

# SOCOPSE



SOURCE CONTROL OF PRIORITY SUBSTANCES IN EUROPE

**Project contract no. 037038**

**SOCOPSE**  
**Source Control of Priority Substances in Europe**

*Specific Targeted Research Project*

**Work Package 5-D.5.2**

**Report on Vantaa River case study**

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# 1. Step 0. System Definition

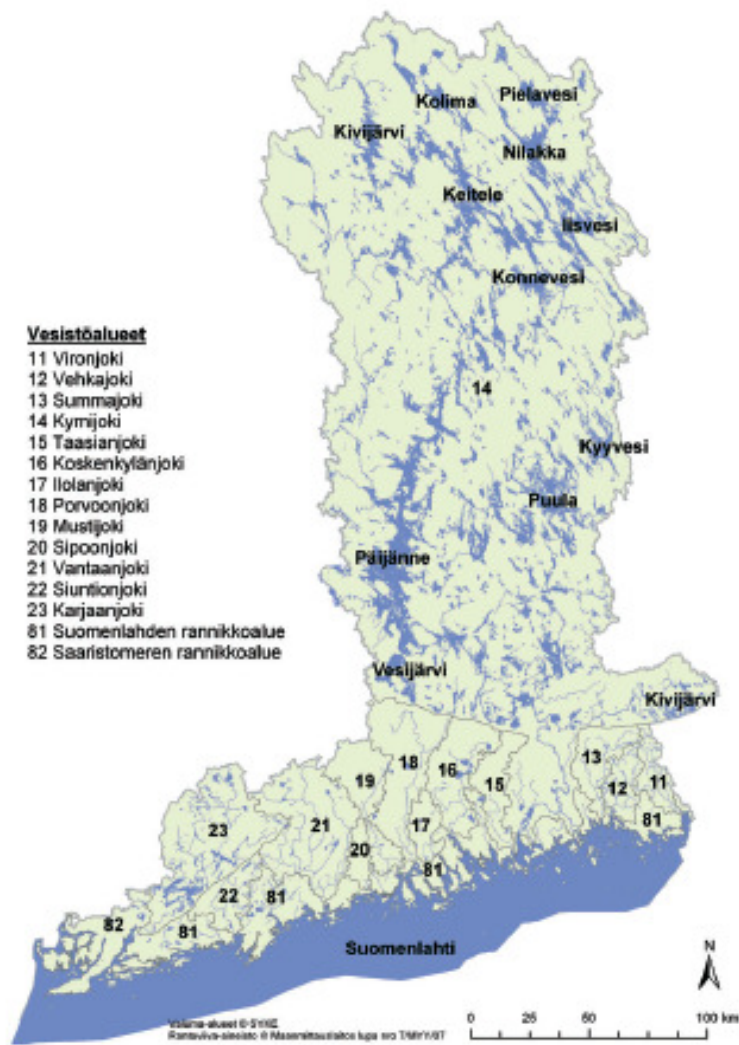
## 1.1 Geographical boundaries

The entire River Vantaa catchment (1680 km<sup>2</sup>) is covered by the Case Study. The River Vantaa runs 99 kilometers long through heavily populated (1 million people) and agriculturally intensive areas. The mean rate of flow is about 17 m<sup>3</sup>/s and there are 150 small lakes in the region. The R. Vantaa (Fig. 1.1) is a subcatchment of the Kymijoki-Suomenlahti River Basin District (VHA2) (Fig. 1.2).



**Figure 1.1.** The catchment area of the River Vantaa and the adjacent coastal areas. (Note that the geographical boundary of the system at the river estuary is bordered by the archipelago.)

The estuary with two bays (Vanhankaupunginlahti and Kruunuvuorenselkä) is located within the coastal boundaries of the study. These areas have considerable harbor activity and receive urban drainage as well.



**Figure 1.2.** The map of Kymijoki-Suomenlahti River Basin District (VHA2). The River Vantaanjoki catchment is no. 21 on the map.

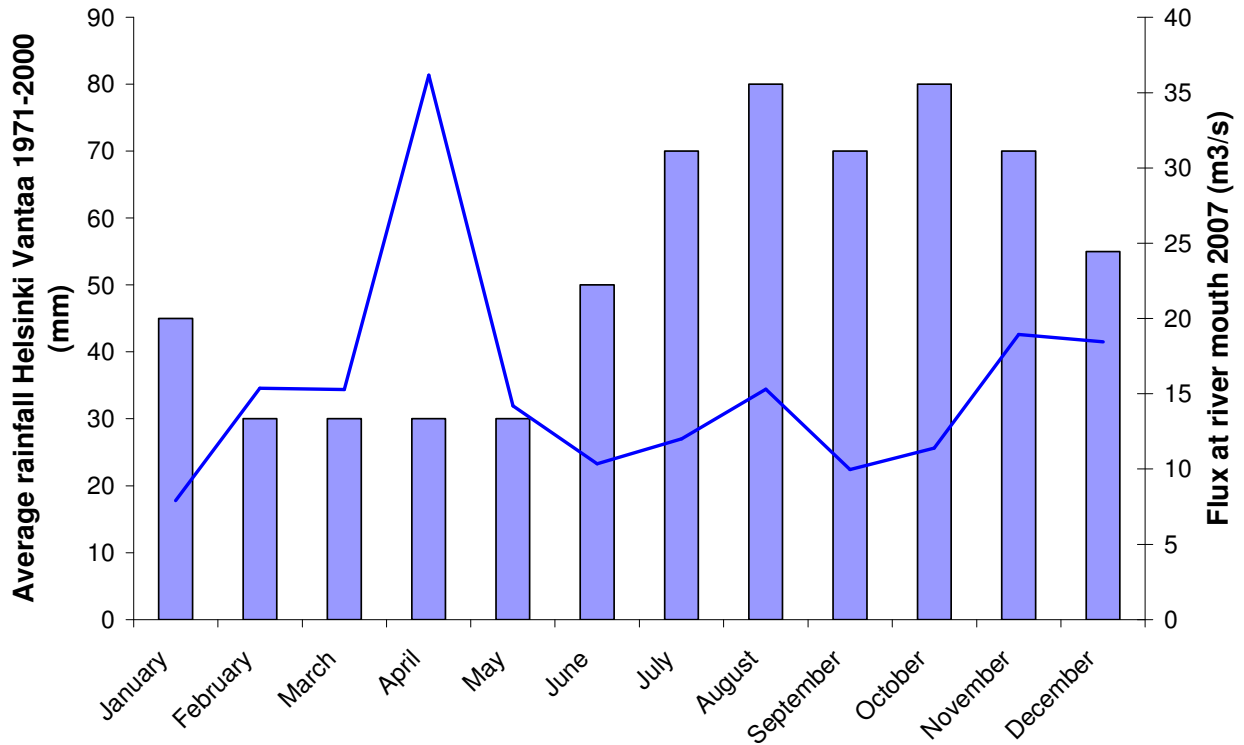
## 1.2 General

The River Vantaa runs through 14 municipalities. It is used as a recipient of treated wastewater from three municipalities, four wastewater treatment plants and some small utilities. The amount of processed wastewater is about 2.5% of the annual mean flow. Industrial wastewaters are treated together with municipal wastewaters. The industrial wastewaters contain dairy, food and brewery waters, waters from metal, paint and detergent manufacturing etc. The Helsinki-Vantaa and Malmi airports are situated in the area. Most of the deicing chemicals are discharged to the municipal wastewater treatment plant of the city of Helsinki. Some 89% of the municipal and industrial wastewaters formed in the study region are led to the central wastewater treatment plant in Helsinki and after tertiary treatment to the sea outside the geographical boundaries of this study.

The river is a secondary drinking water source for the City of Helsinki. It is used as the main water source during the repair of the Päijänne raw water tunnel. The river is also used for recreation and fishing, and additional flow from the Päijänne raw water tunnel has been led to the tributary, River Keravanjoki, in order to maintain adequate recreational value during the summertime.

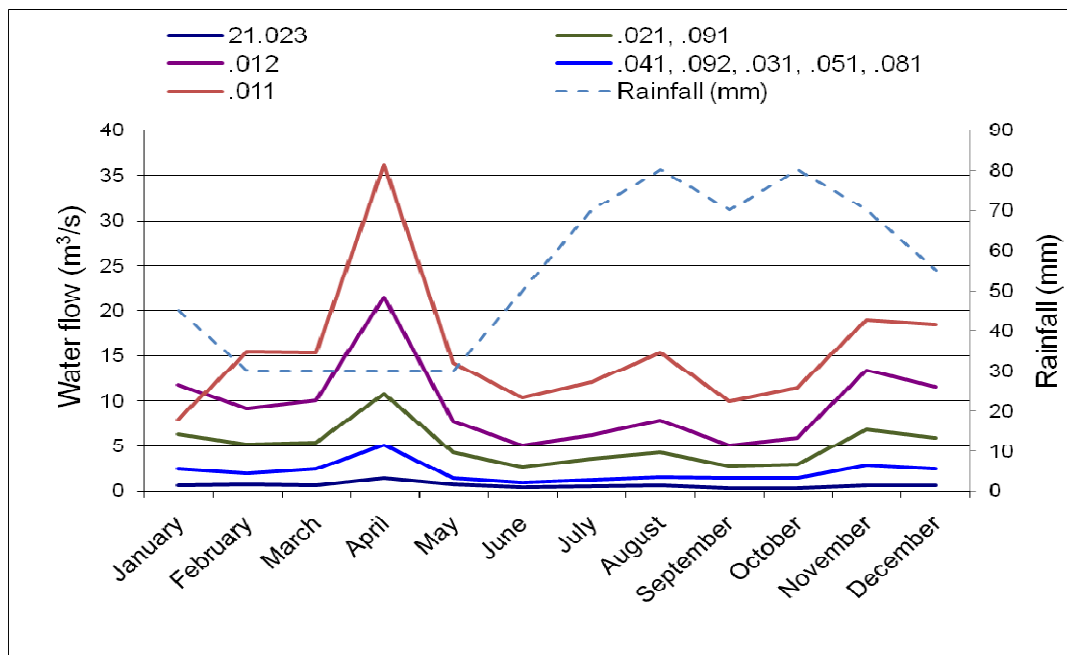
There is considerable variation both in the flow rate and rainfall between months (Fig. 1.3). Most of the rainfall occurs in the autumn and there is generally a high spring outflow of melt water from the

catchment area. These factors affect significantly the temporal dynamics and the interpretation of measured concentrations.



**Figure 1.3.** Mean monthly rainfall and flow rate in the river mouth of the River Vantaa area. (Meteorological data from the FMI Helsinki-Vantaa station. Flow from the water quality model of SYKE.)

In addition, there is a steady increase in the flow rate from the head to the mouth of the river (Fig. 1.4). On some occasions, the flow in the river mouth is 35 times the flow in the smaller sections. This also affects the interpretation of concentrations measured at the river mouth. Since for many substances, dilution is the controlling environmental parameter, concentrations upstream may be many times higher than the ones measured at the river mouth.



**Figure 1.4.** Flow rates in different sections of the Vantaa River. Site numbers refer to Figure 2.3

### **1.3 Stakeholders and decision makers**

Based on the environmental legislation polluters have to carry out statutory monitoring of recipient waters and wastewaters. The stakeholders have voluntarily collaborated in the protection of the river since the 1960s through the Water Protection Association of the River Vantaa and Helsinki region. The association is responsible for monitoring the functioning of the wastewater treatment plants and water quality in the river for the point source polluters. In addition, it aims at improving the recreational values of the river. However, this association is not a decision maker in the strict governmental sense of the WFD.

The Vantaanjoki case stakeholder group was founded in spring 2007 and had the first and second meetings with the research group on 12<sup>th</sup> Sept. 2007 and 23<sup>rd</sup> October 2007. The stakeholder group consisted of the following persons and organizations:

Kirsti Lahti	Managing Director, The Water Protection Association of the River Vantaa and Helsinki region
Pertti Isokangas	Director, Riihimäki Water (- 10.2008)
Kari Korhonen	Director, Riihimäki Water (10.2008 -)
Heidi Åkerla	Senior advisor, Uusimaa Regional Environment Centre
Sirpa Penttilä	Senior advisor, Uusimaa Regional Environment Centre
Ari Kangas	Senior Advisor, Uusimaa Regional Environment Centre (-12.2008)
Tommi Fred	Plant manager, Helsinki Water
Jari-Pekka Pääkkönen	Head of Environmental Research, City of Helsinki, Environment Centre
Päivi Munne	Research Scientist, Helsinki City, Environment Centre (-2. 2009)
Emil Vahtera	Research Scientist, Helsinki City, Environment Centre (-2. 2009)

The stakeholder group held 8 meetings by 12. May 2009. The Decision Support System Handbook was discussed between WP4 representatives (W. van Tongeren, Jaap de Vlies), WP5 leader (E. Brorström –Lunden) and the stakeholder group in the meeting in Helsinki, 12 September 2007.

The River Vantaa catchment is part of the Kymijoki-Suomenlahti River Basin District (VHA2) the water management of which is coordinated by the Uusimaa Regional Environment Centre (UUS). Häme Regional Environment Centre (HAM) together with UUS is responsible for drawing up the river basin management plan, including the programme of measures, for the Vantaa catchment. They also supervise the compliance with the environmental quality standards and initiate the measures necessary if non-compliance is observed. The permits of discharges of PSs from point sources within The R. Vantaa catchment are issued by the Western Finland Environmental Permit Authority as well as UUS and HAM. The supervision of discharges from diffuse sources in the area is carried out by UUS and HAM.

### **1.4 Selected substances**

Based on the preliminary survey of possible sources of selected priority substances (PS) and the limited information on their concentration in sewage water, sewage sludge, sewage outlet and river water a proposal for a selection of the substances was presented to the stakeholder group in September 2007. The group decided to include the following substances in the case study:

***Polycyclic aromatic compounds, (PAH)***

***Brominated diphenyl ethers, (PBDE)***

***Nonylphenol***

***Di(2-ethylhexyl)-phthalate, (DEHP)***

***Tributyltin, (TBT)***

All the substances, except DEHP, are determined as priority hazardous substances (PHS) according to Water Framework Directive.

