treatment technologies, load and sizes is given in Appendix 1, Appendix 2 and in Haglund and Olofsson (2012).

Table 1. WWTPs in the national monitoring programme 2004-2011 for which data is available in the screening database (S-sludge, W-effluent water).

WWTP	2004	2005	2006	2007	2008	2009	2010	2011
Henriksdal	S	S	S	S	S	S	S, W	S, W
Nolhaga	S	S	S	S	S	S	S, W	S, W
Öns	S	S	S	S	S	S	S, W	S, W
Gässlösa	S	S	S	S	S		S, W	S, W
Ellinge	S	S	S		S	S	S, W	S, W
Ryaverket		S	S	S	S	S	S, W	S, W
Bollebygd		S	S	S	S	S	S, W	S, W
Floda	S	S	S	S	S	S		
Bergkvara							S, W	S, W
Borlänge							S, W	S, W

Methodology

Stormwater inflow to WWTPs

In order to determine the shares of stormwater in the load to the different WWTPs, annual environmental reports from these plants were used. Information about the total yearly inflow of influent, volumes of additional water and information about leakage into the sewage systems or other information of importance was collected for the years for which monitoring data was available.

The main data source has been environmental reports that were available as PDF-files at the website Swedish Portal for Environmental Reporting, SMP (SMP, 2013). Older reports were collected by personal contact with the WWTPs. Further information about the different sources of additional water that enter the WWTPs was collected by contact with the facilities.

Multivariate analysis

Data from the national monitoring, described above, were analysed with multivariate methods to determine if any co-variation exist between part of stormwater inflow and measured concentrations of metals and organic substances. Also the change over time was studied with this methodology.

Principal Component Analysis (PCA)

A brief description of PCA is given here; more details are given in literature e.g. Martens and Naes, 1989. PCA decomposes a data matrix X according to:

$$\mathbf{X} = \mathbf{T}\mathbf{P}^{\mathbf{T}} + \mathbf{E}$$

PCA can be considered a co-ordinate transformation from the original variable space to a model hyper-plane of much lower dimensionality that captures the variance in the data in the most efficient way. The scores, denoted t or T, are the co-ordinates in the new orthogonal co-ordinate system and thus describe the objects (here: chemical substances). The loadings, denoted p or P, describe the relation between the latent variables (principal components) that span the model space and original variables. The matrix E in the equation above contains the residuals, i.e. the part of the data not captured by the model hyper-plane. The substantial dimensionality reduction achieved by applying PCA leads to enhanced interpretation abilities which facilitate classification and clustering of substances. PCA is not a regression method and cannot be used for finding quantitative relationships between descriptors and responses.

The interpretation of the score and loading plots are illustrated in the Figure 2 below.

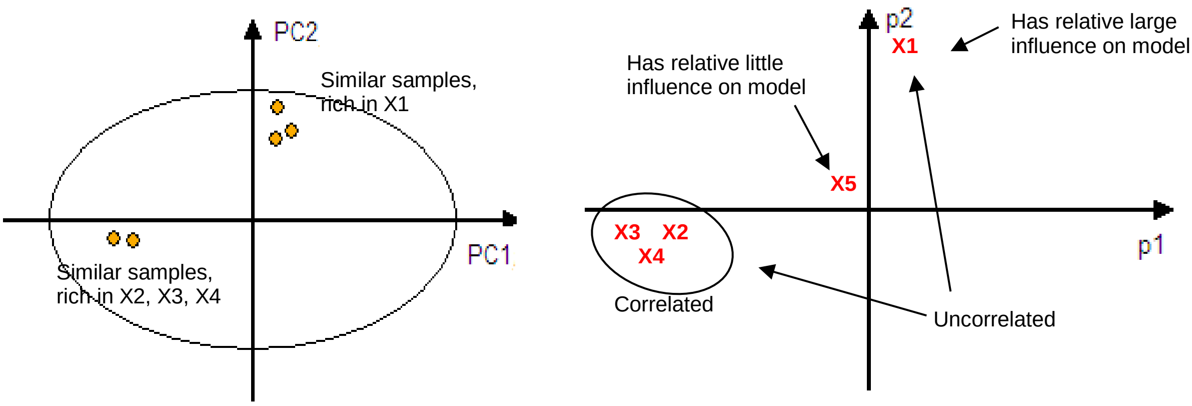

Figure 2. To the left an example of a score plot and to the right an example of the corresponding loading plot.

Chemical analysis, samples and analytes

Effluent and sludge were sampled on one occasion each at Henriksdal WWTP, Stockholm, Rya WWTP, Göteborg, Gässlösa WWTP, Borås and Bollebygd WWTP, Bollebygd. In addition sediment was sampled near the discharge points of the four WWTPs. Sample details are listed in Appendix 3.

The samples were analysed for the alkyl phenols 4-nonylphenol and 4-t-octylphenol, the phtalates DEHP (diethylhexyl phtalate), DINP (diisononyl phtalate), and DIDP (diiosdecyl phtalate), 24 PAHs and 10 metals. For a complete list of individual analytes see Appendix 4.

Chemical analysis, methods

For analysis of octylphenol, nonylphenol and phtalates, isotopically labelled surrogate standards ($^{13}C_6$-4-t-octyl phenol and D_4-DEHP) were added to all samples. Water samples were solid phase extracted. Sludge and sediment were extracted using MAE (microwave assisted extraction). After clean up the extracts were analysed for phtalates using GC-MS-MS and after silylation once more for octylphenol and nonylphenol.

For analysis of PAHs isotopically labelled surrogate standards (D_8-Naphtalene, D_{10}-Acenaphtene, D_{10}-Phenanthrene, D_{10}-Pyrene, D_{12}-Chrysene, D_{12}-Perylene, and D_{12}-Benzo(ghi)perylene) were added to all samples. Water samples were solid phase extracted. Sludge and sediment were extracted using acetone and hexane+MTBE. After clean up the extracts were analysed for PAHs using GC-MS-MS.

Sample preparation and analysis of metals was carried out by ALS Scandinavia AB, Luleå. To effluent water HNO_3 was added and the sample digested in an autoclave. Sediment and sludge was dried, HNO_3/water was added and the samples digested in closed vessels using MAE. For analysis of Sb in sediment and sludge digestion was done using *Aqua Regia*. Instrumental analysis was done using ICP-SFMS (Inductively Coupled Plasma Sector Field Mass Spectrometry).

Results

Stormwater inflow to WWTPs

Generally, the level of knowledge about the proportion of stormwater in the influent varied among the different WWTPs. It was, in some cases, difficult for the facilities to determine the origin of the influent water, other than the sanitary sewer. Models or extensive monitoring surveys are often necessary to estimate the sources of the additional water and further separation into stormwater, drain water or leak water. Only a few of the WWTPs could access this information. In Table 2 information about the different inflow of additional water to the selected WWTPs is compiled. The information was collected from the environmental reports and by personal communication with the WWTPs.

Table 2. Information about the origin and content of the additional water collected from the environmental reports and personal contacts with the WWTP.

WWTP	Information about additional water
Henriksdal WWTP	The share of different inflow to the WWTP has been modelled for 2012 and recalculated for the other years. Stormwater corresponds to approximately 10-15% and the leak and drainage water to 20-30% of the total inflow (incl. sanitary sewer) to the WWTP. Stormwater corresponded to approximately 30% of the additional water.
Nolhaga WWTP	Only a minor share of the influent water corresponds to the run off from roads, largest part enter the recipient directly. There may be some leakage into the sewage system due to old pipeline systems. Further, the largest inflow of additional water is the run off from the roofs and pavements.
Öns WWTP	The proportion of additional water is reasonable and the majority corresponds to stormwater. Only a small and probably insignificant proportion is due to the leakage of groundwater to the sewage system.
Gässlösa WWTP	The inflow of additional water to the WWTP was investigated for the period of 2008-2011. Approx. 5% of the total inflow (incl. sanitary sewer) to the WWTP during this period could be correlated to direct impact of precipitation (stormwater), 29% to leak and drain water and 20% due to indirect impact of precipitation. Stormwater corresponded to 9% of the additional water.
Ellinge WWTP	The additional water contains of the drain water and stormwater, the drain water being the most significant.
Ryaverket WWTP	As an average for 2000-2010, the largest part of the additional water corresponded to leak and drain water (86%) and the rest (14%) to stormwater.
Bollebygd WWTP	There is no information available about the share of stormwater in the sewage system. The largest variation in inflow of additional water is mostly due to inflow of stormwater.
Floda WWTP	There is no detailed study about the origin of the additional water inflow to the WWTP. It can probably be assumed that almost all additional water is stormwater of any kind.
Bergkvara WWTP	High share of additional water due to leakage to the sewage during periods of snow melting. The volumes of additional water can be equated with the volume of stormwater.
Borlänge WWTP	The inflow of additional water to the WWTP was investigated for the period of 2002-2006. Approx. 6% of the total inflow (incl. sanitary sewer) to the WWTP during this period could be correlated to direct impact of precipitation (stormwater), 15% to leak and drainage water and 21% due to indirect impact of precipitation. Stormwater corresponded to approx. 14% of the additional water as an average for the same period.

