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Water quality problems in Baltic coastal waters: The Odra river as a source of human pathogenic viruses

G. Schernewski[1)], T. Huttula[2)], W.-D. Jülich[3)], V. Podsechin[4)] & I. Tejakusuma[1)]

1) Baltic Sea Research Institute Warnemünde (Institut für Ostseeforschung Warnemünde)
Seestrasse 15, 18119 Rostock-Warnemünde, Germany, gerald.schernewski@io-warnemuende.de
2) University of Helsinki, Finland
3) Institute of Pharmacy, University of Greifswald, Germany
4) Pirkanmaa Regional Environment Center, Tampere, Finland

ABSTRACT

The hygienic bathing water quality, based on E.coli bacteria measurements, in the Szczecin Lagoon, the Oder estuary and along the Baltic Sea coast nowadays can be regarded as good or very good. Beside E.coli bacteria, human pathogenic viruses can be expected in all surface waters that are affected by municipal sewage. There is an increasing awareness that predisposed persons can be infected by a few infective units or even one active virus. Another new aspect is, that at least Polio-viruses attached to suspended particles can be active over weeks and therefore be transported over long distances. The highest risk of virus inputs for the Odra estuary arise from large amounts of untreated sewage of the city of Szczecin (Poland). The sewage water is released into the river Odra and transported to the lagoon and the Baltic Sea. On the basis of 2D-flow model simulations and laboratory results the potential hazard of virus infections along beaches and shores of the Odra lagoon and adjacent parts of the Baltic Sea is re-evaluated. As a concrete example the weather, flow and transport situation during August 14, 2001 is presented. Despite several uncertainties arising from the scenario, the simulations and especially the laboratory experiments, the results suggest that viruses attached to suspended matter can affect large areas of the lagoon. We have to conclude that human pathogenic viruses are potentially an underestimated risk in coastal waters and should be measured regularly within the hygienic bathing water quality monitoring programme.

INTRODUCTION

Summer tourism is the most important economical factor around the Odra (Oder) estuary and further growth is expected. For a sustainable development of bathing tourism, a high water quality is imperative. At the same time, the river Odra drains about 17 km^3 water per year as well as large amounts of nutrients and pollutants into the lagoon and further into the Baltic Sea. The result is eutrophication with intensive algae blooms. From a hygienic point of view and despite local problems, the bathing water quality in the Szczecin Lagoon and along the Baltic Sea coast nowadays can be regarded as good or very good. This does not mean that hygienic water quality problems does not exist any more. Especially infective viruses, which are usually not measured in the bathing water quality programme, are a largely unknown potential hazard for water sports, swimming and bathing in the lagoon and along the outer Baltic coast.

Human pathogenic viruses can be expected in all waters that are affected by municipal sewage water, but usually these virus concentrations in natural surface waters are low due to dilution and fast decay. Already a few viruses can cause the infection of predisposed persons. Therefore, even lowest virus concentrations can be a problem. Infections and subsequent swimming prohibitions can damage the reputation, public acceptance and economic development of resorts seriously.

The city of Szczecin with a population of about 420,000 inhabitants is located at the river Odra, 21 km upstream of the Szczecin Lagoon. At the present state about 47.4 million m³ waste water accrue per year. 67 % of all waste water is directly and without treatment, discharged into the river Oder (Wallbaum & Rudolph 2000, Boczar & Szaniawski, 1993). The city therefore has to be regarded as a major source for hygienic water quality problems of the coastal waters.