## 2. Step 1: Problem Definition

### 2.1 Framework of the step

In Step 1 the problem definition is set up. The primary goal of the WFD is to achieve good ecological and chemical status of surface water bodies by 2015. For chemical status this means that the concentrations of the priority substances in water do not exceed the environmental quality standards (EQS). If possible, the emissions, discharges and losses of the PHSs are to be phased out by 2020. The basic operational goal is to achieve compliance with this requirement and, consequently, a non-compliance can be defined as a problem. The result of this step is a table or map with areas where PSs cause problems.

### 2.2 Data sources

The data from emissions at municipal sewage treatment plants origins mainly from targeted screenings in 2006-2007, organized to fulfill European Pollutant Release and Transfer Register (Regulation 166/2006) (E-PRTR) requirements. This data was supplemented in 2008.

The environmental data was gathered mainly from SYKEs national screening and monitoring programs serving the WFD implementation (Table 2.1). The City of Helsinki has more data on organotin compounds in sediments and fish in the Helsinki area.

**Table 2.1.** Existing analysis of the selected substances

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Case Vantaanjoki: existing analytical measurements

	Matrix	NP+EO	DEHP	PAH	PBDE	TBT	
POINT	STP influent	H+R	H+,(S),R	H+R	H?	R	PRTR-screening /Hki, VYV, POP-discharge /SYKE
	STP sludge	S,R	S,R	S,R		S	
	STP effluent	H+,S,R	H+,(S),R	H+R	H?	(S),R	
DIFFUSE	runoff / storm						POP-discharge?
	leachate (waste)			+			
	deposition	-	-	?		-	
CATCHMENT	river water	U,S+	S+	S+		+	RBM monitoring/SYKE,UUS
	river sediment	U	S+?	S+?	S+?	+	
	river biota				?	?	
COAST	coastal water	(S)				+	OT scr/SYKE
	coastal sediment	S	S+	S+	S+	H,S+	Hki, Veska+OT/SYKE
	coastal biota	S	S	S	(S+)	H,S+	SYKE Monitor, Nordic sc

DATA:

few / no	H= Helsinki
scattered (<10)	R= Riihimäki
reasonable (>10)	S= SYKE
	U= Reg Centre
	+ = more to come

## 2.3 Result of the step

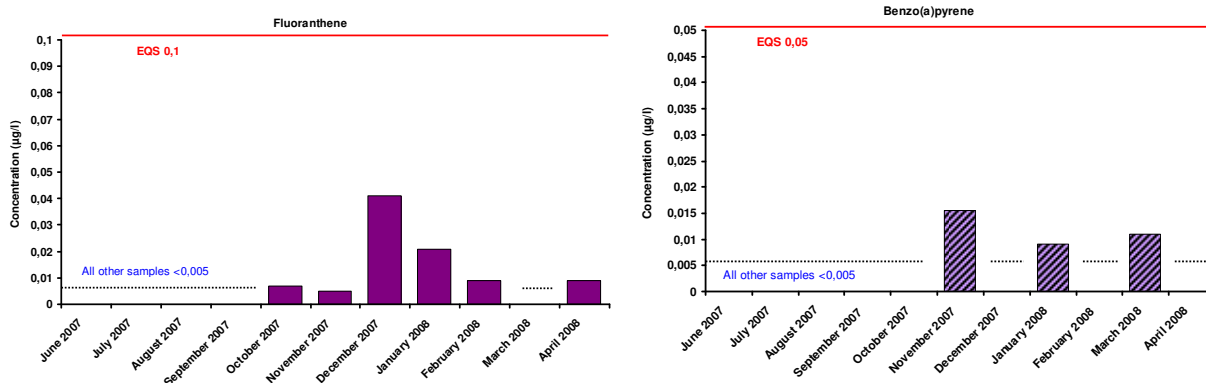
An overview of the measured water concentrations is given in Table 2.2. Data from sewage water, sludge, sediments and fish is listed in Appendix 1.

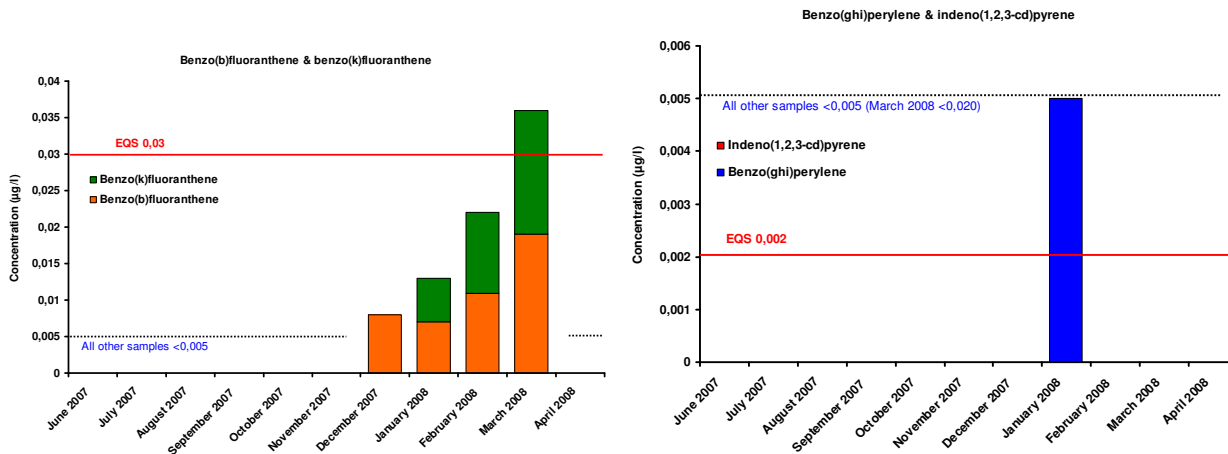
**Table 2.2.** Concentrations of the selected priority substances in surface water at the River Vantaanjoki mouth and at the river estuary (Vanhankaupunginlahti, Kruunuvuorenselkä) in 2006-2008 ( $\mu\text{g/l}$ ).

Substance	min	X	max	n	AA- EQS	MAC - EQS
Anthracene	<0.005	<0.005	<0.005	12	0.1	0.4
Bentso(a)pyrene	<0.005	0.006	0.018	12	0.05	0.1
Bentso(b)fluoranthene	<0.005	<0.005	0.019	12	0.03	n.a.
Bentso(k)fluoranthene	<0.005	<0.005	0.017	12		
Bentso(ghi)perylene	<0.005	<0.005	0.005	12	0.002	n.a.
Indeno(123-cd)pyrene	<0.005	<0.005	<0.005	12		
Fluoranthene	<0.005	0.009	0.041	12	0.1	1.0
DEHP	<1.0	11.7	180	17	1.3	n.a.
NP+NPE	<0.2	<0.2	<0.2	18	0.33*	n.a.
4-n-NP	<0.2	<0.2	<0.2	18	0.3	2.0
TBT (river)	<0.001	0.0004	0.0009	6	0.0002	0.0015
TBT (estuary)	<0.001	-	0.012**	8	0.0002	0.0015
* = 4-n-nonylphenol + nonylphenoxyethylate: TEQ = 0,3 $\mu\text{g/l}$ (national EQS)						
** =highest concentration at sediment surface						

### Polycyclic aromatic compounds, PAH

A cyclic pattern can be observed in the monthly concentrations of PAH substances at the river mouth (Fig.2.1). The concentrations start to rise in late autumn, peak at December - January and then decrease towards spring. Benzo(b+k)fluoranthene is the exception with rising concentrations towards spring. The EQS was occasionally exceeded for benzo(ghi)perylene and benzo(b+k)fluoranthene.





**Figure 2.1.** Individual concentrations of four priority PAH compounds compared with the AA-EQS at the River Vantaanjoki outlet (see Fig. 2.3) in 2007-2008.

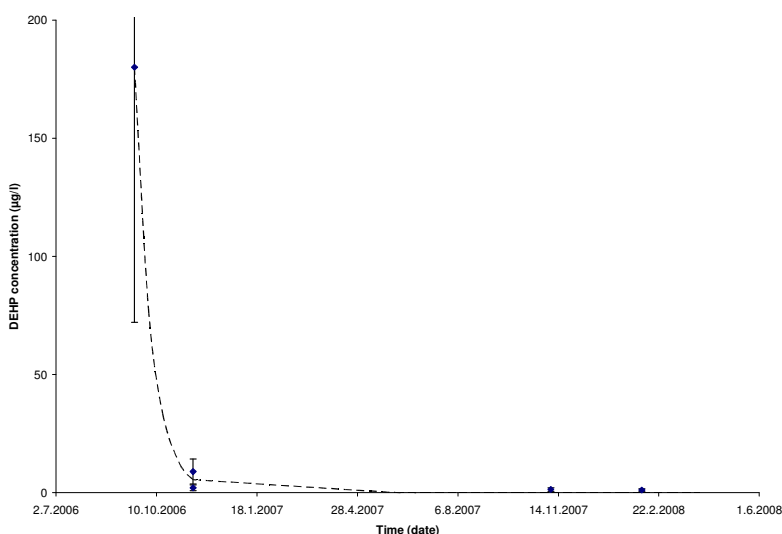
### Nonylphenol, NP

All samples measured in the river mouth showed concentrations less than 0.2 µg/l for both 4-n-nonylphenol and nonylphenol etoxylate and thus were considerably lower than the EQS (0.3 and 0.33 µg/l respectively).

### Di(2-ethylhexyl)-phthalate, (DEHP)

A time series of the observed DEHP concentrations shows three individual exceedances compared with the AA-EQS (Fig. 2.2). Two of these occurred in 2006 and one in 2007. However, there is a considerable possibility for laboratory contamination or analytical error in the analytical measurements from 2006, since they were the first samples analyzed with the current method. In addition, the highest observed concentration (180 µg/l) would require an unrealistic emission on diurnal basis representing an emission of 155 kg of DEHP per day due to the high water flow in the sampling point (10 m<sup>3</sup>/s). The required emission would correspond to more than 22 000 t/d of contaminated dry sewage sludge (with an average measured concentration 7 mg<sub>DEHP</sub>/kg).

As an annual average (AA) from spring 2007 to spring 2008 the AA-EQS was not exceeded.



**Figure 2.2.** A time series of the observed DEHP concentrations in the river mouth. The measurement uncertainty (60 %) was calculated based on two parallel samples.

## 2.4 A modeling approach to check for possible sites of exceedance

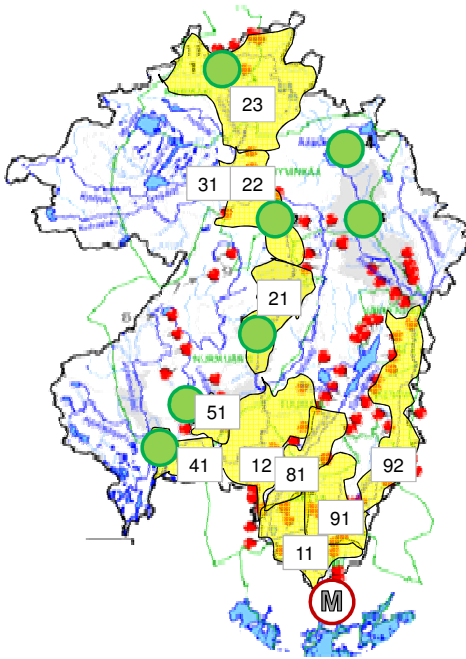
Since the measurements were done at the river mouth, but many of the point sources were high upstream (Figure 2.3), a modeling approach was used to estimate, whether exceedances were likely. The model used was a dynamic fugacity model modified from the POPCYCLING Baltic model (Wania et al. 2000) into a matrix form (Mattila and Verta 2009). The model was parameterized for the Vantaanjoki region using the water fluxes (Fig. 1.4) and the water quality parameters from national surface water surveys (HERTTA database). The modeled river regions and sites of emissions sources are presented in Figure 2.3. A 10 year period was simulated by using the STP emissions (described in Step 2) as the driving force.

The parameters of Wania et al. (2000) were used for the sub catchment areas, but some parameters were adjusted (Table 2.3).

**Table 2.3.** Adjusted parameters used in fugacity modeling (other parameters as in Wania et al. 2000). CPOC = concentration of particulate organic matter.