The percentage of additional water in the total volume of influent to WWTPs is presented in Figure 3, more information is also given i Appendix 2. These data are compiled from the annual environmental reports. There is a large variation of the share of additional water between the different WWTPs. The share of additional water varies from around 30% to 70% of the total inflow of waste water to the treatment plants, with the highest share for Bergkvara, Ryaverket, Gässlösa and Floda. Also, there is some variation in the share of additinal water beteen years. This may be correlated to the different precipitation rates and the geagrafical differences in precipitation pattern.

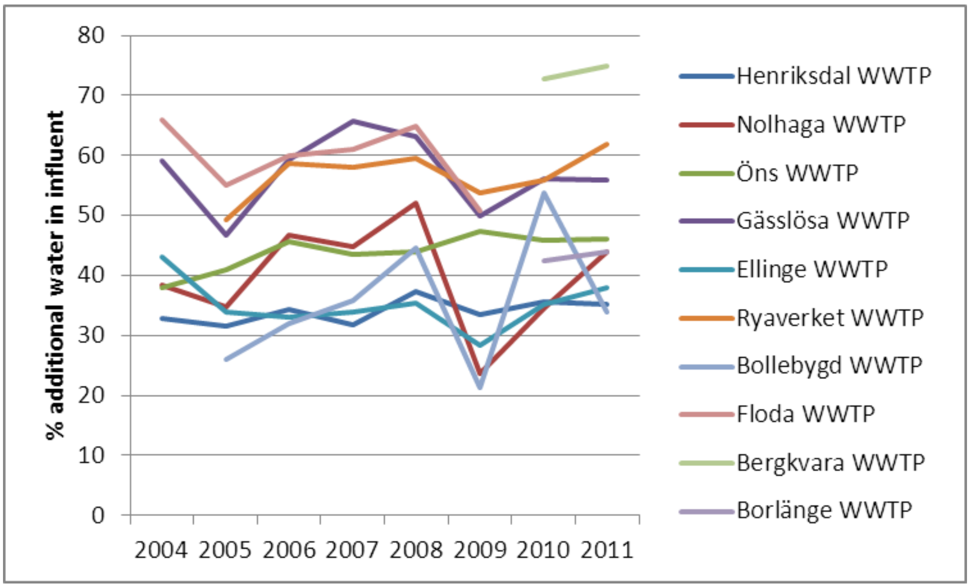

Figure 3. The percentage of additional water in influent to the WWTPs.

According to Lundblad and Backö (2012), stormwater usually corresponds to less than 10% of the additional water supplements. Estimates from WWTPs for which inflow of stormwater could be separated from the total inflow of additional water (Henriksdal, Gässlösa, Ryaverket and Borlänge WWTP) show that the share varies between 9 and 30%. The highest share is from Henriksdal in Stockholm.

As an example, data for Henriksdal WWTP is also presented as modelled share of stormwater in the influent (direct impact of precipitation) and as total amount additional water (stormwater, drain water and leak water), Figure 4.

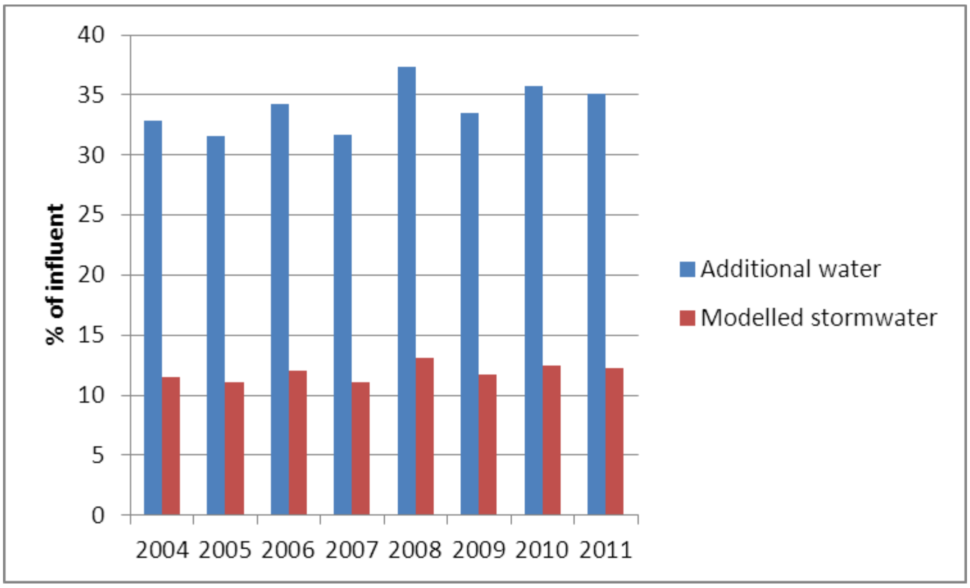

Figure 4. The percentage of additional water and modelled stormwater in influent to Henriksdal WWTP.

The varying levels of information considering the origin of additional water make it difficult to separate the stormwater part from the rest of additional water. In order to get an equal base for the comparison of data, additional water has therefore been chosen as a measure for stormwater. As the data are scaled before performing PCA-analysis an assumed ratio stormwater/additional water equal for all WWTPs will not influence the result. The use of additional water will also facilitate future work, as this information may easily be obtained from the environmental reports.

PCA with national monitoring data

The PCA was performed with the national monitoring data for both sludge and effluent water from WWTPs and data regarding the additional water contribution for each WWTP. Information regarding the different treatment techniques at the WWTPs was included as additional information to the data set but not as an ingoing variable in the PCA.

In Figure 5 sludge and water concentrations are included in the PCA. The observations are colour coded according to WWTP and the labels are the year the monitoring was performed.

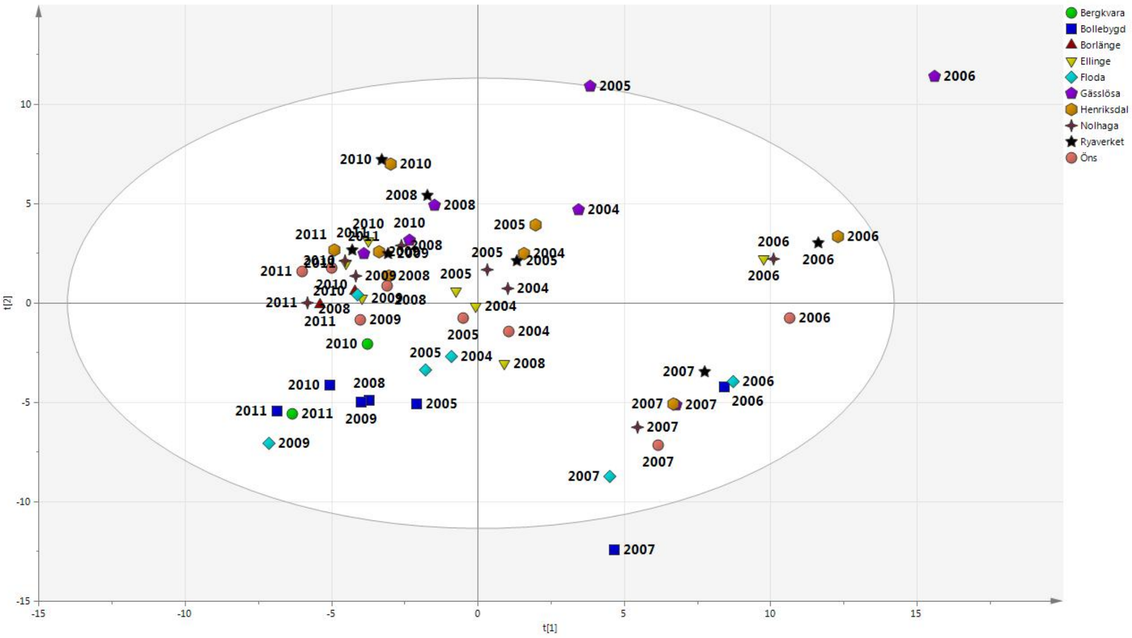

Figure 5. Score plot of the different WWTP and year of monitoring.

The ingoing variables i.e. the measured variables are shown in loading plot in Figure 6. They are colour coded for the origin of the variable, green is from sludge, blue is effluent water samples and grey is additional water.

