Microbiological analysis in urban and coastal waters based on the Bathing Water Directive

Analyse microbiologique des eaux urbaines et littorales basée sur la directive européenne sur les eaux de baignade

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RÉSUMÉ

En 2009, le programme INTERREG IVb “DiPol” (Impact du changement climatique sur la qualité des eaux urbaines et littorales) a été instauré sur la portion urbaine polluée de l'Elbe, aux alentours de Hambourg-Wilhelmsbourg. La concentration moyenne de bactéries indicatrices comme E.coli et les entérocoques s’est avérée relativement faible, à l’exception des concentrations observées dans Wilhlemsbourg même, qui ont présenté par endroits des taux très élevés. Au total, 400 échantillons ont été prélevés sur une période de 26 jours entre mai et octobre 2009.

L'île, qui constitue la source même de la pollution bactérienne, et le fleuve Elbe, qui en assure le transport, ont été tous les deux analysés. La première étape de l'analyse consiste à évaluer l’état actuel du système de façon à prévoir l’évolution possible en considérant les changements environnementaux qui résulteraient du changement climatique à venir.

ABSTRACT

The INTERREG IVb project “DiPol” (Impact of Climate Change on the quality of urban and coastal waters) in 2009 took place in the urban affected part of the river Elbe around Hamburg Wilhelmsburg. The average concentration of indicator bacteria such as E.-coli and Enterococci turned out to be relatively low, although the concentrations in Wilhelmsburg itself have been at some locations extremely high. A number of 400 samples have been taken at 26 sampling days from May to October 2009.

The two systems analysed are the island itself as the source of bacterial pollution and the river Elbe as the transporting sink of it. The first step of the campaign is to evaluate the current state of the system in order to be able to forecast the possible developments under consideration of the changing environmental factors as a result of the Climate Change later on.

KEYWORDS

Bathing water directive, Bathing water profile, Climate change, Faecal indicator bacteria, Faecal pollution

1 INTRODUCTION

The investigation program which is introduced in this paper is embedded into the INTERREG IVb project “DiPol” with partners throughout the whole North Sea region. The aim is to evaluate the impact of Climate Change on the quality of urban and coastal waters at four different case sites. One is Hamburg Wilhelmsburg described under point two. The parameters measured are pesticides, heavy metals, relevant pollutants and pathogenic bacteria due to the EU directives in the water bodies as well as in the sediments. Here only the microbiological measurements are discussed.

In order to consider the impact of Climate Change the first step is to capture the current and past state of the water quality. Therefore two different areas have been defined. First the water bodies on the island (source) and second the river Elbe as the transporting system (sink) whereas the river Elbe might act as well as a source due to tidal effects and coastal transports along the North Sea coast.

The second step will be the prognosis of the future state of water quality under applying a fuzzy logic model to simulate the development and to obtain in the end of the project possible measures to compensate the affects of Climate Change.

This paper presents mainly the first step and will give in the end examples based on literature studies how pathogenic bacteria concentrations might change under changing environmental circumstances.

2 INVESTIGATION AREA

The investigation area of the performed measurements was Hamburg Wilhemsburg. The biggest river island in Europe is located south of the city centre of Hamburg and is bordered by the northern and southern branch of the river Elbe. The 35 km² of this island are densely used and populated. With nearly 50.000 inhabitants it is the biggest district of Hamburg and holds the main part of the harbour of Hamburg. The harbour area is located in the northwest of Wilhelmsburg whereas the south-eastern part is agricultural affected. The residential areas are situated in the middle of the island. The high density of infrastructure cuts Wilhelmsburg in north-south direction several times. Figure 2.1 shows an overview of the island.