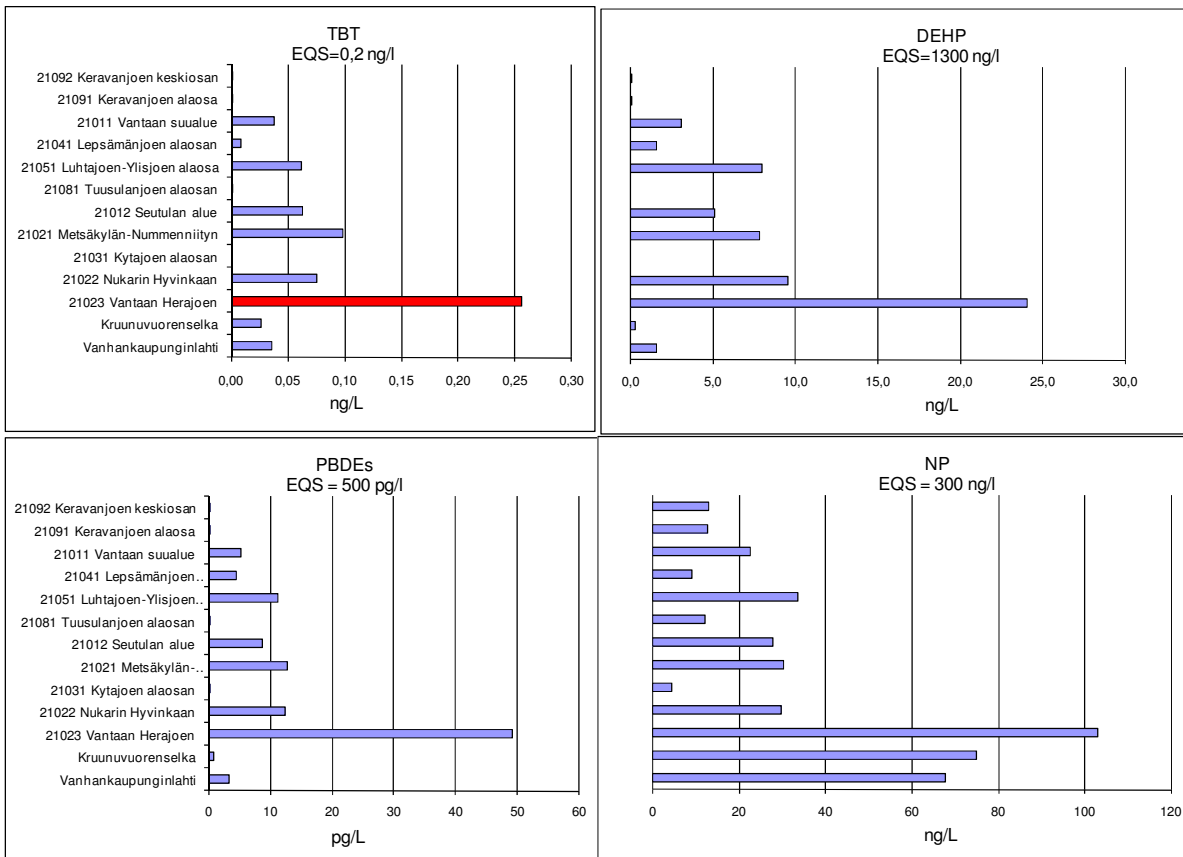
	Catchment area km <sup>2</sup>	Percentage of forest area	River surface area km <sup>2</sup>	River depth m	CPOC (mg/L)
23 Vantaa Hera-joki	129,75	70	0,0908	2	0,40
22 Nukari Hyvinkaa	61,10	25	0,1790	2	0,40
31 Kytajoki lower	29,19	90	0,0350	2	0,40
21 Metsäkylä-Nummenniitty	62,79	20	0,1632	2	0,40
12 Seutula	93,51	40	0,1973	2	0,40
81 Tuusulanjoki lower	33,24	25	0,1100	5	0,40
51 Luhtajoki-Ylisjoki lower	47,16	70	0,2499	5	0,40
41 Lepsämäinjoki lower	28,03	25	0,0798	5	0,40
11 Vantaa mouth	53,62	15	0,4798	5	0,40
91 Keravanjoki lower	51,38	10	0,0878	5	0,40
92 Keravanjoki middle	62,89	25	0,2301	5	0,40

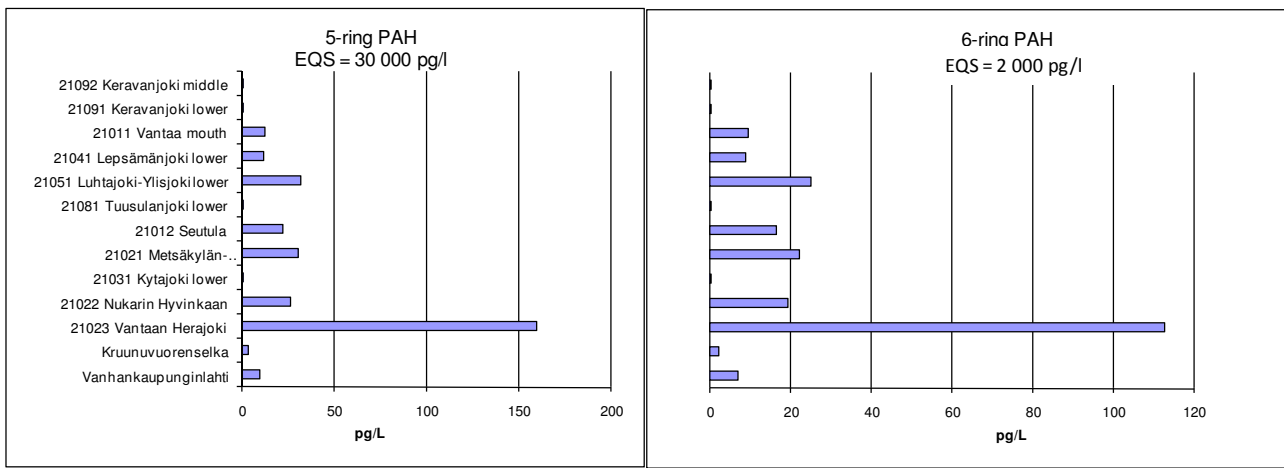
An alternative simpler dilution model was also applied to check for consistency. The assumption for this exercise was that evaporation and degradation were ignored and all emissions flow out of the system through water fluxes. Both models gave similar results indicating that (a) there is very little time for evaporation and degradation in the system and that (b) the more complicated model did not overestimate the concentrations.



**Figure 2.3.** A schematic overview of the modeled region. Boxes describe model compartments and sub catchments, green circles STPs, red circles possible sites of sewage overflow and the large M at the river mouth is the area where samples were taken from.

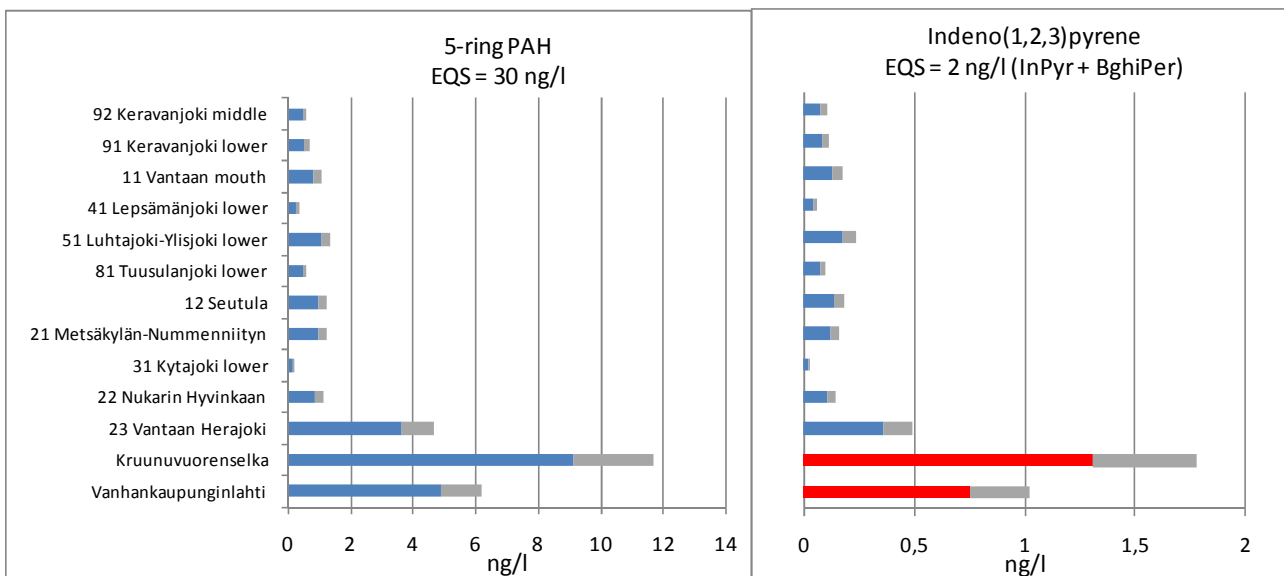
The fugacity model results are presented in Figure 2.4 and the summary for expected and/or measured exceedances in Table 2.4. For DEHP, PBDE and NP no exceedances are expected. For TBT the modeling indicates a possible minor exceedance of the AA- EQS at one region (23) with high percentage of treated sewage in river water. Measured DEHP concentrations however were significantly higher than those expected from the STP emissions alone (Fig. 2.4). This could indicate additional DEHP emission sources or analytical problems/uncertainties of DEHP.





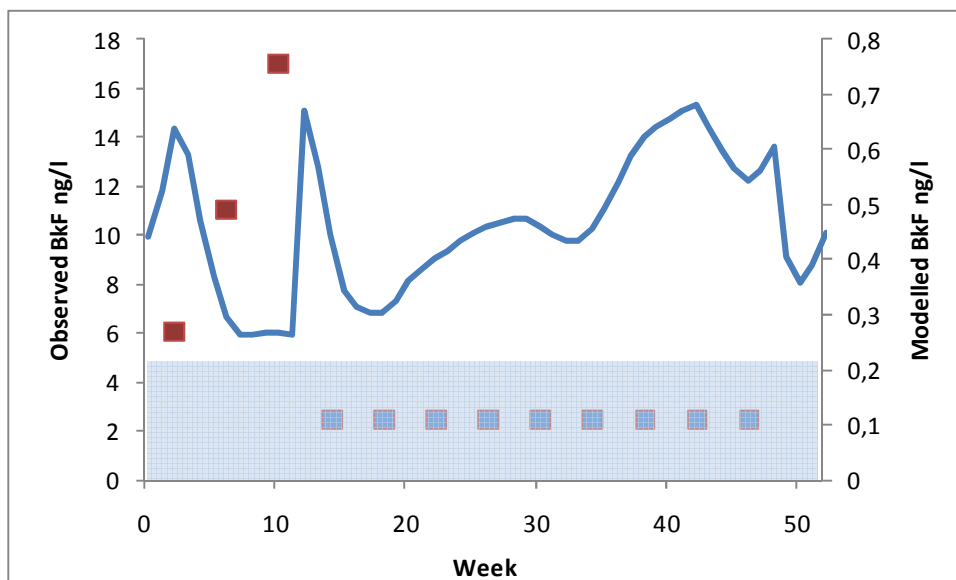
**Figure 2.4.** Predicted annual average substance concentrations in different sections of the river (as pg/l or ng/l). Concentrations exceeding the EQS are marked as red.

For PAH compounds also the effects of atmospheric emissions were estimated from Table 3.10. However urban runoff estimate was not performed and the results are likely to be clear underestimates because of too high adsorption to soils. Results from the atmospheric modeling are presented in Figure 2.5. In the basic atmospheric emission scenario only 25 % of the emissions from the Helsinki city area were taken into account. As a sensitivity analysis, a second scenario including all the atmospheric emissions from Helsinki city were included, was also analyzed. This resulted in a 24-36 % increase in concentrations depending on the specific PAH substance considered.



**Figure 2.5.** Predicted annual average PAH concentrations in different regions by atmospheric deposition on land and on water alone. The grey part of the bar is a possible additional deposition from the Helsinki city region (of which 75 % is outside the catchment area). Red colour indicates possible EQS exceedance noting that benzo(ghi)perylene was not modeled.

Some of the measured concentrations did not correspond well with the modeled concentrations but were an order of magnitude higher (see Table 2.2, and Figs 2.1 and 2.6). Furthermore, the temporal dynamics (caused by rainfall, river flow and temperature variation) did not match the pattern of the observations (Figure 2.6). This would indicate that there may be significant PAH emissions associated with urban films and runoff that are not included in the model but are indicated to be important in literature.



**Figure 2.6.** Comparison of modeled and measured benzo(k)fluoranthene concentrations in the River Vantaa mouth in 2008. The detection limit was 5 ng/l (marked as blue shading). Concentrations below the detection limit were assumed to be 50 % of the detection limit.

### Tributyltin (TBT) in Vantaanjoki estuary,

In the case of TBT a probable non compliance with the WFD EQS was anticipated from the sediment concentrations and from the few measurements of the water above the sediment surface (Vatanen et al. 2006, Kajaste et al. 2009, Mannio et al. 2009, in preparation). The primary source of TBT is the former use of TBT containing antifouling paints and subsequent leaching, dissolution and mechanical scrapping of paints from ships. The area includes several recreational ship and boat harbours and small wrecks and two main ports for trader shipping and passenger traffic (see Appendix 3). The survey of TBT- (and TPhT-) compounds in the River Vantaa sediments did not reveal any major source in the catchment or from the municipal sewage treatment plants (Mannio et al. 2009, in preparation).

**Table 2.4.** Observed and modeled exceedances of EQS limits in the Vantaanjoki region.

Location	TBT	NP	PBDEs	DEHP	5-ring PAH	6-ring PAH
23 Vantaan Herajoki	PE	-	-	-	-	-
22 Nukari-Hyvinkää	-	-	-	-	-	-
31 Kytäjoki (lower)	-	-	-	-	-	-
21 Metsäkylä-Nummenniitty	-	-	-	-	-	-
51 Luhtajoen-Ylisjoki (lower)	-	-	-	-	-	-
41 Lepsämäjoki (lower)	-	-	-	-	-	-
81 Tuusulanjoki (lower)	-	-	-	-	-	-
12 Seutula	-	-	-	-	-	-
92 Keravanjoen (middle)	-	-	-	-	-	-
91 Keravanjoen (lower)	-	-	-	-	-	-
11 River mouth (M)	-	-	-	OE	OE	BD
Vanhankaupunginlahti	OE, PE	-	-	-	-	PE
Kruunuvuorenselka	OE, PE	-	-	-	-	PE

- = no problem, OE = occasional measured exceedance, PE = possible modeled exceedance, BD = EQS below detection limit

## 3. Step 2: Inventory of Sources

### 3.1 Framework of the step

In Step 2 an inventory of sources with effect on PS concentrations at river basin scale is derived from the problem location table (result of Step 1), the EU wide inventory of possible sources and location specific information (e.g. from environmental permits, emission registration data etc.).

The Source Category Split (SCS) prepared by Work Package 2 includes altogether 71 sectors for 5 substances of Vantaanjoki case. The SCS includes sectors representing both point sources and diffuse sources. Due to the large number of sectors the prioritization of the SCS sectors was performed and the sectors relevant in Finland and in the case study region were identified. The prioritization concerning the SCS sectors was mainly based on the Finnish national information on the amount of chemicals used (National register of chemicals, KETU). As a result of prioritization altogether 35 point and diffuse source sectors (Appendix 2) were identified to be potentially important emission sources for TBT, DEHP, NP, PAH and PBDE in Finland.

As shown in Table 2.4 nonylphenol (NP) was not expected to exceed the EQS. Emission sources of nonylphenol (NP) and nonylphenol etoxylates (NPE) were determined however, because of the wide use of NPE in Finland and its possible degradation to NP. The use of NPE in Finland has stabilized to around 200 tons/year.

PAH emissions from combustion of fuels and transport were derived from national emission models (Finnish Environment Institute 2007) (Chapter 3.3). PAH discharges to water were assumed to occur mainly via STPs (Chapter 3.2.2).