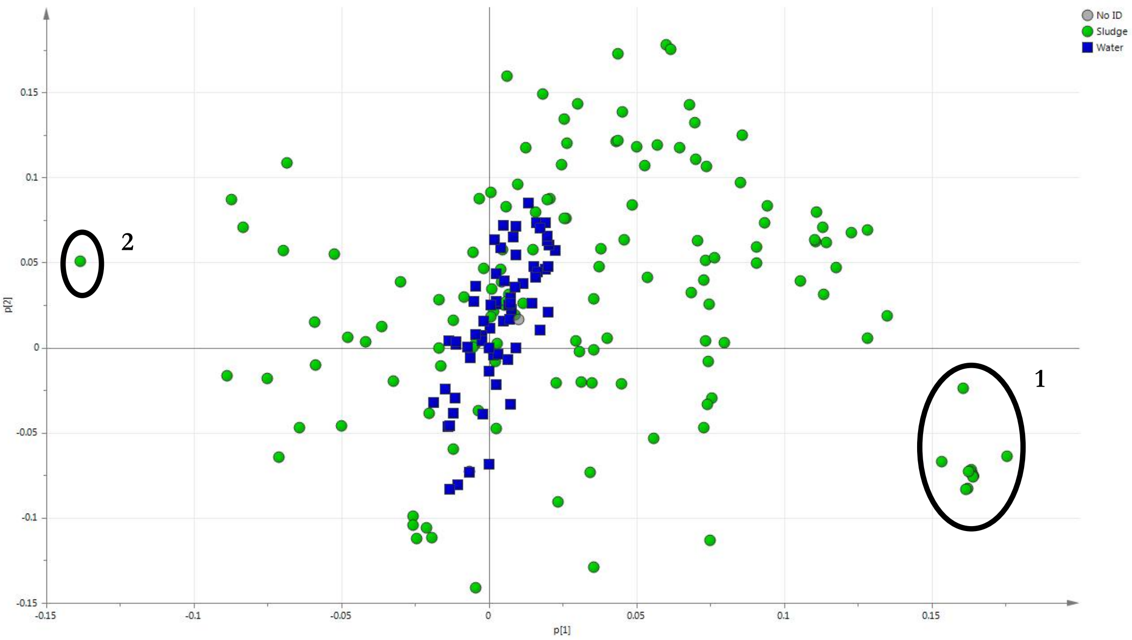

Figure 6. Loading plot where variables from sludge are marked as green and water as blue.

The first interpretation of the score plot is that there is a grouping according to when the monitoring is performed. The monitoring performed in 2006 and 2007 differs from the rest. The group of substances in the circle marked with 1 in the figure above consist of Chlorophenols, PBDE99, Perfluorobutane sulfonate and Perfluoropentadecanoic acid. In circle marked with a 2 Butylhydroxytoluene is outlined.

Since there are a lot of variables in the PCA the names of the variables in the loading plot is not highlighted. The sludge samples variables are well spread in the plot but the water samples are centred in the plot. It should also be noted that sampling of effluent water is only from 2010 and 2011.

One of the variables in the PCA above is the part of the total inflow that consists of additional water. In the loading plot it is positioned near origo which means that the observed patterns in the score plot has little influence from this variable.

Removing the organic compounds from the PCA, the score plot, Figure 7, changes compared to the previous one. The different WWTPs are now grouping mainly to them selfs.

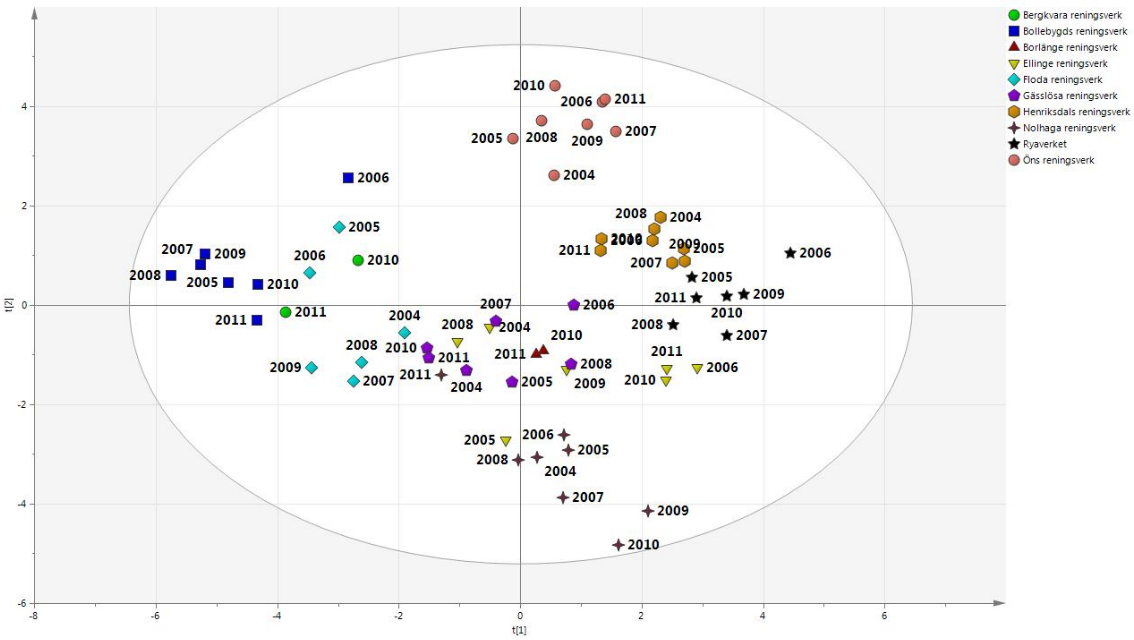

Figure 7. Score plot when metal concentration in sludge and water are included together with additional water.

The relation between the metals is shown in the loading plot below, Figure 8.

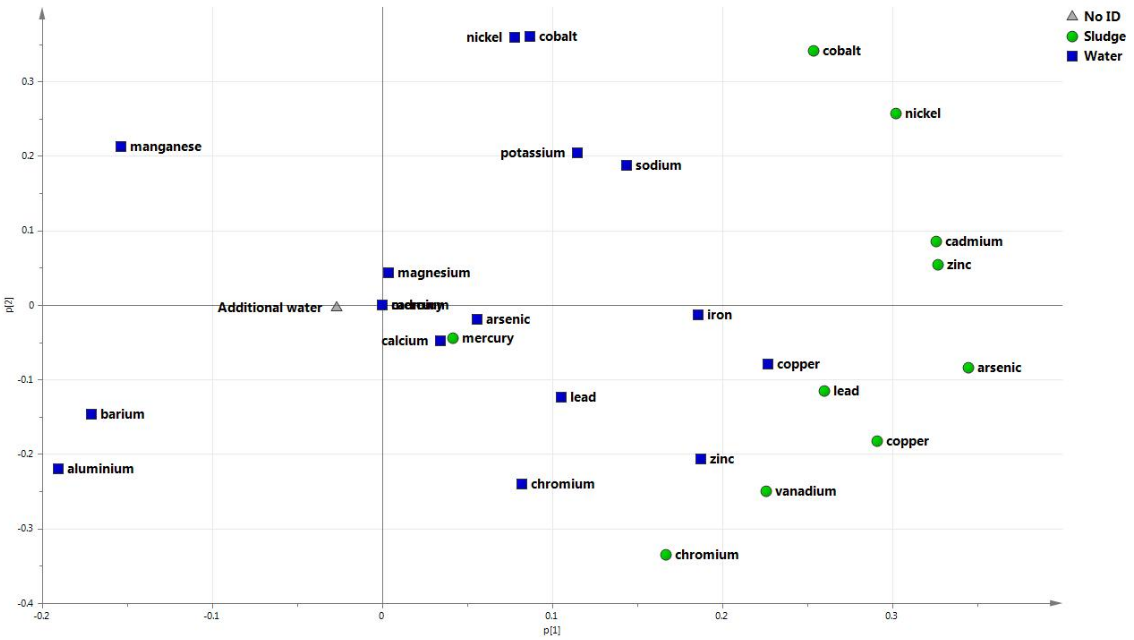

Figure 8. Loading plot for metal concentrations in sludge and water.

As in the previous score plot the variable additional water is centred close to origo and hence has little influence on positions in the plot of the different WWTPs.

Figure 9 is the same score plot as Figure 7 but also distinguishes the WWTPs with digestion of sludge (blue) from the WWTPS without digestion (green).

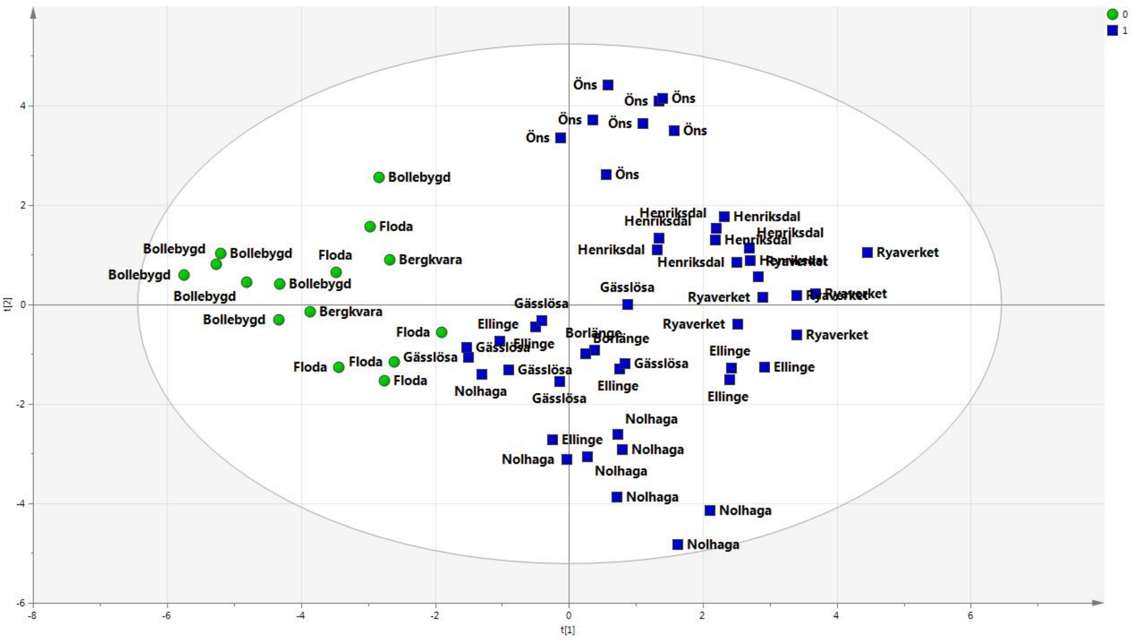

Figure 9. Score plot showing the difference between treatments of sludge. Blue observations: digestion, green observations: no digestion.