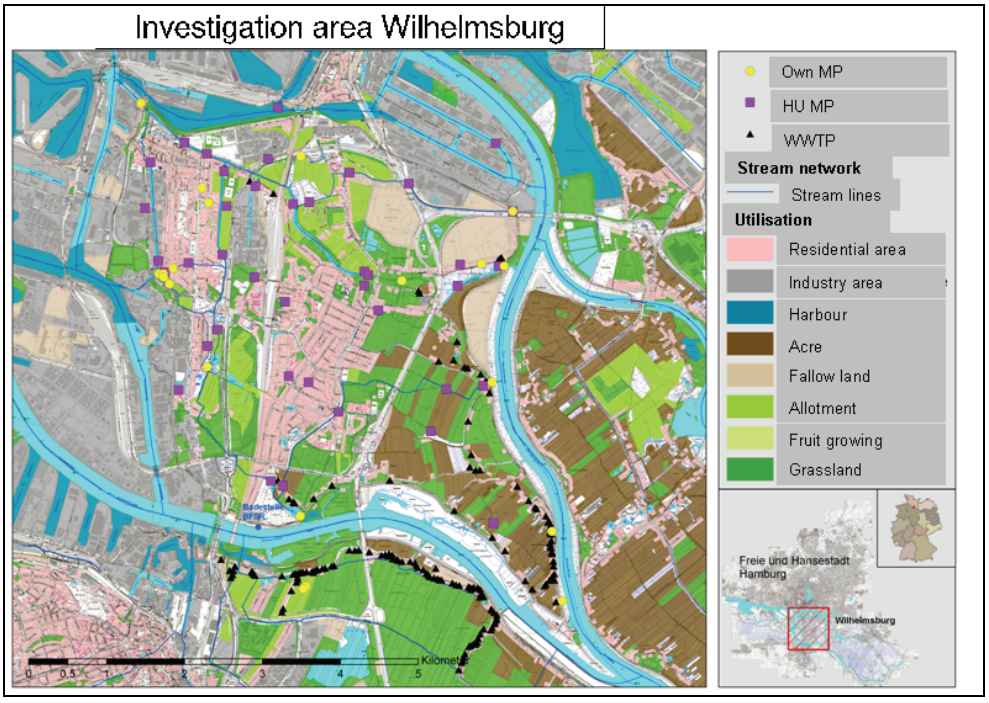

Figure 2.1 Investigation area Hamburg Wilhelmsburg (WWTP: decentralised waste water treatment plants: 4-50 inhabitant equivalent) (RG, 2009)

The river Elbe in the area of Wilhelmsburg is a sand affected river of the midlands where the soil hydro geologically is affected by 2-8 m thick non-rigid layers in which pin holes sand is located. In the

harbour area those layers are partly removed by anthropogenic modifications or displaced by sand layers. The bottom of the Elbe runs trough the quaternary aquifer and thus stands in exchange with it. Some harbour basins, which usually have no interference with the aquifer, on account of a certain depth stand in contact with the aquifer and are an exception (BWS, 2006). As a consequence of the human encroachment the tidal range has significantly raised in the last century. In 1870 the range was about 1,5 m whereas today a tidal range of 3,6 m is usual. Only from 1975 to 2005 an increase from 3,15 m to 3,51 m was detected at the measurement point “northern Elbe” (Magazin, 2009). This phenomenon is responsible for the sediment transport into the harbour because of the slope between high and low tide which is linear correlated to the increase of the tidal range. To investigate the impacts of the Wilhelmsburg island along the river Elbe see figure 2.2.