The scattered settlements and the following sectors (from Appendix 2) were identified to be potentially important **diffuse sources** (see Chapter 3.3)

- 3.6 Municipal sewage sludge application
- 4.4 Shipyards and navigation (includes dredging)
- 6.20 Urban storm water

### 3.2 Point sources

The point sources of TBT, DEHP, NP and PBDE in River Vantaanjoki catchment area were identified. Firstly, the survey on national database on environmental information (VAHTI database) was performed. The results indicated that there were some 250 plants representing potential source sectors of TBT, DEHP, NP and PBDE. The activities presented in Appendix 2 that did not exist in Vantaanjoki catchment area were excluded from further work. The further work concerning point sources was focused on 19 point source sectors.

Based on Finnish national information on the amount of chemicals (TBT, DEHP, NP and PBDE) used (National register of chemicals, KETU), three different approaches were used to estimate emissions. The sectors were classified to three different point source groups called A, B and C.

**Point Source group A:** The group consists of four sectors (when manufacturing of primary plastics/ rubber and plastics/rubber products are seen as one entity) where DEHP or NP / NPE are still widely used and / or discharges to surface waters are estimated to be significant in Finland (Table 3.1). Sector-specific chemical questionnaires were sent to all plants of sectors in the source group A. Generally, these sectors were subject of study on the number of plants but also on the use and

discharge of these chemicals in the River Vantaanjoki catchment area. See more detailed information below in chapter 3.2.1.

**Point Source group B:** The group consists of nine sectors which mainly related to waste life-cycle stage (Table 3.2). Additionally, TBT, DEHP, NP/NPE or PBDE are still used on these sectors to the some extent (but not major uses) in Finland and/or discharges to surface waters are estimated to be significant in Finland. These sectors were subject of a study on the number of plants and fate of discharges in the River Vantaanjoki catchment area. See more detailed information below in chapter 3.2.2.

**Point Source group C:** The group consists of six sectors where TBT, DEHP, NP/NPE or PBDE are not allowed to be used anymore or they pose only minor use in Finland or discharges to surface waters were estimated to be insignificant (Table 3.3). Concerning these sectors, only information on the number of plants was collected. See more detailed information below in chapter 3.2.3.

**Table 3.1.** Point source sectors under Source group A in the River Vantaanjoki catchment area.

Source with SCS code	NACE code	Substance of concern
2.25 Manufacturing of paints	24.30	NP
2.21 Manufacturing of polymers (e.g. primary plastics and rubber)	24.16 and 24.17	DEHP
Manufacturing of rubber products (no SCS code)	25.10	DEHP
2.27 Plastics processing (or manufacturing of plastic products)	25.20	DEHP
Manufacturing of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (no SCS code)	24.50	NP (manufacturing not in SCS!)
3.12 Public laundries – dry-cleaning	93.01	NP

**Table 3.2.** Point source sectors under Source group B in the River Vantaanjoki catchment area

Source with SCS code	NACE code	Substance of concern
3.3 Waste water treatment plants	90.01	DEHP, NP, PBDE & TBT
3.5 Land-filling of urban refuse and commercial products	90.02	DEHP, NP, PBDE & TBT
3.8 Demolition of preserved wood, other dismantling and crushing activities	37.20	DEHP & TBT
3.9 Car shredder	37.10	DEHP & PBDE
3.14 Collection and treatment of wastes (electrical waste)	90.02	PBDE
Washing of tank containers	90.02	DEHP & NP
4.2 Water (sea and coastal) transport	61.10	TBT
4.3 Air transport (airports and heliports)	62.00	NP
7.3 Sediment re-suspension from coastal harbours and small boat ports	e.g. 63.22	TBT

**Table 3.3.** Point source sectors under Source group C in the River Vantaanjoki catchment area

Source with SCS code	NACE code	Substance of concern
2.28 Textile processing	17	NP & PBDE
6.16 Electrical appliances	31.13	PBDE (decaBDE)
6.19 Treatment and coating of metals	28.51	NP
7.4 Dockyards	35.10	TBT
Treatment of hazardous waste in hazardous waste disposal plant (no SCS code)	90.02	DEHP, NP, PBDE & TBT
Printing in printing houses (no SCS code)	22.20	NP

### 3.2.1 Source group A

Source group A includes 4 sectors which are mainly related to the chemical use life cycle stage. DEHP and NP/NPE are still widely used (major uses) and/or discharges to surface waters are estimated to be significant in Finland. Sector-specific chemical questionnaires on the use and discharges/emissions of DEHP and NP / NPE at plant level were sent in October-November 2008 to 85 plants or installations (Table 3.4). On more general level, these sectors were subject of study on the number of plants but also on the use and discharge of these chemicals from the national database on environmental information (VAHTI database). Additionally, environmental permits of plants were searched and checked and local information on these activities in the River Vantaanjoki catchment area was disseminated by the case study Stakeholder group.

**Table 3.4.** Sectors and number of plants targeted by the questionnaire on DEHP and NP/NPE.

Sector with NACE code	Chemicals of interest	Number of plants subject of questionnaire	Number of plants in Finland *
24.30 - Manufacture of paints, varnishes etc.	NP / NPE	9	27
24.16 – Manufacture of plastics in primary forms 24.16 – Manufacture of synthetic rubber in primary forms 25.10 - Manufacturing of rubber products 25.20 - Manufacturing of plastic products	DEHP	6	134
24.50 - Manufacturing of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	NP / NPE	9 (10)	33
93.01 - Public laundries	NP / NPE	41	-

\* VAHTI database in December 2008; number is probably underestimate

The main conclusions of sector-specific chemical questionnaires are the following:

**DEHP** is used about 7 tons/a at one plant in the manufacture of synthetic rubber in primary forms in the River Vantaanjoki catchment area. Nevertheless, it has been estimated that DEHP is not discharged from this plant to surface waters or to STP. Industrial use of DEHP is not an important source in the River Vantaanjoki catchment area.

**NP** is used 600 kg/a at two plants and **NPE** 163 tons/a at four plants in the manufacture of paints in the River Vantaanjoki catchment area. Some plants are discharging waste water (and NPE) to STP, but one plant collected the waste water for treatment in hazardous waste plant. About 50-150 kg NPE /year is discharged via treated waste water of one STP to the River Vantaanjoki catchment area. About 700 kg NPE /year was discharged via treated waste water of Helsinki STP directly to outer archipelago in the Gulf of Finland (i.e. outside the case area). It was found out that waste water containing NP is not entering the environment or STP. Instead, these waste waters are collected for treatment in hazardous waste plant. NP and NPE is not used in the manufacturing of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations or in public laundries posing dry-cleaning.

### 3.2.2 Source group B

#### The discharges to surface waters from other Source group B sectors than STPs

Source group B includes 9 sectors which mainly concern waste life-cycle stage. TBT, DEHP, NP/NPE or PBDE are still used in these sectors to some extent (but not major uses) in Finland and / or discharges to surface waters are estimated to be significant in Finland. These sectors were studied on the number of plants and fate of discharges. As in case of source group A, VAHTI database and information from the Stakeholder group was used. The relevant information is compiled to Table 3.5.

In general terms, only few landfills are loading the River Vantaanjoki with all case study substances, but their waste water is treated on-site or in STPs. Most active and closed landfills are discharging their effluents via Helsinki STP to the outer archipelago of the Gulf of Finland (not to case study area). Washing of tank containers was identified as a potential source for occurrence of at least DEHP and NPE/OPE. Sea transport (antifouling paints) and sediment re-suspension from coastal harbours and small boat ports are potential TBT sources to coastal part of the case study area. Nevertheless, the importance of antifouling paints as TBT source is decreasing due to the demand to over-paint or remove the TBT anti-fouling paints from the ships. Respectively, the relative importance of contaminated sediments of coastal harbours and small boat ports is increasing. Additionally, it seems that NPE is not used in anti-icing in the airports within the River Vantaanjoki catchment area. Demolition of preserved wood is not a TBT source in the case study area.

Based on the findings from the previous steps it was concluded that the discharges of STPs are predominant point sources in the River Vantaanjoki catchment area. Thus, it was decided that the discharges of TBT, DEHP, NP, PBDE and PAH to surface waters via STPs will be researched in more detail (see next chapter). Thus, the further work was clearly focused on the STPs.

**Table 3.5.** Sectors under Source group B and the respective number of plants and fate of discharges in the River Vantaanjoki catchment area.

Source with SCS code	Substance of concern	Number of plants	Fate of discharges
3.3 Waste water treatment plants (STPs)	DEHP, NP, PBDE & TBT	8	To case area except one STP (Helsinki) discharges the treated waste water directly to outer archipelago in Gulf of Finland
3.5 Land-filling of urban refuse and commercial products	DEHP, NP, PBDE & TBT	3 active 5 closed <sup>1</sup>	<b>Active:</b> * 1 landfill: treatment on-site and then to River Vantaanjoki * 2 landfills; to Helsinki STP and then outside the case area (to outer archipelago) <b>Closed <sup>1</sup>:</b> * 1 landfill; to STP and then to River Vantaanjoki * 3 landfills; to Helsinki STP and then outside the case area (to outer archipelago) * 1 landfill: no information
3.8a. Demolition of preserved wood	DEHP & TBT	1	Does not treat preserved wood; not TBT source!
3.8b. Other dismantling and crushing activities	DEHP & PBDE	6	2 plants: plastic waste received, packed, distributed to other plant for material use or energy production (incineration), cleaning waste water to STP, storm water outside the case area 1 plant: plastic waste received and used as one compo-

			<p>ment in produced REF. REF is burnt in incineration plants to produce energy, discharges to STP</p> <p>1 plant: plastic waste not received</p> <p>1 plant: no information</p>
3.9 Car shredder	PBDE	32	<p>5 plants: pre-treatment of waste water on-site and then to STP</p> <p>1 plant: waste water formed inside collected and distributed to STP, pre-treatment of storm water on-site and then to River Vantaanjoki catchment</p> <p>8 plants: waste water formed inside collected and treated properly in another plant, fate of storm water unknown</p> <p>2 plants: pre-treatment on-site and then to River Vantaanjoki catchment</p> <p>3 plants: discharges directly to River Vantaanjoki catchment</p> <p>12 plant: no information</p>
3.14 Collection and treatment of wastes (electrical waste)	DEHP & NP	2	<p>1 plant: no discharges to STP or aquatic environment</p> <p>1 plant: no information</p>
Washing of tank containers	TBT	2	<p>* 1 plant: partially to hazardous waste disposal plant and partially pre-treatment on-site, to STP and then to River Vantaanjoki</p> <p>* 1 plant: pre-treatment on-site, to Helsinki STP and then outside the case area (to outer archipelago); use alcohol ethoxylates (probably NPE and/or OPE) for cleaning of tanks containing plasticiser (perhaps DEHP)</p>
4.2 Water (sea and coastal) transport	TBT & PAH	3 harbors	The importance of hulls as TBT source is constantly decreasing
4.3 Air transport	NP	3 airports 4 heliports	<p>* 1 airport: anti-icing agents to River Vantaanjoki; no use of NPE in anti-icing</p> <p>* 1 airport: anti-icing agents partially to River Vantaanjoki and partially to Helsinki STP; use of NPE in anti-icing has stopped</p> <p>* 1 airport and 4 heliports: no information</p>
7.3 Sediment re-suspension from coastal harbors and small boat ports		3 harbors 21 small boat ports	Directly to coastal water

<sup>1</sup> Closed after year 1980

### Discharges to surface waters via STPs

Based on the findings from the previous steps it can be concluded that the discharges of STPs are predominant point sources in the River Vantaanjoki catchment area. Thus, the discharges of TBT, DEHP, NP, PBDE and PAH to surface waters via STPs was estimated. All available existing data of target substances in STP waste water and sludge in Finland was collected and compiled.

The wide screening survey on the selected hazardous substances in waste water of the 15 biggest STPs in Finland was performed in 2007 (Vesi- ja viemärlaitosyhdistys 2008). The samples were taken twice in spring and autumn 2007. This measured data was used to estimate the discharges of less hydrophobic target substances TBT and NP/NPE, but also DEHP, to surface water in the River Vantaanjoki catchment area. In general terms, it was assumed that the pollutant concentration in the treated waste water of the surveyed STPs is the same as the pollutant concentration in the treated waste water of all the 7 STPs locating in the River Vantaanjoki catchment area. The estimated emissions are presented in Table 3.6.

**Table 3.6.** Estimated discharge of TBT, DEHP and NP/NPE to surface waters via STPs in the River Vantaanjoki catchment area (year 2007).

Location/STP	Discharges to surface waters (g/a)			
	TBT <sup>1</sup>	DEHP <sup>2</sup>	NP <sup>3</sup>	NPE <sup>3</sup>
23/Riihimäki	4.8	823	969	969
22/Hyvinkää, Kalteva	4.8	956	956	956
92/Hyvinkää, Ridasjärvi	0.03	6.4	6.4	6.4
92/Hyvinkää, Kaukas	0.03	5.1	5.1	5.1
21/Nurmijärvi, Kirkonkylä	0.63	126	126	126
51/Nurmijärvi, Klaukkala	2.3	464	464	464
41/Espoo, Rinnekoti	0.5	110	110	110
<b>Total</b>	<b>13</b>	<b>2 491</b>	<b>2 637</b>	<b>2 637</b>
Helsinki, Viikinmäki (loading outside the case area)	103	17 600	20 700	20 700

<sup>1</sup> Concentration in treated waste water was assumed to be 0.001 µg/l (the median of screening data was < 0.001 µg/l (Detection Limit), four of six measurements below DL), data from year 2007 from 6 Finnish STPs (Vesi- ja viemäriulaitosyhdistys 2008)

<sup>2</sup> In general, concentration in treated waste water was assumed to be 0.2 µg/l (the median of screening data was < 0.2 µg/l (Detection Limit), 10 of 21 measurements below DL), data from year 2007 from 14 Finnish STPs (Vesi- ja viemäriulaitosyhdistys 2008)

<sup>3</sup> In general, concentration in treated waste water was assumed to be 0.2 µg/l NP and 0.2 µg/l NPE (the median of screening data was < 0.2 µg/l NP (Detection Limit) and < 0.2 µg/l NPE (Detection Limit), 15 of 19 measurements below DL), data from year 2007 from 16 Finnish STPs (Vesi- ja viemäriulaitosyhdistys 2008)

For PBDE and PAH emissions the measured data of screening survey performed by the Finnish Environment Institute in 2003 was used (Appendix 1). The samples were taken from two STPs, three times from each STP, in 2003. The data contained measurements of the STP sludge. In general, it was assumed that the pollutant concentration in sludge of the surveyed STPs is the same as the pollutant concentration in the suspended solids of treated waste water. Based on these assumptions the emission estimates are presented in Table 3.7 and Table 3.8).