Observations, in this case the WWTPs, that are found in the right part of the score plot have higher concentrations of metals in the sludge and water with the exception of aluminium, barium and manganese in water which are increasing in the right part of the plot. Comparing one WWTP at the time also changes over time could be observed in the score plots above.

In addition to the results above a PCA were conducted with selected organic parameters that will be analysed in the upcoming measuring campaigns at the WWTP. The PCA gave no significant results and is hence not shown here. In this PCA only twelve of the organics listed in the measuring campaign were found in the existing data set and that is a reasonable explanation for the non-significant result.

Results from chemical analysis

All results from the chemical analysis of effluent, sludge and sediment from Henriksdal, Ryaverken, Gässlösa and Bollebygd WWTPs are listed in Appendix 4. An overview of the results is given in Figure 10, Figure 11 and Figure 12.

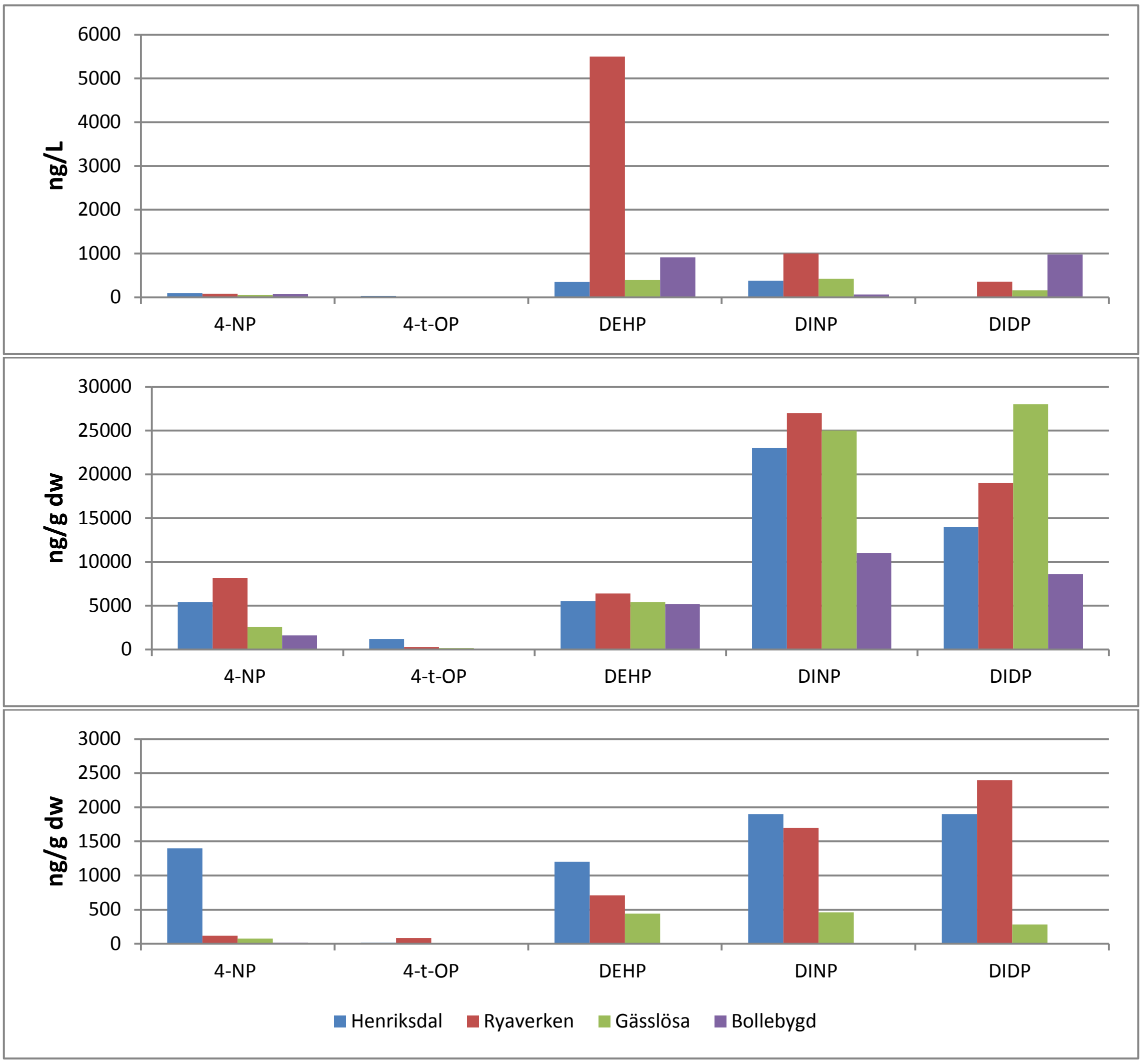

Figure 10. Concentrations of alkyl phenols and phtalates in, from above, effluent water, sludge and sediment from four WWTPs.

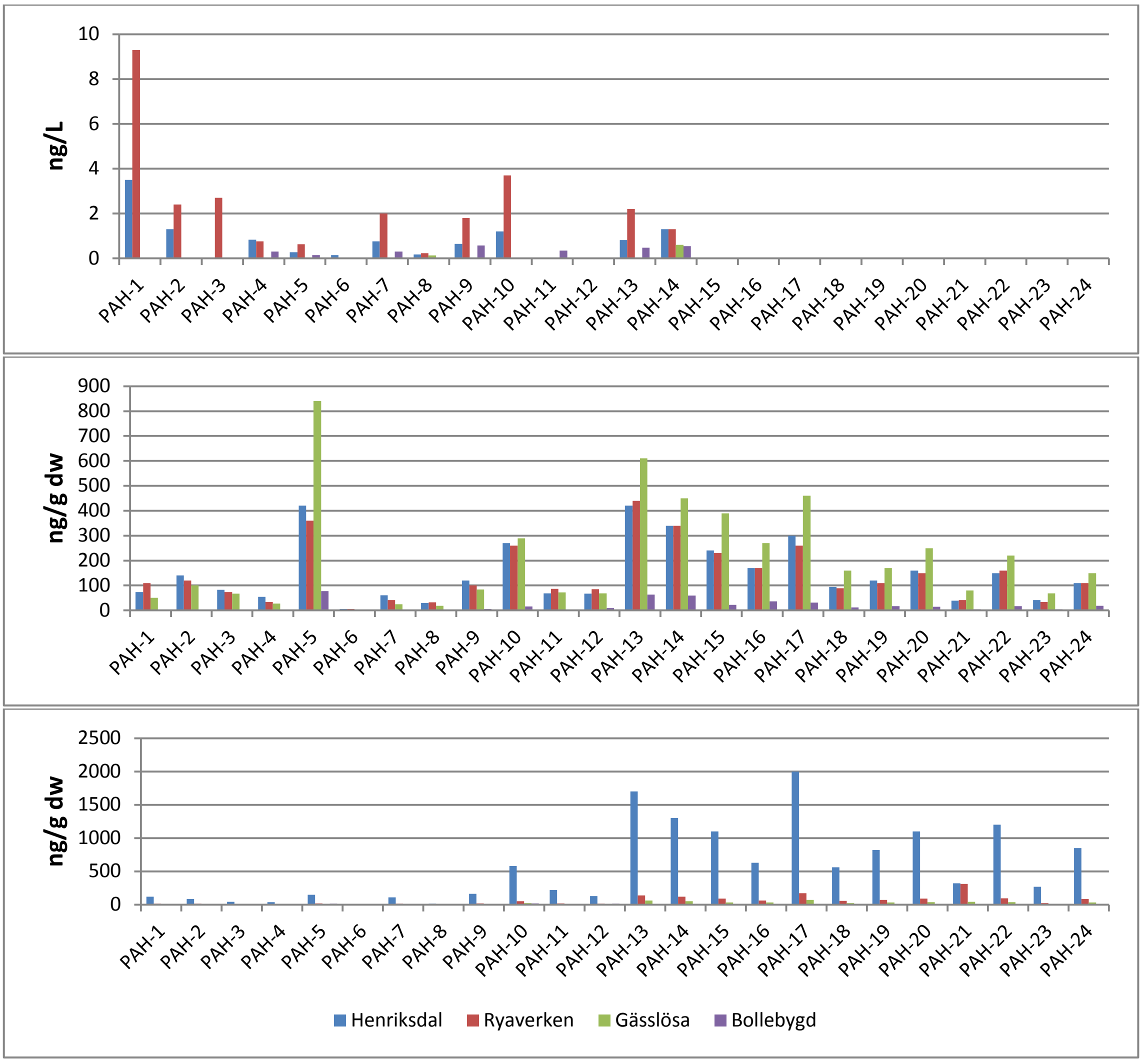

Figure 11. Concentrations of PAHs in, from above, effluent water, sludge and sediment from four WWTPs. The numbering of PAHs is explained in the list below.