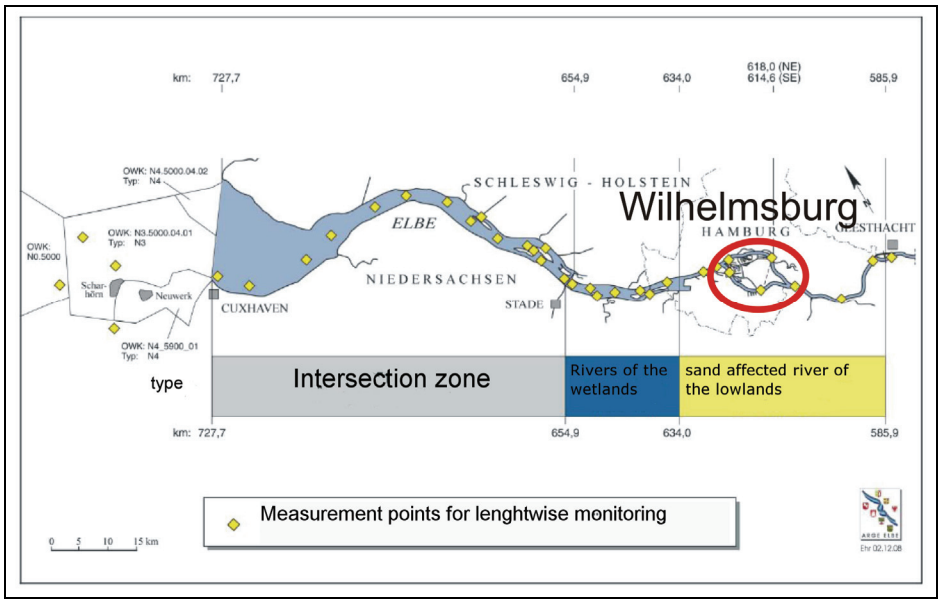

Figure 2.2 Exposure of the Wilhelmsburg island along the river Elbe together with the measurement points for lengthwise monitoring(FGG, 2009)

3 MEASUREMENT CAMPAIGN 2009

The measurement campaign in 2009 started in the beginning of May in Hamburg Wilhelmsburg. The sampling points where chosen under cooperation with the authority for urban development and environment, Hamburg. Strategic relevant points have been chosen to make a statement on the quantity of water which is flowing into the creeks of Wilhelmsburg island as well as into the river Elbe. Therefore most of the points are located at the pumping stations at the eastern boarder of the river island (see figure 2.1). Another point is located at the water gate (Ernst August Schleuse) and at one of the storm water holding basins from a highway runoff. Altogether there have been taken 400 samples at 26 sampling days in and around Wilhelmsburg.

Additionally some special investigations were performed at two of the described sampling points. One was the creek called Großsander Wettern together with the creek called Bauwiesen Wettern (see figure 4.2 and 4.3) and the other location was the Rothenhäuser Wettern (figure 4.4 and 4.5). These points were chosen because they turned out to be the creeks with the highest concentrations of faecal indicator bacteria in Wilhelmsburg. The intensive investigations should give the possibility to trace the sources for the pollution of bacteria and finally to write a proposal in which the results shall be communicated to the responsible authorities, in order to eliminate or reduce these sources.

Another investigation program was held together with the Institute for Hygiene and Environment, Hamburg. They take samples once per month upstream and downstream of Wilhelmsburg island in order to get the amount of substances and bacteria which is disposed from the city and the harbour into the river Elbe. Therefore it is important to take the respective sample at the absolute low tide at the sampled spot to avoid accumulation of pollutants due to tidal effects.

3.1 Applied Method

The method applied for the microbiological measurements uses the micro plates for statistical analysis of the taken water samples. The calculation of the most probable number (MPN) is detected with the help of tables and allows a detection of the MPN within a confidence interval of 95% with a lower and upper limit. The method is certified after the DIN EN ISO7899-1 and the DIN EN ISO 93-08-3. The advantage is the fast detection of faecal bacteria in outlets of waste water treatment plants or surface waters. The units used in the Bathing Water Directive are cfu (colony forming units). The MPN gives the number of bacteria in the taken sample which is statistically to be expected. Under real circumstances the number of bacteria is higher than the colony forming units because they may adhere together. The unit cfu takes this phenomenon into account (BioRad, 2000).

4 RESULTS

4.1 Wilhelmsburg island (source)

Before starting to take own samples a literature review was held in order to get an overview of the existing data and to get a range of the concentrations of bacteria in the samples.

Although the data base is relatively small, there have been done some measurements in the past. The oldest data available are from 1992 and were published 1994 under the title “Stress of the water bodies of Wilhelmsburg” in the context of the environmental reports of Hamburg. They showed that two sampling sites had high concentrations of E.-coli. The results of one of the sites are exemplary shown in figure 4.1.