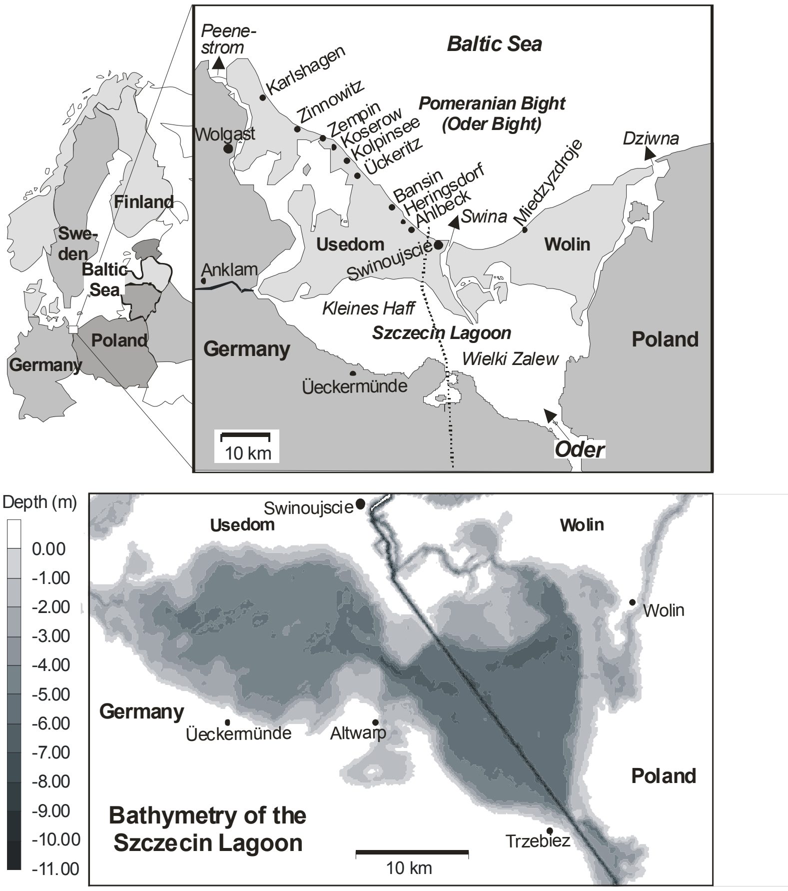

Fig. 1: Location of the Odra estuary, consiting of the Szczecin Lagoon and the Pomeranian Bight. The discharge by the Oder as well as the outlets Peenestrom, Swina Strait and Dziwna are indicated by arrows. Below: Bathymetric map of the shallow Szczecin Lagoon at the German/Polish border.

METHODS

To analyse the hazard of virus infections along the shores and beaches of the Oder Lagoon we linked laboratory measurements to a 2-dimensional flow and transport simulation model and carried out scenario simulations. Here we present the example of August 14, 2001. Other, more detailed examples are presented in Schernewski & Jülich (2001). The Oder Lagoon is shallow (average depth of 3.8 m) and only some central areas show a temporary vertical stratification. It allowed the application of the two-dimensional, finite element, flow model FEMFLOW2D. The Model is described in detail in Podsetchine & Schernewski (1999). The virus transport was calculated with a particle tracking module. The passive particles movement was simulated on the basis of the pre-calculated flow field. The decay of viruses was simulated by repetitive applications with logarithmic reduced particle numbers and increased simulation times. Transport simulations need reliable flow fields, which are in agreement with flow measurements. For August 14, 2001 detailed flow measurements from 3 independent sources were available and allowed the model validation. Several cross sections measurements with an Acoustic Doppler Current Profiler (ADCP), installed on a small boat, were carried out in the Kleines Haff. On several stations the boat anchored and measured detailed vertical current profiles. In Fig. 2 the depth-averaged current values for these 4 stations are given. Close to the shore, vertical current profiles with an inductive current-meter ISM 2000 were taken and the 2 stations with the largest distance to the shore are presented, too (Fig. 2). Close to the German/Polish border a fixed station by GKSS, Geestacht measures current time series. This data is not shown but in good agreement with our simulated flow field.