PAH-1	Naphtalene	PAH-9	Fluorene	PAH-17	Benzo(b)fluoranthene
PAH-2	Naphtalene, 2-metyl-	PAH-10	Phenanthrene	PAH-18	Benzo(k)fluoranthene
PAH-3	Naphtalene, 1-metyl-	PAH-11	Anthracene	PAH-19	Benzo(e)pyrene
PAH-4	Biphenyl	PAH-12	Phenanthrene, 1-methyl-	PAH-20	Benzo(a)pyrene
PAH-5	Naphtalene, 2.6-dimethyl	PAH-13	Fluoranthene	PAH-21	Perylene
PAH-6	Acenaphtylene	PAH-14	Pyrene	PAH-22	Indeno(123cd)pyrene
PAH-7	Acenaphtene	PAH-15	Benzo(a)anthracene	PAH-23	Dibenz(ah)anhracene
PAH-8	Naphtalene, 2.3.5-trimethyl-	PAH-16	Chrysene	PAH-24	Benzo(ghi)perylene

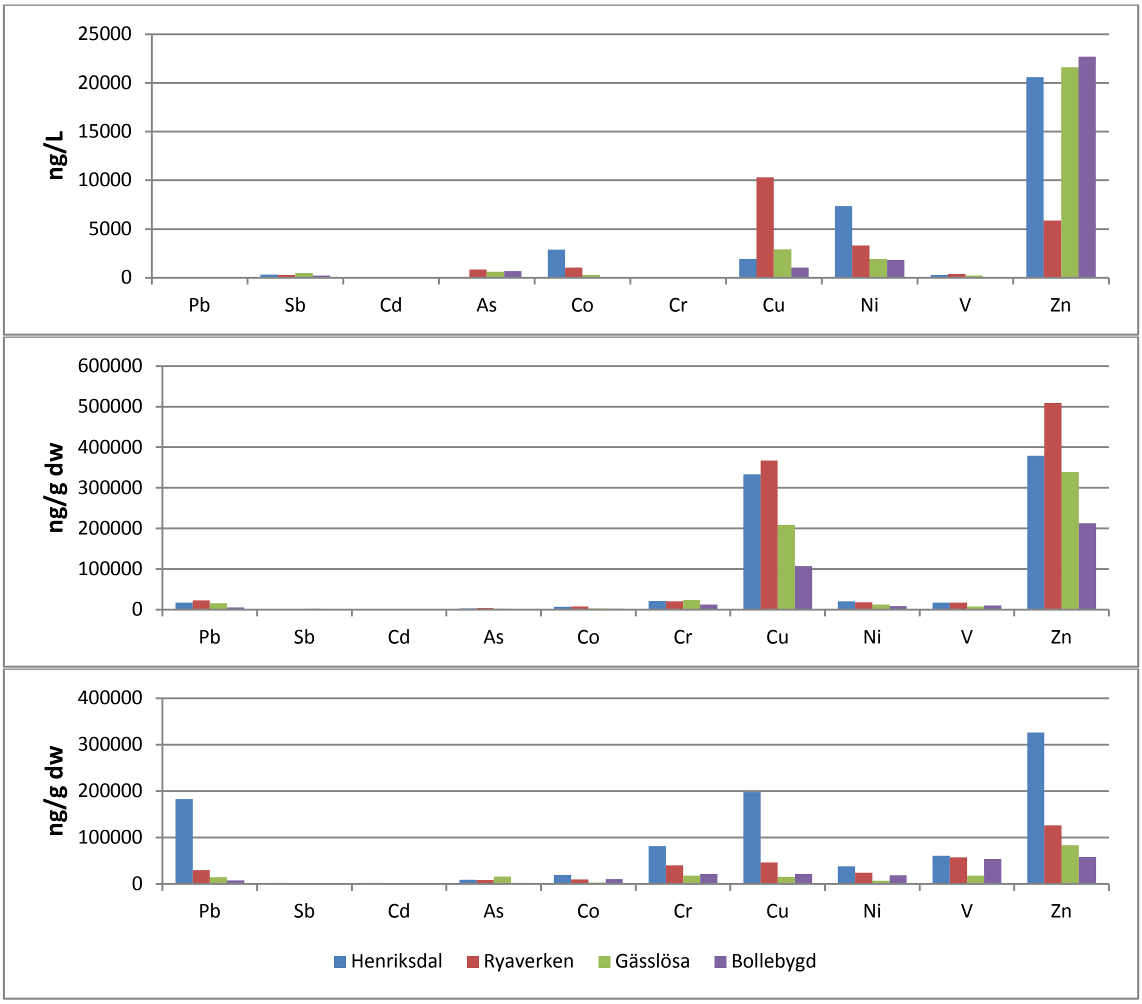

Figure 12. Concentrations of metals in, from above, effluent water, sludge and sediment from four WWTPs.

PCA with data from chemical analysis

PCA was performed on all or parts of the data from chemical analysis together with the share of additional water (Appendix 3).

Figure 13 shows the result of PCA on all variables. There is a clear separation on sample types. The four effluents are grouped close together showing small differences within the group. The sludge from Bollebygd is closer to origo compared to the other sludges due to lower concentrations. The sediment from Henriksdal is separated from the other sediments indicating higher concentrations.

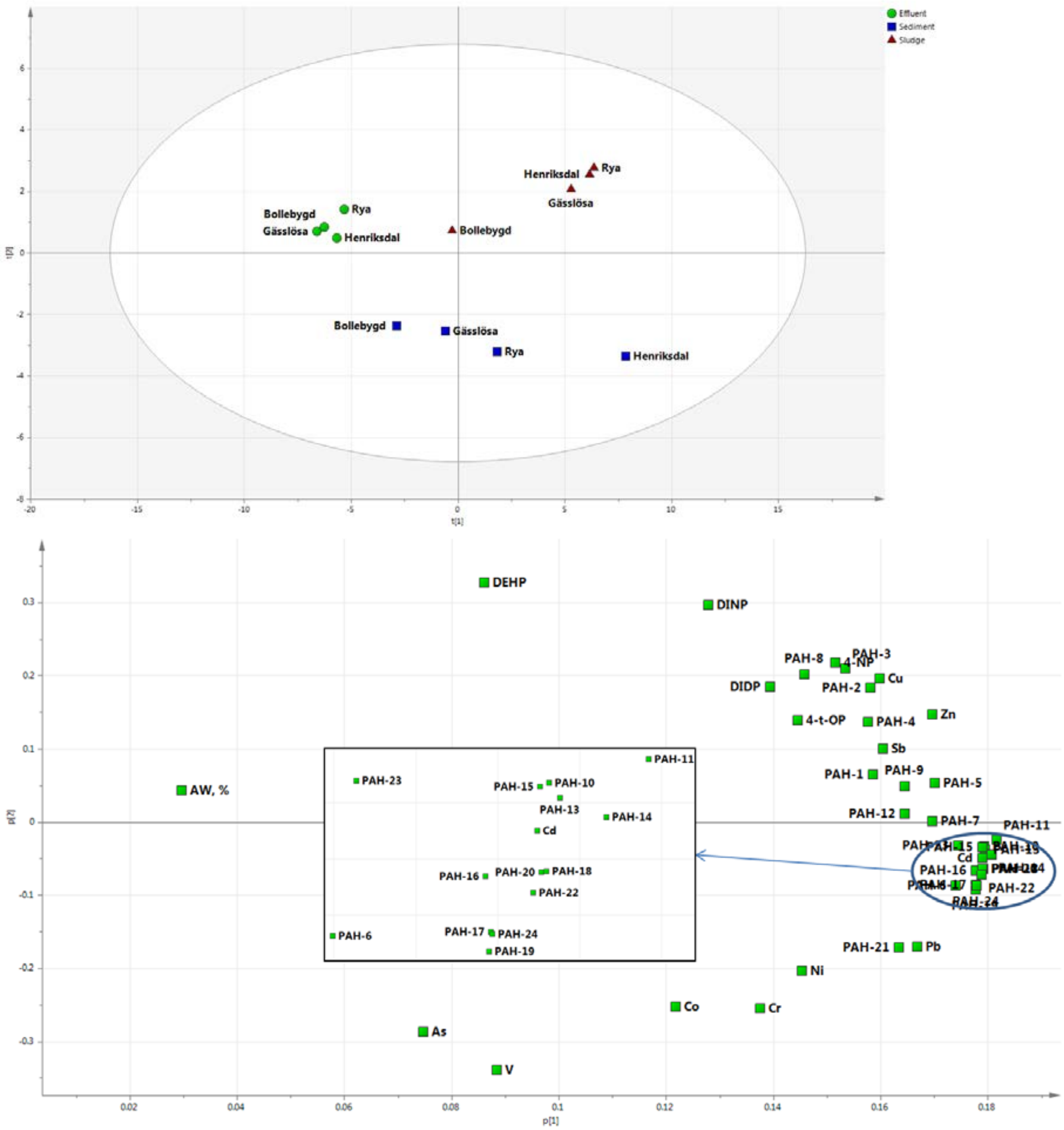

Figure 13. Score plot (above) and loading plot (below) PCA with all variables.