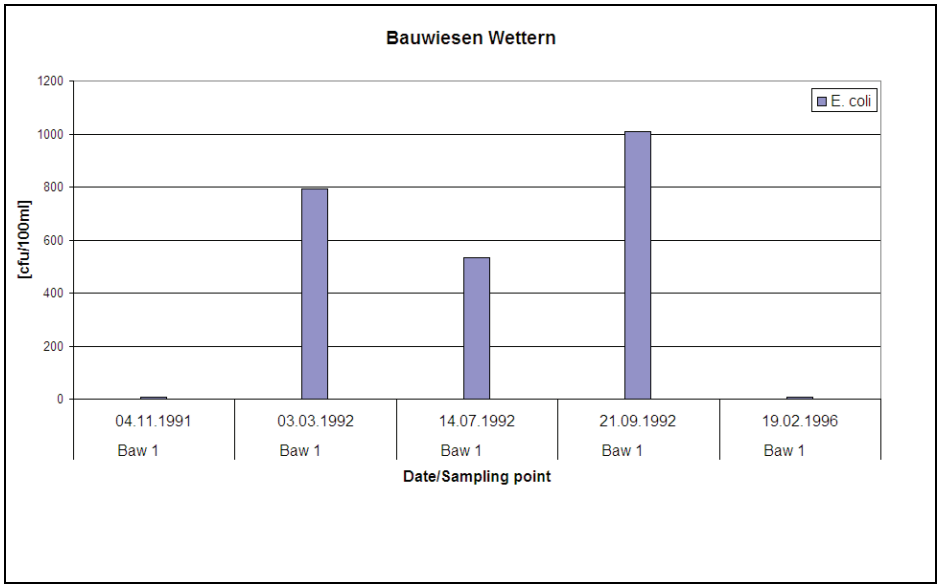

Figure 4.1 Results from the creek “Bauwiesen Wettern” from 1991 to 1996 (only the results from 1992 where published in the mentioned report 1994) (cfu: colony forming units) (Dannenberg et al. 2009)

In comparison to the results in figure 4.1 those of this year are of much higher concentrations. See figure 4.2. At the 11th of August the pumping station at the end of the creek Bauwiesen Wettern and the creek Großsander Wettern was pumping water from the two streams into the Veringkanal and thus finally into the Elbe. Therefore the concentration in the Veringkanal (B 1) was nearly of the same concentration like the one in front of the pumping station (B 1-01). At any other sampling day the concentrations of B 1 were always the lowest compared to the other points of this day. The northern branch has the number 02 and the southern one 03. (See figure 4.3).

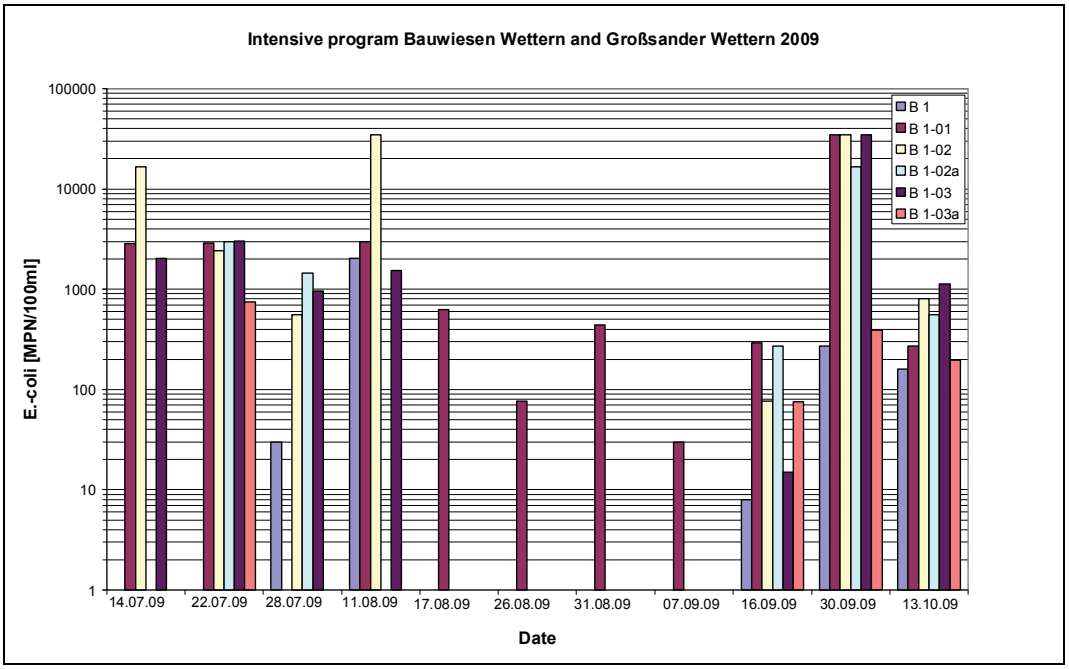

Figure 4.2 Results from the creek Bauwiesen Wettern from this year's intensive program (MPN (most probable number: equivalent to cfu))