**Table 3.7.** PBDE discharges to surface waters via STPs in the River Vantaanjoki catchment area in 2003.

Location/STP	Discharges to surface waters (mg/a)					
	BDE28 <sup>1</sup>	BDE47 <sup>1</sup>	BDE99 <sup>1</sup>	BDE100 <sup>1</sup>	BDE153 <sup>1</sup>	BDE154 <sup>1</sup>
23/Riihimäki	10	666	755	127	68	17
22/Hyvinkää, Ka	5.7	373	420	71	38	10
92/Hyvinkää, Ri	0.054	3.6	4.0	0.68	0.36	0.092
92/Hyvinkää, Kau	0.048	3.2	3.6	0.60	0.32	0.082
21/Nurmijärvi, Ki	3.5	231	262	44	24	6.0
51/Nurmijärvi, Kl	3.8	250	283	48	26	6.5
41/Espoo, Ri	1.9	127	143	24	13	3.3
<b>Total</b>	<b>25</b>	<b>1 654</b>	<b>1 871</b>	<b>315</b>	<b>170</b>	<b>43</b>
STPs discharging outside the study area;						
Helsinki, Viikinmäki	373	24 400	27 700	4 650	2 500	636

<sup>1</sup> Concentration adsorbed on suspended solids in treated waste water; calculated specifically to each STP based on averages of sludge measurements of year 2003 at two Finnish STPs (unpublished screening study)

**Table 3.8.** PAH discharges to surface waters via STPs in year 2003 in the River Vantaanjoki catchment area.

Location/STP	discharges to surface waters (mg/a)			
	Ben- zo(b)fluoran thene <sup>1</sup>	Ben- zo(k)fluoranthene <sup>1</sup>	In- deno(123cd)pyrene <sup>1</sup>	Ben- zo(ghi)perylene <sup>1</sup>
23/Riihimäki	2 500	1 100	1 100	1 700
22/Hyvinkää, Ka	380	160	220	260
92/Hyvinkää, Ri	13	5.8	5.9	9.2
92/Hyvinkää, Kau	12	5.2	5.3	8.2
21/Nurmijärvi, Ki	850	380	390	600
51/Nurmijärvi, Kl	920	410	420	650
41/Espoo, Ri	470	210	210	330
<b>Total</b>	<b>5 100</b>	<b>2 300</b>	<b>2 400</b>	<b>3 600</b>
STPs discharging out- side the study area; Helsinki, Viikinmäki	155 000	70 000	67 000	109 000

<sup>1</sup> Concentration adsorbed on suspended solids in treated waste water; calculated specifically to each STP based on averages of sludge measurements of year 2003 at two Finnish STPs (unpublished screening study)

### 3.2.3 Source group C

Source group C includes 6 sectors where TBT, DEHP, NP/NPE or PBDE are not allowed to be used anymore or they pose only minor use in Finland or discharges to surface waters are estimated to be insignificant in Finland. These sectors mainly concern chemical use and waste life cycle stage. As in case of source groups A and B, VAHTI database and information from the Stakeholder group was used. The relevant information is compiled to Table 3.9. The source group C sectors are not significant sources of above mentioned substances. Only the sediments locating next to the dockyard can be contaminated with TBT (i.e. historical contamination).

**Table 3.9.** Sectors under Source group C and respective number of plants in the River Vantaanjoki catchment area

Source with SCS code	Number of plants	Substance of concern
2.28 Textile processing	4	NP & PBDE
6.16 Electrical appliances	3	PBDE (decaBDE)
6.19 Treatment and coating of metals	9	NP
7.4 Dockyards	1 (small-scale)	TBT
Treatment of hazardous waste in hazardous waste disposal plant (no SCS code)	1	DEHP, NP, PBDE & TBT
Printing in printing houses (no SCS code)	7	NP

### 3.3 Diffuse sources

#### Scattered settlements

Based on the fact that the portion of scattered settlements (i.e. persons not connected to STP sewerage system), is low in the River Vantaanjoki catchment area (about 1%, includes summer cottages), it can be concluded that diffuse load from the consumer use of the target substances in scattered settlements is also relatively low even if taking into account that the efficacy of waste water treatment is generally much lower in scattered settlements compared to the STPs.

#### PAH emissions to air from energy production and traffic

PAH (benzo(b)fluoranthine, benzo(k)fluoranthine & indeno(123cd)pyrene) emissions in Vantaanjoki catchment area in 2006 have been estimated using mainly the emission data produced for national CLRTAP/EMEP emission inventory database. Firstly, four most significant PAH emissions sources in Finland (Table 3.10) were identified from report on air emission pollutant emissions in Finland (Finnish Environment Institute 2007). These sectors were responsible for more than 90% of the total emissions of PAHs in Finland. Then individual emission figures were calculated for these sources. The figures have been derived from PAH-4 values (i.e. the estimated total of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene & indeno(123cd)pyrene). Estimated PAH emissions of most significant sources to air in year 2006 in Vantaanjoki catchment area have been shown in Table 3.10.

**Table 3.10.** Estimated PAH emissions to air from the most significant sources at the Vantaanjoki catchment area in 2006. (25 % from Helsinki emissions included / 100 % from Helsinki emissions included).

Emission source	Estimated emission to air (kg/a)		
	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Indeno(123cd)pyrene
Public electricity and heat production; combustion of fuels (mainly coal and oil)	0.46 / 0.47	2.2 / 3.5	1.0 / 2.0
Passenger cars	8.3 / 12	8.3 / 12	9.2 / 13
Heavy duty vehicles (including buses)	19 / 28	2.4 / 3.5	0.94 / 1.4
Residential combustion of fuels (mainly oil and wood)	49 / 60	126 / 153	14 / 18
<b>Total</b>	<b>77 / 101</b>	<b>139 / 172</b>	<b>25 / 34</b>

#### Municipal sewage sludge as a potential source of TBT, DEHP, NP, PBDE and PAH

Based on their physical and chemical properties sewage sludge may contain substantial amounts of all selected priority substances. Some 80 percent of sludge in Finland is used for landscaping, 12 percent on agricultural soils and only six percent is disposed to landfills (Rantanen et al. 2008). Currently there is no scientific information available on the possible leakage of priority substances from these environments.

## **Shipyards and navigation (including dredging) as a source for TBT in coastal and sea area**

Dredging of contaminated sediments may play a significant role as a source especially for TBT (see Chapter 4.3), but also for other contaminants like PAH compounds, other persistent organic pollutants (POPs) and heavy metals. The dredged sediments are not disposed at the case study area. Currently there are no estimates of the effect of navigation and dredging of contaminated sediments on concentrations of priority substances in water in the study region. For shipyards, see the table 3.9 on dockyards.

## **Urban storm water as a source for PAH, DEHP, PBDE, NP**

Urban storm and runoff water may play a role as a source for selected substances especially for PAHs. In addition to the emission sources to air (described above), oily dirt from vehicles and asphalt, vehicle washing, litter etc. contribute to urban runoff. Leaching and evaporation of DEHP from polymer (mainly PVC) outdoor and indoor products are known sources to the urban surfaces, where they are subject to transport into storm water collection systems. Urban run-off is recognized as an important source, but currently there is no estimate available on the magnitude of this issue in the study region (City of Helsinki 2008).

# **4. Step 3: Definition of the Baseline Scenario**

## ***4.1 Framework of the step***

This step outlines an answer to the following questions:

- To what extent additional measures are necessary to improve the water quality taking into account the measures already taken (autonomous development)?
- Is there reason to assume that the present situation with respect to the water quality will change or will be different in the future? If so why? Will the problem definition change?

## ***4.2 Baseline scenario as based on Kymijoki-Suomenlahti River Basin Management Plan***

A draft river basin management plan (RBMP) with the relevant programmes of measure for the Kymijoki-Suomenlahti River Basin District (RBD) was published 9th December 2008. After the public consultation process the final plan is to be approved by the Government of Finland in December 2009. The River Vantaanjoki with its tributaries and together with the adjacent coastal water bodies belong to the scope of the Kymijoki-Suomenlahti RBMP (see Fig. 1.2).

The ecological status of the River Vantaa is classified as satisfactory (L. Tuusulanjärvi poor). The status in the coastal areas covered by the SOCOPSE Vantaanjoki case study is poor. The chemical status in the draft plan, on the other hand, is estimated as good for all these water bodies. As for Table 2.3, the model calculations indicate possible exceedance at some locations for PAHs and TBT especially in the estuary regions. Some measured concentrations support the model calculations and for some substances (PBDEs, 6 ring PAHs) the detection limit of available analytical technique is higher than the EQS. According to the modelling study, emissions from sewage treatment plants are generally not sufficient source to cause concentrations exceeding the EQS in the river. Urban storm-

water runoff and possible contaminated soil sites were also identified as possible sources, but could not be quantified.

Several measures are listed in the RBMP in order to improve the ecological status of the R. Vantaanjoki and the adjacent coastal water bodies. The areas of measures include:

- improvement of the management of waste waters from scattered dwellings (new sewers to sewage treatment plants and better on site purification of waste waters in houses not connected to public sewers)
- renovation of urban sewage treatment plants and sewer systems
- better management of sewage sludge use
- better urban storm water management
- better management of agricultural activities, including establishing of more buffer zones, in order to curb the load of nutrients and other harmful substances
- better management of risks in industrial activities, more advice and support to the industry in environmental issues
- increase of water transfer from L. Päijänne to the R. Vantaanjoki
- prevention of oil and chemical accidents in the coastal areas

Specific measures are also determined in order to minimize risks to groundwater and improve its status.

The implementation of the programme of measures is expected to improve the ecological status of the R. Vantaanjoki to good by 2021. Particularly the phosphorus loads are estimated to decrease by 30-50 % during the period of 2009 - 2015. For the coastal water bodies good status is not, however, expected to be achieved until 2027.

*Several of the suggested measures also affect the emissions of the priority substances in question. In general, better management of the scattered dwellings (point 1), renovation of SWT plants (point 2), better management of sludge (point 3), better urban storm water management (point 4) and management of industrial activities (point 5) will all have a potential impact on all five studied substance groups. Moreover, the dilution effect (point 6) will decrease the concentrations in the river although it will not decrease the emissions.*

### **4.3 Baseline by substance**

#### **Nonylphenol (NP)**

The use of nonylphenol has decreased in a stable manner during the last few years. Based on the questionnaire, it is not used or anticipated to be used in the future in many activities: manufacturing of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations and public laundries. The current major use is in manufacturing of paints and is expected to be stable. The release from textile washing (originating from imported material) has not been estimated. Recently more attention has been paid to chemicals in imported clothing and textiles indicating no major increase in emissions from this source in future. The measured and modelled concentrations are well below the AA-EQS and therefore even significant increases in emissions are very unlikely to change the situation. The use of nonylphenol etoxylates (NPE) is far higher than the use of nonylphenols: 163 tonnes/a at four paint manufacturing plants. However the concentrations of nonylphenol etoxylates in sewage treatment plant effluents were of similar magnitude as those of nonylphenols.

## **Di(2-ethylhexyl)-phthalate, (DEHP)**

The industrial use of DEHP is about 7 tonnes per year and is restricted to one plant in manufacture of synthetic rubber in the River Vantaanjoki catchment. Other emissions include leaching during service-life from plastic indoor products into sewage systems and from polymer outdoor products into surface waters. The modeled concentrations from the STPs are two orders of magnitude below the EQS and thus no exceedance originating from these systems is expected. However occasional exceedances have been observed and the possibility of an unknown point source is discussed below in Step 4.

## **Polycyclic aromatic compounds, PAH**

PAH concentrations exceeding the EQS have been observed occasionally during the winter period. The modelling suggests that exceedances due to atmospheric emission and deposition may take place at the estuary region (Fig. 2.5). The increased concentrations during the winter period at the river mouth could possibly be explained by increased emissions (from wood burning), increased scavenging from air to surfaces through snow and by increased urban runoff during the wet winter period. However, this was not modelled. If urban runoff is treated, this will most likely remove the problem of high wintertime PAH concentrations.

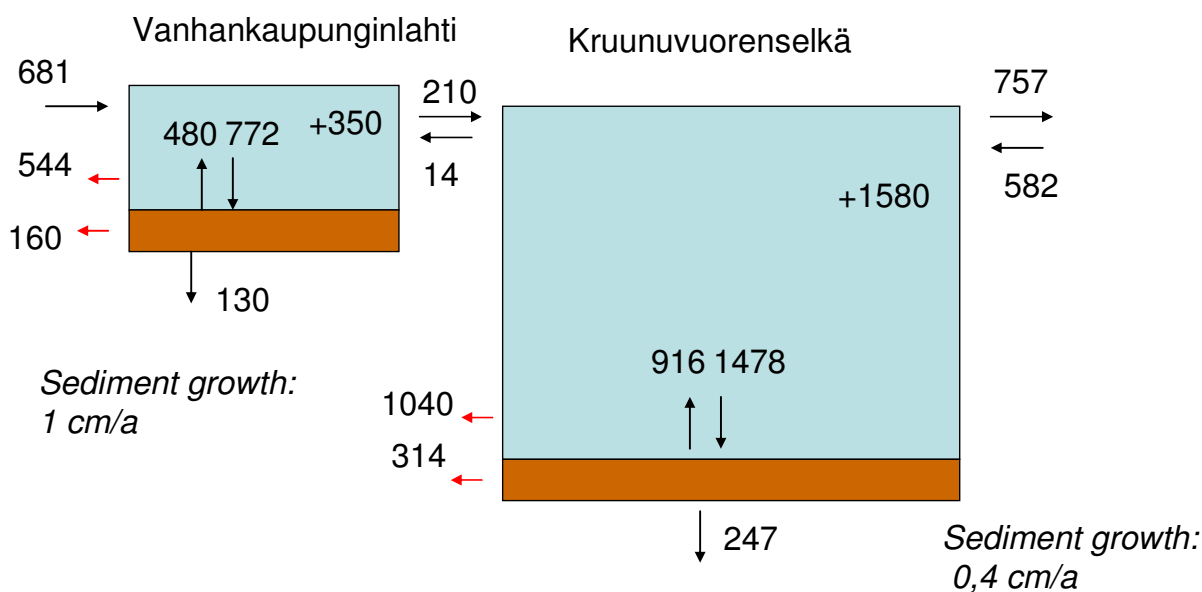
## **Brominated diphenyl ethers, PBDE**

The use of PBDE congeners #47, #99 and #153 has been banned and the emissions have likely decreased during the last few years. However, there is a significant delay between the stopping of use and the stopping of emissions from the STPs since the flame retardants are evaporated and leached slowly from consumer products. Consequently, no exceedance is expected in future.