From the scoreplot it can be seen that the sediments have relatively lower concentrations of DEHP and higher concentrations of Vanadin. The variable "Additional water" (AW) is closer to origo than any other variable which means that its influence on the separation of the samples in the score plot is low.

Figure 14 shows the result of PCA on PAHs only. Sediment and sludge are less clearly separated. The PAHs are numbered in order of increasing molecular weight and decreasing volatility. It can be seen that the low molecular weight PAHs have higher relative concentrations in sludge than in sediment, high molecular weight PAHs have higher relative concentrations in sediment than in sludge. AW has little effect on the grouping of the samples.

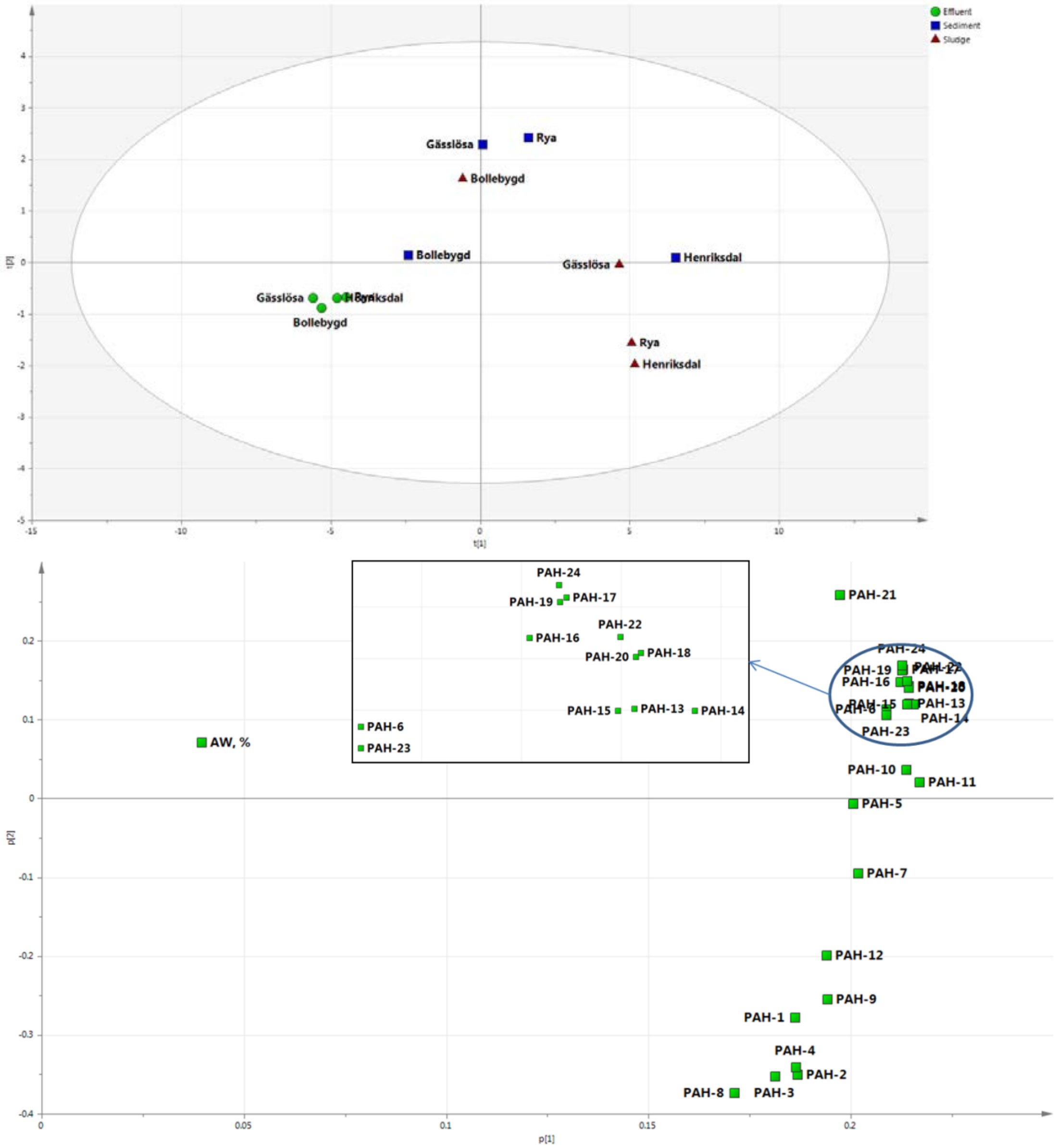

Figure 14. Score plot (above) and loading plot (below) PCA with PAHs only

Figure 15 shows the result of PCA on metals only. The score plot is very similar to what was seen when all variables were included. Cu, Zn, Sb is relatively higher in sludge, As, V is relatively higher in sediment. The influence of "additional water" is low.

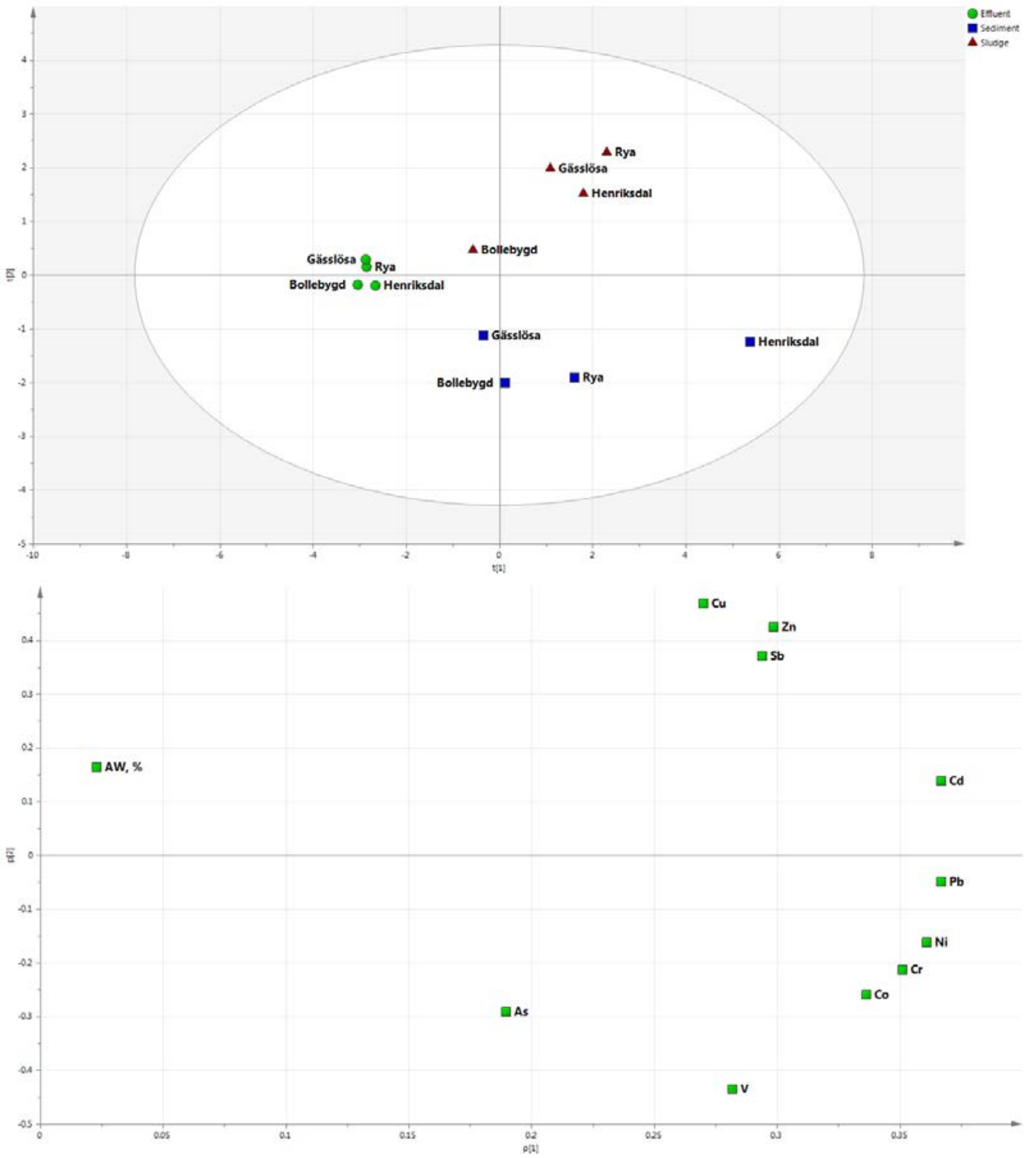

Figure 15. Score plot (above) and loading plot (below) PCA with metals only.