In figure 4.2 it is to be seen that the high bacteria concentrations are coming from the creek Bauwiesen Wettern. Because the concentrations at B 1-03a are always lower than B 1-02 or 1-02a. These two last mentioned points are both located in the creek Bauwiesen Wettern. A side inspection along the stream of the creek Bauwiesen Wettern showed that after a pipe work under some houses the subsequent part is completely dried out. Consequently the high loads can not originate from upstream the houses. The comparison between the E.-coli concentrations and those of the Enterococci showed that the origin of the pollution must be anthropogenic. The values of the Enterococci were much lower than the E.-coli ones. Otherwise it would have been possible that the source could have been from ducks or other birds (Gasse et al. 2006). For a detailed overview see figure 4.3.

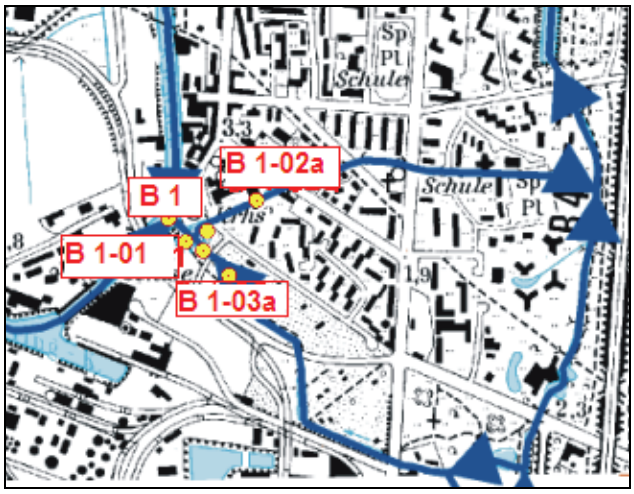

Figure 4.3 Map of the sampling site B 1 Groß Sand (RG, 2009)

The other sampling site with high bacteria concentrations was at the creek Rothenhäuser Wettern in the residential area of Wilhelmsburg. The investigations showed that in the local storm water retention basin an inflow was detected even though it has not rained for days. The inflowing water was very clear (turbidity of 1-4 NTU) and did not smell at all. The sampling point B 14 is located in the creek Rothenhäuser Wettern where the water from the basin is dewatered into the Aßmann-canal, from there into the Ernst-August-canal and finally passing the water gate into the river Elbe. Several intensive sampling events took place in order to localise the source and to ensure that the pollution is not occurring from the connected rain water canalisation. The results are shown in figure 4.4.

Figure 4.4 Results of the intensive program at B 14 Zeidlerstraße

It is obvious that the concentrations of B 14 and B 14-01 are depending on each other. But there was no clear tendency which sampling point reaches higher bacteria concentrations in the daily comparison.

Figure 4.5 Map of the sampling site B 14 Zeidlerstraße (RG, 2009)

The sampling points B 14-02 and 03 are located directly in the Zeidlerstraße under the manholes. The connection between the basin and the Wettern (creeks) is cased under the street. There is a chamber (B 14-02) where B 14-03 is dewatering in, together with the basin. The outlet is connected directly to the Wettern and thus to B 14.

The sources for faecal pollution on the island are mainly diffuse pollution sources such as wrong connected sewage pipes or resuspension from old sources due to changing turbulence conditions resulting from pumping the water out of a creek (see figure 4.2 at the 11th of August 2009).

4.2 River Elbe (sink)

These results from the island of Wilhelmsburg compared to those of the river Elbe are relatively high but compared to the outlet of the WWTP Dradenau, which is the biggest point source for pollution in the area, relatively low. Nevertheless, under ideal circumstances of dispersion in the river Elbe, the outlet of the WWTP Dradenau causes an increase of around 3 MPN/100 ml[1]. This fact shows the ability of the Elbe to buffer highly polluted discharges. The analysis of the sampling program of the last year confirmed this fact. The review of the existing data allows to control the own methods and results on reliability and plausibility. The values from 2008 are shown in figure 4.6. Sampling point Zollenspieker is located upstream from Wilhelmsburg island. Sampling points Moorwerder (green) and Finkenriek (red) are located at the southern branch of the Elbe and sampling point Seemannshoeft downstream respectively.