## **Tributyltin, (TBT)**

For TBT, the sediment concentrations suggest that the water concentrations may very well be above the EQS. The direct emissions of TBT to the water column have ceased and contaminated sediments remain as the main emission source. In order to estimate the baseline scenario, a modeling study about the TBT kinetics (debutylation, resuspension, sedimentation, burial) in the sediment was carried out.

The analysis begins with a mass balance of water and organic carbon in the area. A high resolution gridded water quality model (HESPO) has been developed for the region, but its water balance was unavailable due to technical problems during the modeling session. This data gap was circumvented by assuming that the water residence time in the bay area is approximately the same as in other Baltic coastal areas, i.e. 43 days (Wania et al. 2000). In addition to this estimate, the effect of the River Vantaa was included, resulting in residence times of 3.2 d for the inner bay and 33 d for the outer. Using the POC concentration in water, default values for POC production and degradation (Wania et al. 2000) and the approximated sediment accumulation rate (Mattila *et al.* 2006) as an input, a mass balance for organic carbon was constructed (Figure 4.1).



**Figure 4.1.** An organic carbon mass balance of the Vantaanjoki estuary. Note that the exchange between the outer Gulf of Finland and Kruunuvuorenselkä is a crude estimate.

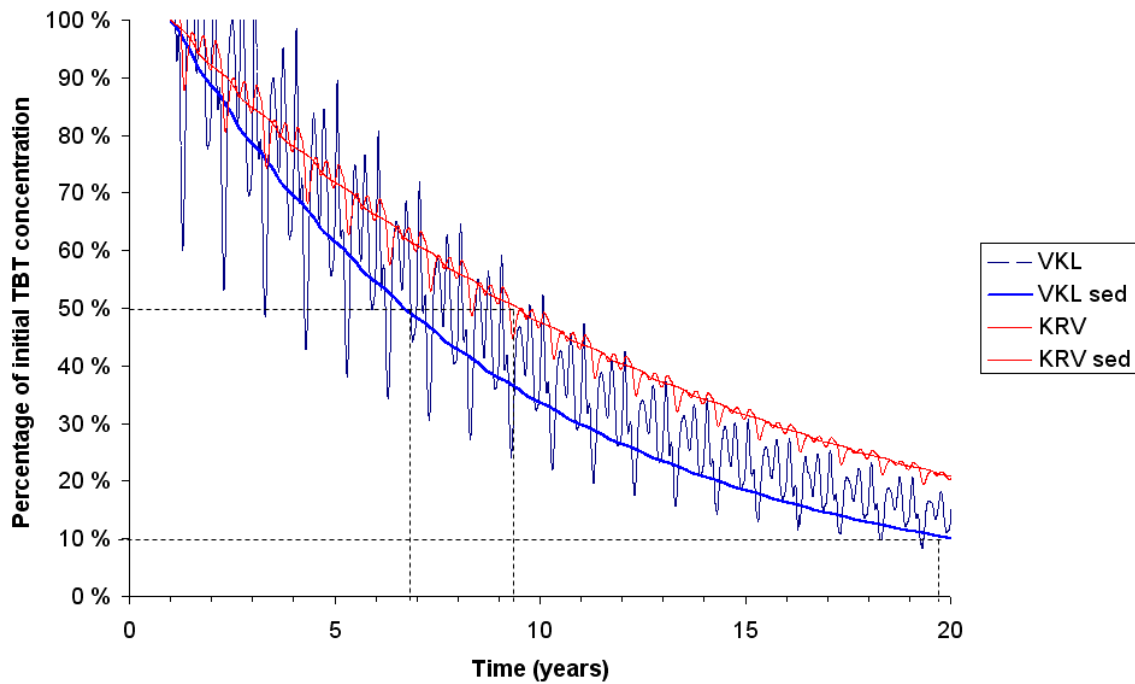
### Modeling the baseline scenario for TBT

Based on the mass balances of organic carbon and water, a dynamic mass balance for TBT was constructed (transport equations from the POPCYCLING Baltic model of Wania et al. 2000). Emission of 20 kg/a to the water column of Kruunuvuorenselkä (from TBT containing paints) was simulated, resulting in a steady state concentrations of 150  $\mu\text{g/kg}$  (dw) in sediment, which is close to the observed mean concentration (Appendix 3). This corresponds to 8 ng/l in the water column (40 times the EQS), which is at the range of the few measured analyses of TBT from water (<1 ng/L to 12 ng/L) (Table 2.2). Consequently, this "load" can be used as a starting point for the baseline scenario.

After this "loading stage" emissions were set to zero and the recovery of sediments was modelled. Since the direct emissions from ship paints stopped latest from November 2008 (see Step 4 below) this is practically the situation in the system. **One year after the cessation of emissions, sediment concentrations would be practically the same, but the water column concentrations would have decreased to 0.1  $\mu\text{g/l}$  (i.e. 50 % of the EQS).** After that point, the recovery is presented in figure 4.2, with the point of one year after emissions set as 100%. Halving of concentrations is predicted to take 7-10 years and a 90% reduction in is predicted to require more than 20 years (Figure 4.2). Major uncertainty in model calculation is the degradation rate of TBT in the oxic water/sediment interface.

Based on the baseline scenario, the water column concentrations are likely to decrease below the EQS very rapidly, making management based strictly on WFD unnecessary. However, dredging may be considered as a possibility to increase the speed of recovery in sediments, since the sediment pore water concentrations are likely to be significantly higher than in the water column (mainly due to dilution).

Moreover, the water concentrations were most likely overestimated by the assumption of similar residence times as in the Baltic coastal regions, since the Bay is small and is likely to have a reduced residence time.



**Figure 4.2.** Recovery of the surface sediments (0-7 cm) after cessation of the emissions. Lines depict concentrations in two areas VKL and KRV and in two media: sediment and water column. One year after the cessation was chosen as the base year and the percentages are calculated on that basis. Halving of concentrations is predicted to take approximately 7-10 years.

## 5. Step 4: Identification of Possible Measures

### 5.1 Framework of the step

Step 4 concerns the identification of relevant and possible management options for the priority substances for actual (Step 2) and future (Step 3) areas of exceedance. This step also covers management options for contaminated sediments.

### 5.2 Measures by substance

#### Nonylphenol (NP)

*Possible measures:*

- No measures needed.

#### Di(2-ethylhexyl)-phthalate, (DEHP)

It is likely that the observed maximum concentrations are not reliable and the possibility of water emissions higher than 150 kg/d is ignored. However, even the exceedance of 1.3 µg/l in the river

mouth corresponds to a flux of 2.1 kg of DEHP per day. This amount would correspond to 300 m<sup>3</sup>/d sludge emissions to water, which is also highly unlikely. This would indicate that there may be direct emissions of DEHP to the water phase associated possibly storm water run off, outflow of untreated sewage from pumping stations or flow from an unknown polluted point source. These hypotheses can not be validated without further measurements and research, but they are supported by the co-occurrence of high concentrations and heavy rainfall and the findings of high concentrations of DEHP in sediments of the Vanhankaupunginlahti in the river estuary (Kajaste et al. 2009)

**Possible measures:** (see table 5.1)

- Screening/identification of a possible point source
- Elimination of a possible point source
- Preventing outflow of untreated sewage

## **Polycyclic aromatic compounds, PAH**

PAH concentrations increase in the autumn and during the winter, suggesting that their major route to the water phase is associated with either decreased temperatures (resulting in less evaporation and more sorption to solids) or rainfall. In many cases urban storm water has been identified as a main source of PAHs to waterways. Modeling of atmospheric emissions and deposition also indicated that exceedance in the coastal bay areas may be caused by PAHs originating from atmospheric emissions and urban run off. Several other possible diffuse PAH sources to urban run off also exist as listed in Chapter 3.3.

If the PAHs in the River Vantaa can be thought of as following the route: atmospheric emissions - wet/dry deposition - run off, then the main factor in controlling concentrations would be management of atmospheric emissions and/or run off water. In addition to that, other diffuse sources (such as contaminated soil sites) should be further investigated.

**Possible measures:** (see table 5.1)

- Reductions of atmospheric PAH emissions (renovation of residential wood burning facilities)
- Renovation of sewer systems (hindering the outflows of untreated sewage from pumping stations)
- Urban storm water management (buffer strips and zones, sedimentation basins, bio-filters etc.)

## **Brominated diphenyl ethers, PBDE**

PBDE concentrations in the water column have not been measured. However, based on the modeling of suspended solid emissions from the STPs, it is likely that the EQS is not exceeded for PBDEs in the river system. The PBDEs are tightly associated with suspended solids and all measures that reduce the outflow of suspended solids from the STPs will also reduce PBDE emissions.

**Possible measures:**

- No measures needed.

## **Tributyltin, (TBT)**

In the case of TBT a probable no compliance with the EQS was anticipated from the sediment concentrations and from the few measurements of water above the sediment surface, which call for an

assessment of the effects of the possible management options. The primary source of TBT is the former use of TBT containing paints and subsequent leaching, dissolution and mechanical scraping of paints from ships. The area includes several recreational ship and boat harbours and small wrecks and two main harbours for trader shipping and passenger traffic (see Appendix 1). The survey of TBT- (and TPhT-) compounds in the River Vantaa sediments did not reveal any major source in the catchment or from municipal sewage treatment plants (Mannio et al. 2009, in preparation).

The use of TBT in small ships was banned in Finland in 1991 and in large ships from 2003 onwards, which consequently already decreased the emissions from these sources. Furthermore, over painting or total removal of TBT containing paints was mandatory from the beginning of 2008. A major change in the baseline situation took place in November 2008, when the port for trader shipping at Sörnäinen was closed and the ship traffic was moved to a newly built port of Vuosaari, some 20 km east of Sörnäinen.

According to the TBT fact sheet (An Inventory and Assessment of Options for Reducing Emissions: tributyltin, TBT) emission abatement measures include sediment dredging with environmental friendly method or remediation of sediment. After consultation with the local stakeholder group we decided to include here three different options for sediment dredging with different sediment locations and velocities (see in Step 5, table 5.1).

**Possible measures:**

*-Environmental dredging and disposal of contaminated sediments*

**Table 5.1.** An overview of possible measures, identified from the substance reports and applicable to the Vantaanjoki case.

	<b>TBT</b>	<b>PBDE, NP</b>	<b>PAHs</b>	<b>DEHP</b>	<b>Note</b>
Emission source	Sediment	STP, run off	STP, run off	Possible point source, run off	
Dredging	X				
Renovation of sewer system		x	X	x	
Solids settling in STP		x	X	x	<sup>1</sup> RBMP
Urban run off management		x	X	x	
Local soil remediation			x?	x?	
Renovation of residential combustion appliances			X		

<sup>1</sup>RBMP= includes also other measures listed in River Basin Management Plan for VHA2 (see Chapter 4.2). X= measures needed, x= measures not needed but emissions will further decrease if measures are taken, x? Identification need for a possible source is discovered.

## **6. Step 5: Assessment of the Effects of the Measures**

### ***6.1 Framework of the step***

In Step 5 an assessment of the effects of the possible management options/measures takes place. Once the possible alternative measures have been defined (the result of Step 4), it is necessary to determine which categories of effects need to be taken into account in order to decide on the most appropriate selection method (Step 6). The assessment of the effects is at least a calculation/estimation of the Costs of Reduction and of the performance of the measure: the reduction in PS concentration.

### ***6.2 Effects of measures by substance***

#### **Di(2-ethylhexyl)-phthalate, DEHP**

For DEHP municipal STPs and urban storm water runoff and/or contaminated point source may be the main emission sources. For DEHP, it may be possible that accidental leakage of sewage contributes slightly to the problem. It is likely that the sources other than a possible point source would decrease with the general measures listed in the RBMP and without special priority substance management. Exceedances of EQS are currently rare and not measured after 2007.

The findings support further monitoring and research on the localization of a possible polluted point source.

#### **Polycyclic aromatic compounds, PAH**

Atmospheric deposition/urban water runoff may be the main emission sources for PAH compounds. Measures listed in the RBMP would decrease emissions, but according to the mass flow estimate these would not have any major effect on total emissions to water. Exceedances of the EQS are currently rare, and are likely to be even more infrequent when atmospheric emissions are expected to decrease due to measures caused by the Air Quality Directive and UNECE/LRTAP requirements. Additional measures (e.g. bio-filters) have proven effective and could be applied in case further exceedances occur.

#### **Brominated diphenyl ethers, PBDE**

The highest modelled concentrations for PBDEs and NP in water are well below the EQS. It is likely that the reduction of emissions of suspended solids (as in the RBMP) further reduce the concentrations. After the ban of some PBDEs in the EU, the restrictions on PBDE containing products and waste will also have a decreasing effect in water concentrations.

# Tributyltin, TBT

## Scenarios

Because of anticipated natural attenuation (see Step 3 above), dredging in Kruunuvuorenselkä may only fasten the recovery of sediments. For this analysis three hypothetical dredging options were defined.