Conclusions

The varying levels of information considering the origin of additional water make it difficult to separate the stormwater part from the rest of the additional water. In order to get an equal base for the comparison of data, additional water has therefore been chosen as a measure for stormwater.

Conclusions from the PCA on monitoring data are that it is hard to see any trends regarding the additional water and its influence on the concentrations of pollutants in sludge or water. New measurements at the inflow to the WWTP and on sludge samples together with additional parameters, such as antimony or other specific markers, which could contribute to the explanation of the load from additional waters, are needed. Time trends at the different sites are observed with the present data but no correlation with the amount of additional water is seen. It is clear that the use of "additional water" as an approximation for stormwater is not ideal. Better estimates of the stormwater share could perhaps reveal correlations in the data that was now hidden.

Effluent and sludge from the WWTPs Henriksdal, Ryaverken, Gässlösa and Bollebygd, and also sediment sampled downstream of the plants was chemically analysed. PCA on the data from chemical analysis did not reveal any correlation between the share of additional water and any of the measured parameters. As above, a better estimate of the stormwater share than "additional water" would have been beneficial.

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Screening database (2013): Data from national monitoring of WWTP sludge and effluent, 2004-2011. www.ivl.se

SMP (2013) Annual legal environmental reports 2007-2011: Borlänge, Bergkvara, Bollebygd, Ellinge, Floda, Gässlösa, Ryaverket, Henriksdal, Nolhaga, Öns WWTPs. Swedish Portal for Environmental Reporting, SMP, https://smp.lansstyrelsen.se/

Appendix 1

Purification technologies for the different WWTPs (REF, 2013)

WWTP	Henriksdal	Nolhaga	Öns	Gässlösa	Ellinge	Ryaverket	Bollebygd	Floda	Bergkvara	Borlänge
Facility Id	0180-50-002	1489-1001	2480-131-01	1490-1001	1285-50-001	1480-1131	1443-1001	1441-1003	0834-005	2081-50-001
Municipality	Stockholm	Alingsås	Umeå	Borås	Eslövs	Göteborg	Bollebygd	Lerum	Torsås	Borlänge
x-coord, RT 90	6578860	6427700	7085223	6401540	6190450	6403663	6397700	6414050	6250350	6706150
y-coord, RT 90	1631830	1304520	1721043	1328470	1342950	1266636	1304900	1294610	1517900	1482650
Screening	x	x	x	x	x	x	x	x	x	x
Primary sedimentation	x	x		x	x	x				x
Activated sludge	x		x	x	x	x	x	x	x	x
Trickling filter		x		x		x				
Pre-precipitation			x							x
Co-precipitation			x			x	x			x
Post-precipitation		x			x			x	x	
Two point precipitation	x		x	x						
Filtration	x									
N-removal	x			x	x	x				
Anaerobic digestion	x	x	x	x	x	x				x
Aeration								x		
Liming									x	
Centrifuge	x	x	x		x	x		x		x
Belt-Filter Press						x			x	
Recessed-Plate Filter Press				x						
Other							x			

Appendix 2

Information about the WWTPs for the year for which monitoring data is available is presented. The information was compiled from the legal environmental reports for the different facilities and from Haglund and Olofsson (2012).

Pe - person equivalents

Henriksdal WWTP

Henriksdal WWTP located in Stockholm, is one of the largest in Sweden. In Henriksdal waste water from households, hospitals and industries (e.g. laundries, food industries) is treated.

	2004	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP				705000	721700	736597	752700	767650
No of pe connected to the WWTP				850000	801000	656000	622000	680000
Influent water (M m^3)	88	86	90	86	94	89	92	91
Additional water (M m^3)	10	10	11	10	12	10	11	11
Share of stormwater in total influent (%)	12	11	12	11	13	12	13	12
Share of additional water in total influent (%)	33	32	34	32	37	34	36	35
Annual sludge production (tonnes DW)				15000	14500	14400	14500	15100

Nolhaga WWTP

Nolhaga WWTP, a medium sized WWTP located in Alingsås, treat domestic and industrial waste water (laundry, landfill).

	2004	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	24364	24525	24840	24905	25244	26151	26370	26645
No of pe connected to the WWTP	36681	39374	39765	40509	31577	27332	30068	27816
Influent water (M m^3)	4.6	4.2	4.9	4.7	4.6	3.2	3.7	4.4
Additional water (M m^3)	1.8	1.5	2.3	2.1	2.4	0.8	1.3	2.0
Share of additional water in total influent (%)	38%	35%	47%	45%	52%	24%	35%	44%
Annual sludge production (tonnes DW)	771	743	773	861	761	688	753	720

Öns WWTP

Öns WWTP is a medium sized treatment plant located in Umeå. This WWTP treat waste water from households, a hospital and a university. Only a small part of the influent consists from industries.

	2004	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	83764	87765	87765	89963	90918	92118	92118	93364
No of pe connected to the WWTP	100018	112153	110387	108511	117055	128699	123955	131495
No of pe from industry connected to the WWTP			16143	14886	15114	17723	18657	12999
Influent water (M m^3)	12	12	13.2	12.8	13.0	12.9	12.5	12.5
Additional water (M m^3)	4.5	4.9	6.0	5.6	5.7	6.1	5.7	5.7
Share of additional water in total influent (%)	38%	41%	46%	44%	44%	47%	46%	46%
Annual sludge production (tonnes DW)	2343	2650	2732	2614	2526	2279	2419	2485

Gässlösa WWTP

Gässlösa is a medium sized WWTP that treat water from households, several textile industries and from a hospital. Further, waste water from plastics and chemical industries is also treated in Gässlösa.

	2004	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	78937	79602	81035	81014	81544	81936	82336	82600
No of pe connected to the WWTP	98250	101200	105950	90745	67309	73257	76529	72297
Influent water (M m^3)	18	15	16	19	17	13	14	16
Additional water (M m^3)	11	7.0	10	12	10	6.3	7.7	9.0
Share of additional water in total influent (%)	59%	47%	59%	66%	63%	50%	56%	56%
Annual sludge production (tonnes DW)	3500	2147	2292	2321	2217	2436	2291	2431

Ellinge WWTP

Ellinge is a medium sized WWTP in which large part of the waste water treated originate from food industries. The WWTP also treat waste water from a laundry and from households.

	2004	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	17500	17500		19100	19100	19500	19820	19958
No of pe connected to the WWTP	100169	82677	84185				94975	91721
No of pe from industry connected to the WWTP	73739	58577	61655		61658	63551	67982	63558
Influent water (M m^3)	4.6	4.1	4.7	4.5	4.2	3.7	4.2	4.4
Additional water (M m^3)	2.0	1.4	1.6	1.5	1.5	1.0	1.5	1.7
Share of additional water in total influent (%)	43%	34%	33%	34%	35%	28%	35%	38%
Annual sludge production (tonnes DW)	1627	1235	1391	1308	1126	1098	1246	1429
Municipal inflow (M m^3)	3.9	3.4	3.8	3.7	3.5	3.1	3.5	3.7
Industrial inflow (M m^3)	0.7	0.7	0.9	0.8	0.7	0.6	0.7	0.7

Ryaverket WWTP

Ryaverket is one of the two largest WWTPs in Sweden. In Ryaverket waste water from several municipalities and from several industries is processed. Further leak water from a landfill, waste water from hospitals, laundry and food industries is also treated.

	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	621307	628373	633659	640303	649352	658114	666441
No of pe connected to the WWTP	770725	828603	645550	638043	640157	688885	730137
Influent water (M m^3)	108	133	130	137	119	122	141
Additional water (M m^3)	57	82	79	85	67	72	91
Share of additional water in total influent (%)	53%	61%	60%	62%	56%	59%	64%
Additional water excl. tunnel leakage (M m^3)	53.1	78.0	75.5	81.4	63.8	68.4	86.9
Share of additional water excl. tunnel leakage (%)	49%	59%	58%	60%	54%	56%	62%
Annual sludge production (tonnes DW)	12700	14580	14156	13833	13326	14770	14170

Bollebygds WWTP

Bollebygd WWTP is a small sized treatment plant in which more or less only waste water from households is treated.

	2005	2006	2007	2008	2009	2010	2011
No of persons connected to the WWTP	4029	4029	4080	4072	4115	4115	4115
No of pe connected to the WWTP	2162	1682	2243	2614	3729	2181	2205
Influent water (M m^3)	0.25	0.29	0.30	0.30	0.24	0.26	0.30
Additional water (M m^3)	0.064	0.094	0.11	0.13	0.050	0.14	0.10
Share of additional water in total influent (%)	26%	32%	36%	44%	21%	54%	34%
Annual sludge production (tonnes DW)	139	95	91	92	77	61	61

Floda WWTP

Floda WWTP is a small sized treatment plant no longer included in the monitoring programme of sludge and effluent.