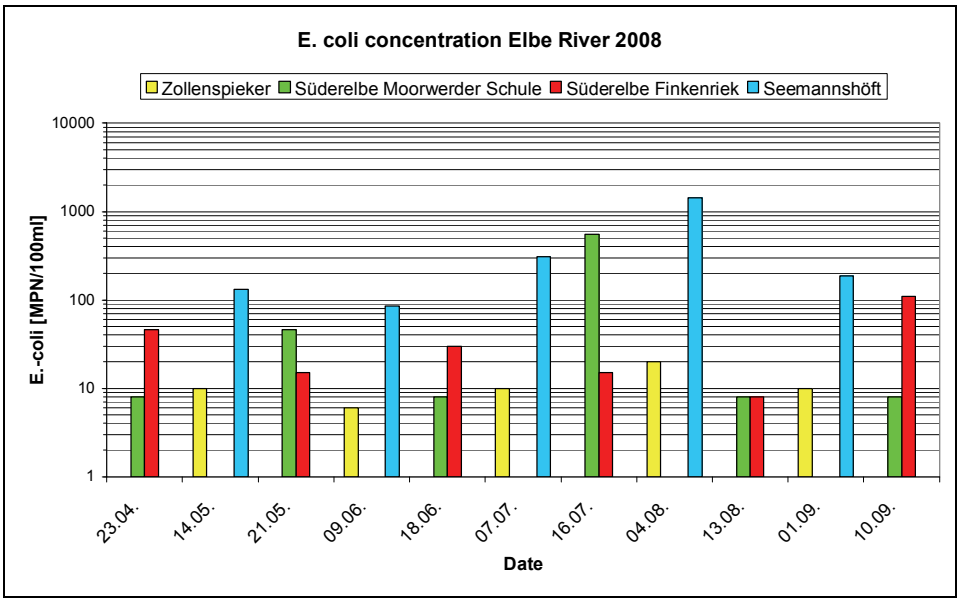

Figure 4.6 Results from investigations of 2008 at different sites along the Elbe (HU, 2009)

The lowest average value is to be seen at sampling point Zollenspieker (yellow) upstream of Hamburg. In comparison to sampling point Seemannshoeft (blue) the impact of Hamburg harbour and city can be identified with respect to bacterial pollution. This correlates with the observation program of the two mentioned sites of the last year from the Hygiene and Environmental Institute of Hamburg at the beginning of each month. The results are shown in figure 4.7.

[1] Assumption: Ideal dispersion of the average outlet concentration of the WWTP Dradenau of 65470 MPN/100 ml and an average discharge of the Elbe of 710 m³/s (Gauge Neu Darchau) (DGJ, 2004) with an associated discharge of the WWTP Dradenau of 5,12 m³/s. (HSE, 2003)

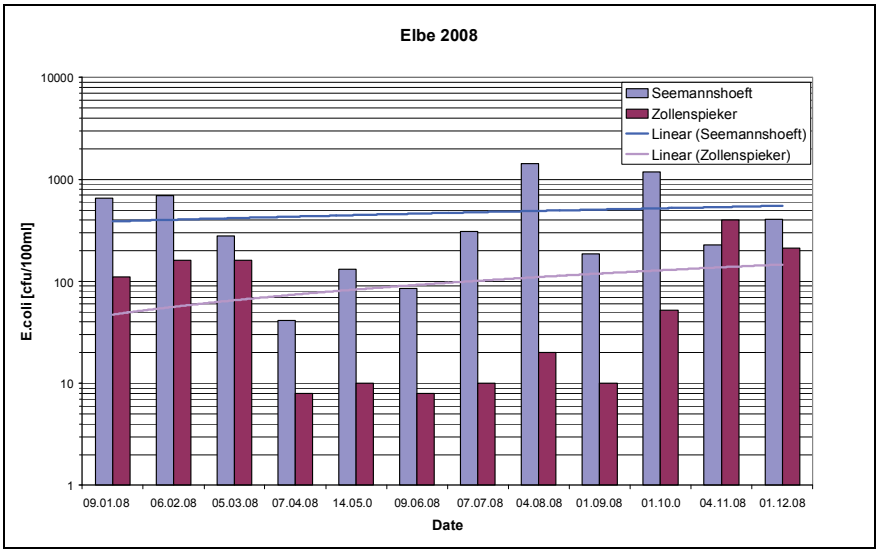

Figure 4.7 Results from monthly investigations of 2008 at two different sides from January 08 until December 08 upstream (sampling point Zollenspieker) and downstream (sampling point Seemannshoeft) of Hamburg. (HU, 2009)