**In the first scenario**, 100 000 m<sup>3</sup> of the most contaminated sediment would be removed from the proximity of measuring point HS 19 (Appendix 3). Current measurements in the area in question were carried out only between 0-20 cm depths. Due to the high TBT concentrations still at 20 cm depth, dredging depth was anticipated to be doubled to 40 cm in order to ensure that the new surface sediment would be clean of TBT. This is realistic when compared to the measurements made in the Vuosaari port. In similar Vuosaari sediments with TBT concentration of about 200 µg/kg at 20 cm depth, TBT concentration of <1 µg/kg was recorded at the depth of 20-50 cm (Niinimäki & Piispanen 2003). The mean sedimentation rates would not be expected to be highly different at these two sites. Acreage of dredging area in this first scenario is 25 hectares and the amount of TBT to be removed is about 13 kg (Table 5.1).

**Second scenario** would be a dredging of the sediment from 125 hectares, corresponding to 500 000 m<sup>3</sup> of sediment. In this scenario the volume of the dredged mass would be approximately the same as in the Vuosaari port. If the dredging would be limited to the shipping route (for the passenger traffic), it would mean 12.5 km long and 100 m wide area. With the expected some what lower average TBT concentration of the dredged sediment (150 µg/kg), the amount of TBT removed would be some 49 kg.

**In the third scenario** 1 000 000 m<sup>3</sup> of sediment would be dredged from the area of 250 hectares. With the same average TBT concentration as in the second scenario, the amount of TBT removed would be some 98 kg (Table 5.1).

**Table 5.1:** Presentation of the dredging scenarios

	<b>1. scenario</b>	<b>2. scenario</b>	<b>3. scenario</b>
Dredged mass m <sup>3</sup>	100 000	500 000	1 000 000
Dredging depth m	0.4	0.4	0.4
Dredged area ha	25	125	250
Average TBT concentration of the dredged sediment µg/kg (dw)	200	150	150
Amount of removed TBT kg	13	49	98

## Cost-benefit analysis

### Earlier experiences (the Vuosaari-case)

The new port at Vuosaari site is an old dockyard with a significant TBT problem in sediment before the construction of the new harbor. During the construction phase the TBT-contaminated sediments were partially dredged and disposed at sea and on land in 2004 and 2005. The experience from the Vuosaari-case forms the basis of the assessment of the effects and the cost-benefit analysis.

Concentrations of TBT in the sediments of this former dockyard area were extremely high at some locations (between 0 and 5000 µg/kg). According to the Finnish national quality standard for dredged sediments the concentration which is lower than 3 µg/kg (dw, normalized to OC and silt content), is regarded as a background concentration (and harmless) and can be relocated at sea. If TBT concentration is more than 200 µg/kg (dw), then sediment is classified as contaminated and principally has to be located on land. Sediments with concentrations between 3.0 µg/kg and 200 µg/kg require a case-specific consideration from the environmental authority on conditions and sites for location.

In the first stage the contaminated area at Vuosaari was isolated from the surrounding sea area with a protective terrace and protective cover structure. In the second stage 450 000 m<sup>3</sup> of contaminated sediment containing 97 kg of TBT was removed by environmentally friendly dredging methods. The sludge was transported by barge to the newly built filling, isolated from the harbour area. In the third stage contaminated sediment was mass stabilized and finally reused as a base structure of the harbour field (Heikkonen 2008).

## Costs

The costs of different dredging scenarios are assumed to consist of preliminary analysis costs, necessary license fees, monitoring and quality control costs, dredging costs and sediment disposal costs (Table 5.2). The total costs for each scenario are presented with the costs of the Vuosaari harbor project (Piispanen, A. personal notification 17.11.2008). The preliminary analysis costs are assumed to be the same as in Vuosaari. All other costs are assumed to be 90 % of the Vuosaari case costs due to the somewhat different nature of the projects. For example the sediment in Vuosaari was more contaminated and it was extensively treated in order to reuse it in the harbor structures. In the three scenarios of this study the sediments are placed either in soil dumping area at sea or to landfills of waste.

**Table 5.2.** Costs of the Kruunuvuorenselkä dredging scenarios based on the costs of the Vuosaari case.

	<b>Vuosaari</b>	<b>1. scenario</b>	<b>2. scenario</b>	<b>3. scenario</b>
Preliminary analysis costs (Mil. €)	0,4	0,4	0,4	0,4
Necessary license fees (Mil. €)	0,5	0,4	0,4	0,4
Dredging, sediment disposal (Mil. €)	11,5	5,2	10,3	20,6
Monitoring and quality control (Mil. €)	0,5	0,4	0,4	0,4
<b>Total (Mil. €)</b>	<b>12,8</b>	<b>6,4</b>	<b>11,6</b>	<b>21,9</b>

The first scenario presumes that all the dredged material is placed to landfills due to its high contamination. In the second and third scenario half of the dredged sediment is assumed to be placed in the nearby sediment dumping area in the sea (Taulukari, see Appendix 3) and the most contaminated half to landfills. None of the sediment was assumed to be reused. It should be noted that the two last scenarios may not be applicable, since for renovation purposes only it may not be feasible to dispose the contaminated sediment at sea and thus having risk to cause environmental hazards on the dumping site. As such the starting point is different from the Vuosaari case, where substantial benefits were gained from harbour/navigation activities following the dredging.

Although the stabilization costs of the contaminated sediments of Vuosaari can be assumed to have been quite high due to very high TBT concentrations of the treated sediment, it is not possible to estimate if they correspond to the costs of placing less contaminated sediments in landfill. To emphasize the difference in costs of placing sediment on land or in the ocean, all three scenarios were

calculated with all other constant but dredging and sediment disposal costs according to TBT-BATman study (Vahanne et al. 2007) as presented in Table 5.3.

**Table 5.3.** Costs of the scenarios based on the estimations of the TBT-BATman.

	1. scenario	2. scenario	3. scenario
Preliminary analysis costs (Mil. €)	0,4	0,4	0,4
Necessary license fees (Mil. €)	0,4	0,4	0,4
Dredging, sediment disposal on land (Mil. €)	6,2	15,5	31
Dredging, sediment disposal to sea (Mil. €)	0	1	2
Monitoring and quality control costs (Mil. €)	0,4	0,4	0,4
<b>Total (Mil. €)</b>	<b>7,4</b>	<b>17,7</b>	<b>34,2</b>

According to the study, the cost of placing the contaminated sediment in the sea is assumed to be 4 €/m<sup>3</sup> and in landfill 62 €/m<sup>3</sup>. The costs of dredging and placing of dredged sediment into the sediment dumping site at sea consists of dredging costs, the costs of transporting the sediment by barge to the dumping site and placing the dredged sediment to the site. The distance of the site from the dredging area used in the calculations was not specified, but the simplifying assumption used in the three scenarios of this case study is, that the distance to Taulukari dumping site falls within the category used in the TBT-BATman study (Vahanne et al. 2007).

Costs of dredging and placing of dredged sediment to the landfill area consists of costs of dredging, treatments, like dewatering, of the dredged mass, transportation and placing the sediment to the landfill. The calculation in the study (Vahanne et al. 2007) was based on the costs of transportation of sediment less than 100 km in the metropolitan area. This is a valid assumption for the transportation distances in these three scenarios as well. For instance, a fraction of the dredged sediment from Vuosaari was placed in a landfill site near the case-study area, which could be a realistic site for the dredged masses of the scenarios as well. (Vahtera, personal notification 16.12. 2008)

## Benefits

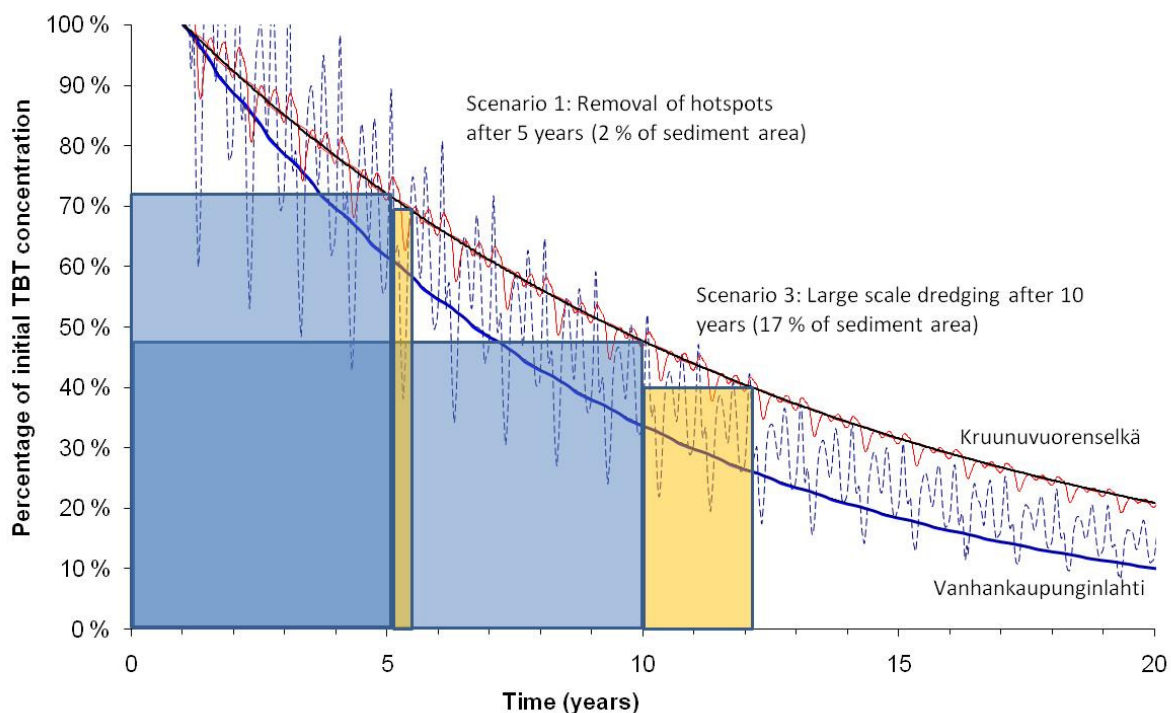
Removal of TBT from Kruunuvuorenselkä Bay will have many benefits. Contamination of Vanhankaupunginlahti will cease, because TBT was drifted there from the Kruunuvuorenselkä Bay. Now that discharges of TBT have ceased to the Kruunuvuorenselkä Bay, both it and Vanhankaupunginlahti will recover on their own in time. There were no suitable studies found about monetized benefits of dredging contaminated sediments to be applied here. However in order to roughly estimate what the willingness to pay should be for the dredging to be beneficial, calculations were made (Table 5.4).

**Table 5.4.** Costs of different scenarios presented as net present values.

	Vuosaari	BATman	Vuosaari	BATman	Vuosaari	BATman
	M€/kg	M€/kg	M€/kg	M€/kg	M€/kg	M€/kg
M€/TBT kg	<b>0,49</b>	<b>0,57</b>	<b>0,24</b>	<b>0,36</b>	<b>0,22</b>	<b>0,35</b>
i	2 %	2 %	2 %	2 %	2 %	2 %
1. scenario	<b>0,49</b>	<b>0,57</b>				
2. scenario			<b>0,23</b>	<b>0,36</b>		
3. scenario					<b>0,21</b>	<b>0,34</b>
i	3 %	3 %	3 %	3 %	3 %	3 %
1. scenario	<b>0,49</b>	<b>0,57</b>				
2. scenario			<b>0,23</b>	<b>0,35</b>		
3. scenario					<b>0,21</b>	<b>0,33</b>

i	5 %	5 %	5 %	5 %	5 %	5 %
1. scenario	<b>0,49</b>	<b>0,57</b>				
2. scenario			<b>0,22</b>	<b>0,34</b>		
3. scenario					<b>0,20</b>	<b>0,32</b>

Table 5.4 presents the net present values of the dredging costs of the scenarios calculated with discount rates of 2 %, 3 % and 5 % and divided by the amount of TBT removed in each scenario. First, there are the abatement costs of TBT dredging as such. Time periods used in the calculation of the net present values are the estimates of how long it would take for the surface sediment to reach the same state as would be attained by dredging. The modeling indicated that it would take less than one year for the surface sediment to decompose the equivalent amount of TBT as would be removed from the surface in the first scenario (Figure 5.1). Consequently, in practice the effects of dredging to decrease the water concentration would be expected to take even longer than the natural attenuation, because of increased sediment resuspension during the operations.



**Figure 5.1.** The effects of dredging scenarios and the predicted natural attenuation of sediments from TBT in Kruunuvuorenselkä and Vanhankaupunginlahti. Details of the scenarios are given in the text. The solid lines are concentrations in sediment and the dotted lines are in the water column.

If it is assumed that it would take one year to dredge, then self-purification would reach the second scenario's state year after the dredging ceased and the third scenario state in two years (Figure 5.1). This means that if people's willingness to pay for the more rapid purification of the sediment was ever estimated, it should exceed the unit costs of scenario in question in table 5.4, in order for the benefits of dredging to exceed the costs. In that case however, a more suitable way might be to determine the people's willingness to pay for the increase of the percentage of uncontaminated surface sediment.

Benefits of the less contaminated sediment may include e.g. benefits for the fishers for less TBT contaminated fish, purification of the adjacent Vanhankaupunginlahti, better conditions for recreational fishing and recovery of bottom dwelling organisms. The model results do not, however, support that these benefits would well outweigh the natural attenuation. However, some benefits from dredging can not be attained by other measures. For example, dredging will also remove other haz-

ardous substances (heavy metals, POPs), which are not as quickly degraded or replaced to deeper sediment layers. The indirect benefits of this can be recreational and economical and it could also reduce health hazards. For instance, fish in the region contain much higher concentrations other organotin compounds than TBT, especially triphenyltin (TPhT). Concentrations are high enough that food authorities recommend some fish species from the region not to be used for human food (Hallikainen et al. 2008). It is likely that dredging would also fasten the recovery of fish from the TPhT compounds.

## **Conclusions of cost/benefit analysis**

The cost-effect analysis and background estimations used in this study are rough, and they are to be taken with caution. Better knowledge of the spatial and vertical distribution of TBT would be needed to determine the hot spots. However, because contamination is wide spread, dredging only the hot spots would not very significantly reduce the overall contamination of the surface sediment. If the further survey would reveal large areas of contamination at only sediment surface, then dredging from a lower depth but from a wider area could help to reduce the amount of contamination in sediment and in water more effectively.