	2004	2005	2006	2007	2008	2009
No of persons connected to the WWTP	9780	10090	10150	9840	9930	9960
No of pe connected to the WWTP	5971	4100	4901	4712	5411	6004
Influent water (M m^3)	1.5	1.4	1.7	1.6	1.5	1.1
Additional water (M m^3)	1.0	0.8	1.0	1.0	1.0	0.5
Share of additional water in total influent (%)	66%	55%	60%	61%	65%	51%
Annual sludge production (tonnes DW)	269	292	342	330	307	268

Bergkvara WWTP

In Bergkvara WWTP, a small sized treatment plant, waste water from households is treated.

	2010	2011
No of persons connected to the WWTP	5900	5900
No of pe connected to the WWTP	1447	1898
Influent water (M m^3)	0.87	0.89
Additional water (M m^3)	0.63	0.67
Share of additional water in total influent (%)	73%	75%
Annual sludge production (tonnes DW)	115	131

Borlänge WWTP

Borlänge WWTP is a medium sized treatment plant to which small industries are connected. The WWTP also process sanitary sewer from pulp industry and a steelwork and from two relatively large facilities that produce cosmetics and hygienic products.

	2010	2011
No of persons connected to the WWTP	44 400	44 400
No of pe connected to the WWTP	33 934	37 926
Influent water (M m^3)	6.2	6.1
Additional water (M m^3)	2.6	2.7
Share of additional water in total influent (%)	42%	44%
Annual sludge production (tonnes DW)	1 087	1 017

Appendix 3

Samples for chemical analysis.

ID	Short name	Site	Sample type	Date	DW, %	WGS84 N	WGS84 E	Additional water, %[1]
2554	HeEf	Henriksdal WWTP, Stockholm	Effluent	2013-10-08		59° 18,585'	18° 6.458'	35
2555	HeSl	Henriksdal WWTP, Stockholm	Sludge	2013-10-08	26	59° 18,585'	18° 6.458'	35
2598	HeSe	Henriksdal WWTP, Stockholm	Sediment	2013-09-25	20	59° 19,0856'	18° 7,0222'	35
2542	RyEf	Ryaverket WWTP, Göteborg	Effluent	2013-09-24 - 25		57° 41,830'	11° 53,500'	54
2543	RySl	Ryaverket WWTP, Göteborg	Sludge	2013-09-25	25	57° 41,830'	11° 53,500'	54
2784	RySe	Ryaverket WWTP, Göteborg	Sediment	2013-11-25	34	57° 41,339'	11° 53,257'	54
2495	GäEf	Gässlösa WWTP, Borås	Effluent	2013-08-27		57° 42,2950'	12° 55,5994'	51
2497	GäSl	Gässlösa WWTP, Borås	Sludge	2013-08-30	23	57° 42,2950'	12° 55,5994'	51
2502	GäSe	Gässlösa WWTP, Borås	Sediment	2013-08-28	69	57° 41,5101'	12° 54,5323'	51
2488	BoEf	Bollebygd WWTP, Bollebygd	Effluent	2013-08-27		57° 39,6897'	12° 31,3355'	25
2490	BoSl	Bollebygd WWTP, Bollebygd	Sludge	2013-08-29	13	57° 39,7759'	12° 32,1868'	25
2491	BoSe	Bollebygd WWTP, Bollebygd	Sediment	2013-08-27	78	57° 39,7064'	12° 32,0815'	25

[1] Data from 2013.

Appendix 4

Results of chemical analysis, PAHs

Short name	Unit	PAH-1	PAH-2	PAH-3	PAH-4	PAH-5	PAH-6	PAH-7	PAH-8	PAH-9	PAH-10	PAH-11	PAH-12	PAH-13	PAH-14	PAH-15	PAH-16	PAH-17	PAH-18	PAH-19	PAH-20	PAH-21	PAH-22	PAH-23	PAH-24
HeEf	ng/l	3.50	1.30	<1	0.83	0.3	0.2	0.8	0.2	0.7	1.2	<0.31	<1	0.8	1.3	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51	<0.51
HeSl	ng/g TS	74	140	83	54	420	5.2	61	30	120	270	69	67	420	340	240	170	300	94	120	160	39	150	42	110
HeSe	ng/g TS	120	83	40	35	150	9.2	110	12	160	580	220	130	1700	1300	1100	630.0	2000.0	560.0	820	1100	320	1200	270	850
RyEf	ng/l	9.30	2.40	2.70	0.76	0.6	<0.11	2.0	0.2	1.8	3.7	<0.32	<1.1	2.2	1.3	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53	<0.53
RySl	ng/g TS	110	120	74	34	360	5.5	41	32	100	260	86	85	440	340	230	170.0	260.0	89.0	110	150	41	160	34	110
RySe	ng/g TS	11	12	6.9	4.4	18	1.8	13	3.1	17	50	20	15	140	120	90	59	170	55	73	92	310	95	25	84
GäEf	ng/l	<1.7	<0.87	<0.87	<0.26	<0.087	<0.087	<0.087	0.1	<0.44	<0.87	<0.26	<0.87	<0.44	0.6	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44
GäSl	ng/g TS	51	100	67	28	840	3.6	25	18	84	290	72	68	610	450	390	270	460	160	170	250	80	220	68	150
GäSe	ng/g TS	4.3	3.2	2.0	2.1	1.6	2.5	1.1	0.4	2.7	21.0	4.9	5.5	61	52	34	33	72	23	34	35	44	38	8.8	33
BoEf	ng/l	<1.8	<0.89	<0.89	0.30	0.2	<0.089	0.3	<0.089	0.6	<0.89	0.3	<0.89	0.5	0.6	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44
BoSl	ng/g TS	<6	<1.2	1.60	<1.2	78	<1.2	<1.2	<1.2	5.0	16.0	1.5	8.9	63	59	22	36	31	12	17	15	4.0	17	4.5	19
BoSe	ng/g TS	1.2	5.9	5.3	4.2	13	0.8	1.1	7.1	2.0	19.0	0.5	12.0	3.7	4.9	0.5	6.3	5.1	1.0	4.3	1.0	7.8	1.2	<0.2	2.0

PAH-1	Naphtalene
PAH-2	Naphtalene, 2-metyl-
PAH-3	Naphtalene, 1-metyl-
PAH-4	Biphenyl
PAH-5	Naphtalene, 2.6-dimethyl
PAH-6	Acenaphtylene
PAH-7	Acenaphtene
PAH-8	Naphtalene, 2.3.5-trimethyl-
PAH-9	Fluorene
PAH-10	Phenanthrene
PAH-11	Anthracene
PAH-12	Phenanthrene, 1-methyl-

PAH-13	Fluoranthene
PAH-14	Pyrene
PAH-15	Benzo(a)anthracene
PAH-16	Chrysene
PAH-17	Benzo(b)fluoranthene
PAH-18	Benzo(k)fluoranthene
PAH-19	Benzo(e)pyrene
PAH-20	Benzo(a)pyrene
PAH-21	Perylene
PAH-22	Indeno(123cd)pyrene
PAH-23	Dibenz(ah)anhracene
PAH-24	Benzo(ghi)perylene

Results of chemical analysis, nonylphenol, octylphenol, phtalates, metals

Short name	Unit	4-NP	4-t-OP	DEHP	DINP	DIDP	Pb	Sb	Cd	As	Co	Cr	Cu	Ni	V	Zn
HeEf	ng/l	96	28	350	380	<50	<500	312	<50	<500	2900	<900	1930	7350	280	20600
HeSl	ng/g TS	5400	1200	5500	23000	14000	17600	1510	705	3430	6700	21600	333000	20200	17400	379000
HeSe	ng/g TS	1400	17	1200	1900	1900	183000	2250	2340	9020	19900	81400	198000	37900	61100	326000
RyEf	ng/l	80	1.5	5500	1000	360	<500	306	<50	852	1050	<900	10300	3330	389	5870
RySl	ng/g TS	8200	290	6400	27000	19000	22500	1720	816	3550	8060	20700	367000	18500	17600	509000
RySe	ng/g TS	120	83	710	1700	2400	29700	402	268	8740	10100	40200	46700	24600	57400	126000
GäEf	ng/l	51	<0.49	390	420	160	<500	508	<50	623	309	<900	2930	1930	218	21600
GäSl	ng/g TS	2600	141	5400	25000	28000	15600	2210	488	2610	2960	23900	209000	12500	7850	339000
GäSe	ng/g TS	74	3	440	460	280	14800	423	120	15800	3080	18200	15600	7240	18100	83500
BoEf	ng/l	68	<0.92	910	64	980	<500	216	<50	693	<200	<900	1050	1850	<200	22700
BoSl	ng/g TS	1600	47	5200	11000	8600	5870	600	351	853	2470	12800	107000	8750	10400	213000
BoSe	ng/g TS	13	1	<20	<80	<80	7830	114	121	2030	10400	21500	21600	18700	54300	58300

4-NP	4-Nonylphenol
4-t-OP	4-t-Octylphenol
DEHP	Diethylhexyl phtalate
DINP	Diisononyl phtalate
DIDP	Diisodecyl phtalate
DIBP	Diisobutyl phtalate
BBP	Butylbensyl phtalate
DOP	Dioktyl phtalate
DBP	Dibutyl phtalate