The samples were taken at the local low tide at each site like it is described in chapter 1. It could be seen that the values from April to October show significant differences in the concentration of bacteria whereas in the beginning of the year as well as in November and December the differences were small. In November the value at Zollenspieker is higher than at Seemannshoeft. This could be an indicator for a strong storm tide and in general, assuming heavier rain events during spring and winter than during the summer. Another reason could be the outlet of the WWTP Dradenau near the sampling point Seemannshoeft causing the high concentrations compared to those of Zollenspieker.

At the 6th of July 2009 the Hygiene and Environmental Institute performed a lengthwise sampling of the tidal influenced part of the Elbe (see figure 2.2, all sampling points are marked yellow). The results are shown in figure 4.8. They show an overall relatively low concentration with no value above 100 cfu/100ml. The significant increase in the middle of the lengthwise profile (downstream of Hamburg around Gluecksatd/Brunsbuettel) is not finally to be defined.

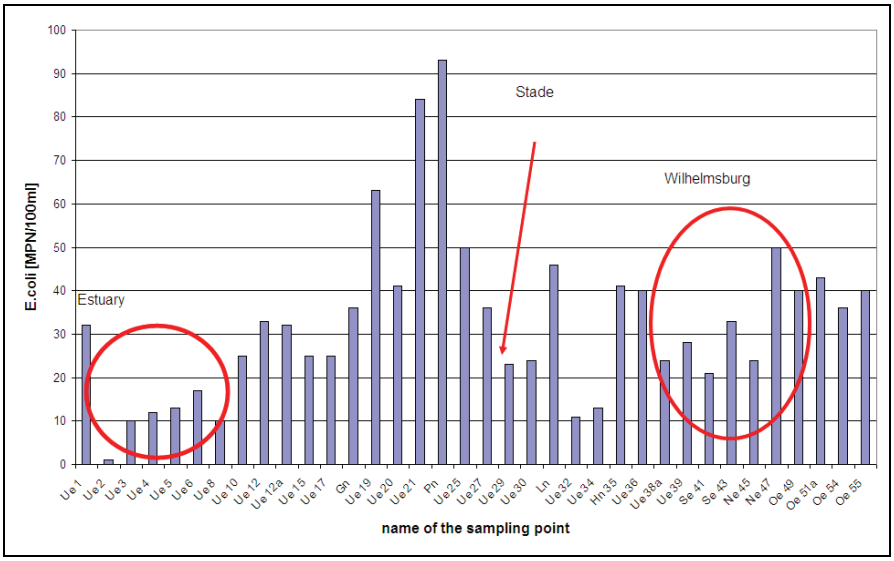

Figure 4.8 Results from the lengthwise sampling at the 6th of July 2009 with the abbreviations of the sampling points (shown in figure 2.2 as yellow marks) (HU, 2009)

The values in figure 4.9 are considered for the evaluation of the EU Bathing areas. This will happen after several years of sampling for the first time in 2011. Until then the old values and limits are to be

considered (at the moment for E.-coli 2000 cfu/100 ml). The guide value is for the E.-coli as well as for the Enterococci at 100 cfu/100 ml. For Enterococci there is no limit in the actual and legal directive.

For coastal waters and transitional waters					
	A	B	C	D	E
	Parameter	Excellent quality	Good quality	Sufficient	Reference methods of analysis
1	Intestinal enterococci (cfu/100 ml)	100 (*)	200 (*)	185 (**)	ISO 7899-1 or ISO 7899-2
2	Escherichia coli (cfu/100 ml)	250 (*)	500 (*)	500 (**)	ISO 9308-3 or ISO 9308-1
(*) Based upon a 95-percentile evaluation. See Annex II. (**) Based upon a 90-percentile evaluation. See Annex II.					

Figure 4.9 Limits of the EU Bathing Water Directive 2006/7/EC (EU, 2006)

Compared to the above seen limits the concentrations of the Elbe itself are mostly in an excellent or at least good quality. Only in winter in figure 4.7 the values are higher than these limit values. And at sampling point Seemnannshoeft (see also figure 4.6) downstream of Hamburg and the harbour the concentrations are too and during an evaluation they would not be considerable inside the range.