In the scenario simulation, that based on this flow field, we assumed a virus concentration of 10^7/m³ sewage water. This means that the sewage water released into the Oder near Szczecin contained an enteric virus number (of varying virus composition) of 10^{11} to 10^{12} (infective units). This is equal to about 100 infected persons (0.02 % of the population of Szczecin), which usually excrete about 10^4 to 10^{10} viruses per g excrement. The assumption holds for an average situation. In an epidemic a much higher virus release can be expected (Schernewski & Jülich 2001).

Altogether about 130 virus types are known to cause water-borne infections (Dumke & Feuerpfeil, 1997). For inactivation measurements in the laboratory, Polio-1 viruses were chosen, which are known to be very stable in natural waters. Polio-1 viruses entirely linked to suspended matter have a 90%-degradation time of 14 days (Schernewski & Jülich 2001) and become inactivated after 57 days. Due to sedimentation, the suspended matter concentration from the Oder mouth into the Baltic Sea is reduced by 90 %. The sedimentation loss in the lagoon was negligible compared to the decay rate and was not taken into consideration. The same is true for inactivation during river transport, which was not considered. Starting condition in the Odra mouth was a virus concentration of 10^4 viruses/m^3. It was assumed that 10 viruses are linked to one particle.

RESULTS and DISCUSSION

The depth averaged simulated flow velocities are very well in agreement with ADCP as well as with conductive flow measurement. The same is true for the current direction. Due to the limited spatial resolution of the triangular flow calculation grid, slight deviations occur. In the simulation a slightly inhomogeneous wind field, with some shelter due to shoreline vegetation was applied. The simulated flow field can be regarded as reliable. The prevailing south-westerly wind conditions during August 14, 2001 are typical, but the average wind speed was comparatively high for a sunny summer situation. The water temperatures were around 20°C and matched the laboratory conditions applied during the virus tests in river water very well.

Due to a short degradation time free viruses effect only the Odra river mouth. The situation for the viruses completely linked to suspended matter is presented in Fig. 2. Starting condition is a virus concentration of 10^4. This again is represented by 1000 particles with 10 viruses each. Fig. 3 shows the spatial distribution and the decrease in number after 14 and 28 days. After 14 days 100 particles are left. After 28 days the number of remaining particles has decreased to 10. EU regulations for bathing water (76/160/EWG) are met, when 95 % of all samples show no viruses in 10 litre water. As a rough estimation it can be assumed, that areas where no trajectories are shown are in compliance with the EU-guideline. Despite that, single viruses can survive up to 56 days in the lagoon and enter the Kleines Haff as well as the Baltic Sea.

These results are in compliance with virus measurements. In 1997 a maximum of 10² infective units per m³ was observed near Police (12 km north of Szczecin). Near the Haff buoy at the German/Polish border and the entrance to the Kleines Haff (Fig.1) an average of 10 infective units per m³ was found once in 1997 and during 1998 and 1999 no viruses were observed. The applied standard method detects the number of free viruses in 10 litre sample water. The values for 1997 were averaged and converted into viruses/m^3.

One has to be aware that the results presented in Fig. 2 are a simplification and contain several uncertainties. All viruses are assumed to be attached to suspended matter and all types of viruses are expected to behave like the Polio-viruses in the laboratory experiment. The uncertainties linked to the virus experiments are a magnitude larger than the one arising from flow and transport simulations. One has to keep in mind that the simulations yield depth-averaged flow velocities single water sheets can show significant higher or even opposite current velocities. The transport was calculated on the basis of T_{90}-values at 20°C. At colder temperatures viruses survive a longer time and the scenarios would be worse at lower temperatures. High virus concentrations are a hazard only during summer, when a lot of water activities take place. Therefore the practical implication of lower water temperatures, which are characteristic for other seasons, is negligible. It is still unknown to what extent viruses can and will be attached to clay in natural surface water, to what extent they survive sedimentation and resuspension processes and remain infective. Linked to clay, viruses generally can be transported far into the Kleines Haff and more detailed studies are necessary to evaluate their behaviour and hazard.