Without more precise valuation of the benefits of dredging, the costs may very well prove to be too high. However, if all the dredged sediments were disposed to land the costs would be even higher. On the other hand, removing the sediment which, as in this case, is contaminated with other hazardous substances has additional benefits. Valuating all the benefits might prove the dredging much more beneficial than what it is when the study is limited solely on TBT.

At this stage dredging is not recommended as a remediation technique due to high costs compared with benefits. It should be noted that possible short time negative effects due to dredging were not calculated in this work or the people's willingness to pay for the dredging.

## **7. Step 6: Selection of the Best Solutions**

Based on the steps taken in accordance with the Decision Support System the stakeholder group selected the following three measures as the best solutions in order to eliminate and reduce the risks caused by the priority substances in the River Vantaa catchment area. The measures considered are under the governance of local regional and national authorities and other actors. On the other hand measures possible to take only on the EU and other international level (e.g. EU product and chemical policies, UN trade and chemical policies) were not surveyed and determined by the stakeholder group. All the identified measures are also effective for reducing nutrient load, the most significant pressure, to the R. Vantaa and the adjacent coastal areas.

### ***7.1 Improved management of urban run off***

Urban run off is a significant source for DEHP and PAH releases to the River Vantaa. The measure comprises establishing new buffer strips and zones, small sedimentation basins, flow reducing constructions, wetlands and bio-filter areas for the urban run off sewers and streams. The responsible actors are the municipal water services, the municipal land use authorities and the regional environment centers and it is recognized and addressed (e.g. City of Helsinki 2008).

## **7.2 Better sewage treatment plant operation**

Priority substances are to a large extent adsorbed to the particles in water. Efficient removal of solid matter in sewage treatment plants reduces the releases of harmful substances. Therefore, particular focus should be placed on achieving a very high degree of solid removal in all the urban wastewater treatment plants of the River Vantaa catchment area. The responsible actors are the municipal waste water treatment companies.

## **7.3 Renovation of sewer systems**

Existing extensive sewer systems in the River Vantaa catchment area call for good management of storm water over flows and other disturbances as well as prevention of leaks from the system. Renovation of old sewers and pumping stations, including construction of storage basins for disturbances and accidents, is needed in some areas. The measure curbs releases of all harmful substances present in urban untreated sewage to the rivers and coastal water bodies. The responsible actors are the municipal waste water treatment companies.

## **8. Conclusions**

The SOCOPSE Decision Support System (DSS) provided a clear and logical, but also practicable, approach and tool to apply for the River Vantaa catchment area and the adjacent coastal water bodies. All the steps could be implemented, at least to some extent, in line with the DSS handbook. Yet we recognized some problems and gaps of information that should be addressed when further developing and applying the DSS.

We see that the tool suited well to the spatial scale of the River Vantaa case, which is about 2 000 km<sup>2</sup> with a population of approximately one million people. The setting up and active involvement of a stakeholder group proved to be of vital importance for a successful implementation of the DSS. Due to a different timetable of the WFD river basin management planning process the DSS could not be smoothly coupled with the preparation of the programs of measures under the WFD but a deeper incorporation may take place for the second planning period (2016 – 2021).

The DSS process did not drastically change the general picture we already had on the priority substance (PS) problem and the possible solutions in the case study area but it revealed some potential sources of PSs that were not adequately well known, neither addressed, before.

As a starting point we had a fairly scarce, although better than the national average, information and data on the emissions and losses of the PSs in the study area. Furthermore, measurements on the concentrations of the PSs in the studied water bodies were few and they were mostly made at the mouth of the River Vantaa. Many significant potential emission sources, on the other hand, lie far upstream in the catchment.

Although analytical methods have developed markedly during the last few years the EQS (in water) of some priority substances (e.g. PAH, TBT, PBDE) is so low that the compliance with the EQS is very difficult to define due to the analytical uncertainty. We applied modeling of the concentrations of the PSs as a supplementary tool to the measurements of concentrations and found the approach most useful in grasping the general picture throughout the river system and the coastal water bodies. The modeling enabled us to test on how different emission levels in the catchment and dredging of

the coastal sediments impact the concentrations of the PSs and what is the effect of natural attenuation.

The SOCOPSE substance reports provided useful background information for the DSS inventory and measures steps. However, the specific material flows of the PSs in the River Vantaa case area differed considerably from the general EU picture presented in the SOCOPSE material flow analysis (MFA) sheets. Consequently, the SOCOPSE MFA could hardly be used as a supportive element for the River Vantaa DSS.

The River Vantaa case study results are presented and widely disseminated to the river basin management authorities and other actors throughout Finland during 2009. There clearly are several other catchments in Finland where a similar DSS process in connection with the second round of the river basin management planning is needed. The identification of such potential areas and the development of a cost-effective approach for applying the DSS process to the specific Finnish catchment characteristics could commence in 2010.

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## Appendixes

**Appendix 1.1.** Concentrations of nonylphenol (NP), nonylphenol etoxylates (NPE), di(2-ethylhexyl)-phtalate (DEHP), and polyaromatic hydrocarbons (PAH) in sewage treatment plants, sediments, fish, and sewage sludge.

	Site	Influent µg/l			Effluent µg/l			Sediment mg/kg dw			Fish µg/kg fw			Sludge mg/kg dw					
		x	N	Min	X	Max	N	Min	X	Max	N	Min	X	Max	N	Min	X	Max	N
nonylphenoletoxylate	1			<0,2	0,28	0,33	4	-							7	19	33	3	
	2	24,8	2	<0,2			1												
	3			0,40			1	-								9,3		1	
* = 4-n-nonylphenol + nonylphenoletoxylate: TEQ = 0.33 µg/l																			
4-n-nonylphenol	1			<0,2	<0,2	0,20	4	-							<2	4,9	6,6	3	
	3			<0,2			1	-								3,5		1	
DEHP	1	28,9	1	1,00			1	<50			1	<30	<30	2	7,3		1		
	2	32	2	0,13		0,2	2								3,2		1		
	3			19			1	63	120	5400	3				7		1		
		µg/l			µg/l			µg/kg dw			mg/kg fw			µg/kg dw					
Anthracene	1	0,012	1	<0,01	-		1	<100			5	0,03	<10	2	<5		45	2	
	3							<10	<10	<100	3					5,4		1	
Bentso(a)pyrene	1	<0.003	1	<0.003	-		1	<100			5	<0,01	<10	2	160		210	2	
	3							10	12	<100	3					27		1	
Bentso(b)fluoranthene	1	<0.01	1	<0.01	-		1	<100			5	<0,01	<10	2	210		230	2	
	3							16	22	<100	3					35		1	
Bentso(k)fluoranthene	1	<0.01	1	<0.01	-		1	<100			5	0,01	<10	2	88		110	2	
	3							<10	10	<100	3					15		1	
Bentso(ghi)perylene	1	<0.01	1	<0.01	-		1	<100			5	<0,01	<20	2	140		170	2	
	3							<10	17	<100	3					24		1	
Indeno(123-cd)pyrene	1	0,094	1	<0,01	-		1	<100			5	<0,02	<20	2	62		130	2	
	3							<10	<10	<100	3					20		1	
Fluoranthene	1	0,032	1	<0.015	-		1	200	230	4					680		720	2	
	3															61		1	
		ng/l			ng/l			µg/kg dw			µg/kg fw			µg/kg dw					
TBT	1	2,1	1	<0,5			2	21,0			1	6	37	10	13		1		
	2	4	1	<1			1												
	3			<0,5			1	0,7			1				12		1		

**Appendix 1.2.** Concentrations of polybrominated diphenylethers (PBDEs) in sewage treatment plants, sediments, and sewage sludge.

PBDE		sediment	Influent $\mu\text{g/l}$	Effluent $\mu\text{g/l}$	Sludge $\text{ng/g dw}$
		ng/g dw	Helsinki	STP 1	STP 1
<b>BDE-17</b>	Min				nd
	X	0,01	<0.1	<0.01	
	Max				1,05
	N	1	1	1	2
<b>BDE-28</b>	Min				nd
	X	nd	<0.1	<0.01	
	Max				nd
	N	1	1	1	2
<b>BDE-47</b>	Min				30,94
	X	0,11	<0.1	<0.01	
	Max				31,36
	N	1	1	1	2
<b>BDE-66</b>	Min				nd
	X	nd	<0.1	<0.01	
	Max				nd
	N	1	1	1	2
<b>BDE-85</b>	Min				0,82
	X	nd	<0.1	<0.01	
	Max				1,79
	N	1	1	1	2
<b>BDE-99</b>	Min				36,26
	X	0,15	<0.1	<0.01	
	Max				38,44
	N	1	1	1	2
<b>BDE-100</b>	Min				6,14
	X	0,03	<0.1	<0.01	
	Max				9,59
	N	1	1	1	2
<b>BDE-153</b>	Min				2,83
	X	0,02	<0.1	<0.01	
	Max				3,06
	N	1	1	1	2
<b>BDE-154</b>	Min				nd
	X	nd	<0.1	<0.01	
	Max				nd
	N	1	1	1	2
<b>BDE-183</b>	Min				0,67
	X	0,01	<0.1	<0.01	
	Max				1,13
	N	1	1	1	2
<b>BDE-203</b>	Min				nd
	X	0,07	<0.1	<0.01	
	Max				1,90
	N	1	1	1	2
<b>BDE-209</b>	Min				585,65
	X	6,99	<0.1	<0.01	
	Max				680,57
	N	1	1	1	2
total sum BDE		7,4			769

**Appendix 2.** Sectors / sources identified to be potentially important sources in Finland. Note that some sectors are overlapping each other.

<b>Source with SCS code</b>	<b>NACE code</b>	<b>Substance of concern</b>
1. Combustion of fuels		
1.2 Combustion of coal (and oil) in central heating plants		PAH
1.7 Combustion of wood (and oil)		PAH
2. Industrial processes		
2.12 Manufacturing of basic chemicals (TBT)		TBT & PAH
2.20 Manufacturing of pulp and paper		TBT & NP
2.21 Manufacturing of polymers (e.g. primary plastics and rubber)	24.16 and 24.17	DEHP
2.23 Rubber tyre manufacturing		PAH
2.24 Manufacturing of paints	24.30	NP
2.25 Manufacturing of DEHP		DEHP
2.26 Manufacturing of NP and NPE		NP
2.27 Plastics processing (or manufacturing of plastic products)	25.20	PBDE (& DEHP)
2.28 Textile processing	17	NP & PBDE
2.31 Leather processing	19	NP
3. Waste disposal/waste generation		
3.3 Waste water treatment plants	90.01	DEHP, NP, PBDE & TBT
3.5 Land-filling of urban refuse and commercial products	90.02	DEHP, NP, PBDE & TBT
3.6 Municipal sewage sludge application		DEHP, NP, PAH, PBDE & TBT
3.8 Demolition of preserved wood, other dismantling and crushing activities	37.20	DEHP & TBT
3.9 Car shredder	37.10	DEHP & PBDE
3.12 Public laundries	93.01	NP (not included to SCS!) & PBDE
3.14 Collection and treatment of wastes (electrical waste)	90.02	PBDE
4. Transport		
4.1 Road transport		PAH
4.2 Water (sea and coastal) transport	61.10	TBT & PAH
4.3 Air transport (airports and heliports)	62.00	NP
4.4 Shipyards and navigation (includes dredging)	e.g. 35.10	TBT & PAH
6. Uses of chemicals		
6.8 Plasticizer use; e.g. (see also e.g. SCS 2.21 & 2.27)	24.16, 24.17, 25.10 & 25.20	DEHP
6.16 Electrical appliances	31.13	PBDE (decaBDE)
6.18 PAH uses - creosote		PAH
6.19 Treatment and coating of metals	28.51	NP
6.20 Urban storm water		DEHP, NP, PBDE (PAH & TBT)

7. Other sources		
7.3 Sediment re-suspension (from coastal harbours and small boat ports)	e.g. 63.22	TBT
7.4 Dockyards (similar to SCS 4.4)	35.10	TBT
Sources not identified by WP2 but potentially important		
Manufacturing of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (no SCS code)	24.50	NP (manufacturing not mentioned in SCS!)
Manufacturing of rubber products (no SCS code)	25.10	DEHP
Washing of tank containers	90.02	DEHP & NP
Treatment of hazardous waste in hazardous waste disposal plant (no SCS code)	90.02	DEHP, NP, PBDE & TBT
Printing in printing houses (no SCS code)	22.20	NP

### Appendix 3

**Table 1, Appendix 3:** TBT concentrations in Kruunuvuorenselkä Bay and Vanhankaupunginselkä Bay in 2005. (Vatanen 2005) (TBT, norm.) indicates normalized concentration to 10 % of TOC in sediment.

point	date	depth cm	solid matter %	combustion loss %	TBT µg/kg	TPT µg/kg	TBT (norm.) µg/kg
HS12	24.8	0-5	56	3,9	16	<10	41
HS13	24.8	0-5	35	7,8	14	<10	17,9
	24.8	10-20	39	7,5	36	<10	48
HS14	24.8	0-5	29	8,5	48	33	56,5
HS15	24.8	0-5	33	7,5	73	97	97,3
		10-20	45	6,7	131	141	195,5
HS16	24.8	0-5	37	6	94	16	156,7
HS17	24.8	0-5	25	8,9	107	10	120,1
HS18	24.8	0-5	28	9,7	135	<10	139,2
<b>HS19</b>	24.8	0-5	24	10	<b>223</b>	20	223
	24.8	10-20	29	9,1	<b>205</b>	26	225,3
HS20	24.8	0-5	31	8,2	121	29	147,6
HS21	16.8	0-5	26	8,8	99	195	112,5
HS22	16.8	0-5	55	2,4	<3	<10	<3
	16.8	10-20	52	3,2	<3	<10	<3
HS23	16.8	0-5	52	2,6	<3	<10	<3

**Figure 1, Appendix 3:** TBT sampling points in Kruunuvuorenselkä Bay and Vanhankaupunginselkä Bay in 2005. (from Vatanen 2005) (gray oval= harbor for small ships, dashed red oval = shipyard for small ships, black oval = harbor for trader shipping and large passenger ships, dashed blue oval = sediment disposal site)