The results of the sampling campaign at the bathing area Finkenriek, located at the southern branch of the river Elbe, show partly higher concentrations compared to the lengthwise results. Especially the first value in May is high compared to the others and to the limit values (see figure 4.10).

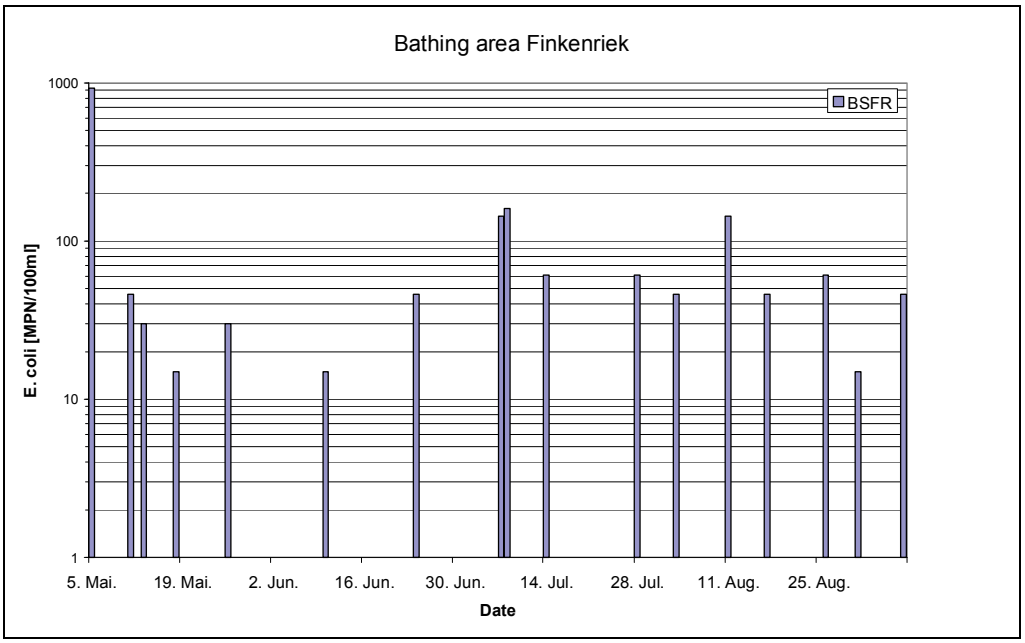

Figure 4.10 Results from the bathing area Finkenriek in 2009

All the other values are in an excellent range. Compared to the concentrations of figure 4.8 the concentrations are in the same range and can be related to each other.

CONCLUSION / OUTLOOK

In general the concentrations of pathogenic bacteria in the river Elbe are in relatively low ranges although there are some exceptions. The situation might get worse in association with extreme weather events (Holzapfel et al. 2008). A wet weather measurement campaign is planed for 2010 in order to identify the influences of storm events. After this campaign the influence of climate change on the hygienic water quality shall be forecasted. Pednekar et al. (2005) stated that most of the sources for bacterial pollution come from storm water runoffs from the surrounding watersheds. Nevertheless the water body of the river Elbe is able to buffer highly concentrated pollutants (to be seen by the example of the WWTP Dradenau, chapter 4.2, page 6).

Thus, the impact of high concentrations from inside of Wilhelmsburg island on the river Elbe seems not to be a serious problem, especially considering the much higher bacterial concentration and load at the outlet of the WWTP Dradenau. Further on, the results from the sampling points upstream and downstream of Hamburg (fig 4.7) showed that the impact of Hamburg city and its harbour is significant and has to be reduced considering that the situation might become more extreme in the future, as there are various parameters (like temperature) influencing the appearance and concentration of bacteria (Crowther et al., 2001).

Bertrand-Krajewski et al. (1998) stated that many polluting substances are of higher concentrations in runoffs after long periods without rainfall. This phenomenon is known as the first flush effect and could become an important factor regarding the shift of precipitation from summer into winter (Storch et al., 2009) in addition with more heavy rain events due to climate change, although bacterial concentrations are have a higher variety than chemical substances (Ackermann et al., 2003).

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