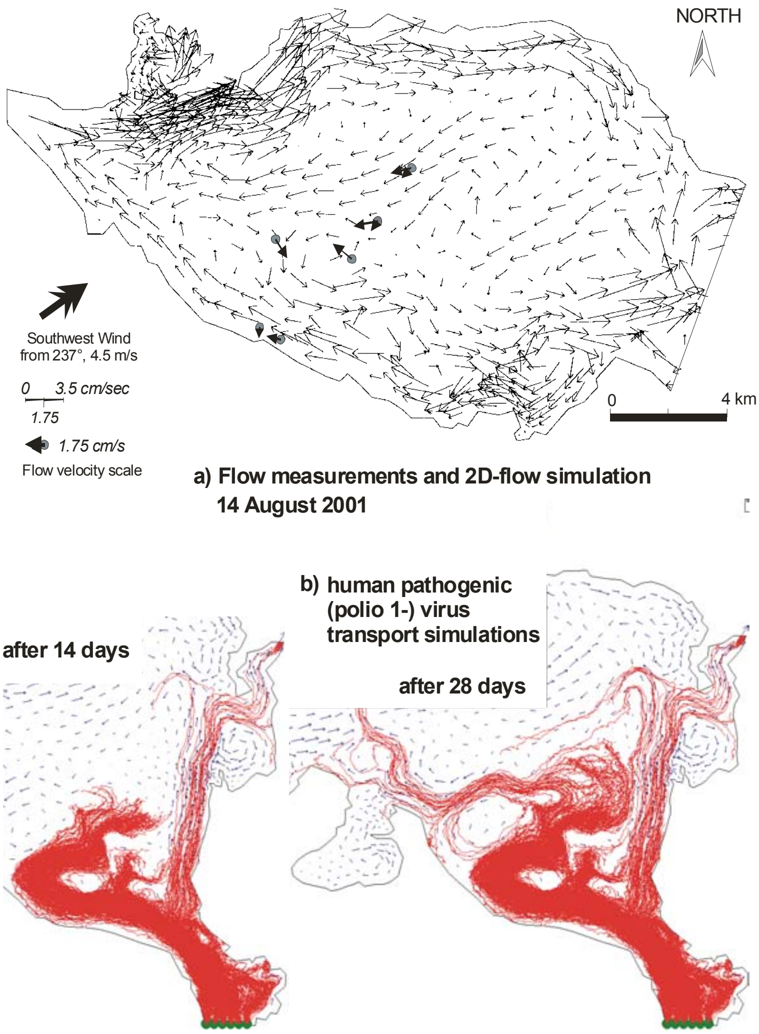

Fig. 2: a) The simulated depth-averaged flow field as well as measured depth-averaged currents in the Szczecin Lagoon (Kleines Haff) on August 21, 2001. b) Virus transport simulations. Source for the human pathogenic viruses is poorly treated sewage of the city of Szczecin (Poland) that is released into the river Odra 21 km upstream. Trajectories of particles indicating transport and decay of active (Polio-1) viruses attached to natural suspended particle matter in the Odra Lagoon under the conditions of August 14, 2001. The starting concentration was 10^4 viruses/m^3 water at the river mouth, attached to.10^3 particles. After 14 days a concentration of 10^3 viruses/m^3 remained and after 28 days the number decreased to 10 particles (100 active virus/m^3). As a coarse approximation, one can say that all areas outside the range of the shown trajectories have no realistic infection risk at least during this concrete situation.

Our results clearly show that all beaches north of Szczecin along the river Odra as well as in the river mouth have a potentially high virus infection risk. Examples are shown in Fig. 3. The fast virus decay suggests, that smaller pollutants like cities along the coast of the lagoon might be of higher importance than a heavy but more distant pollutant like the city of Szczecin. During the last decade new sewage treatment plants on the German side of the lagoon improved the released sewage water quality and decreased the risk of high virus release into the Kleines Haff. Recently new sewage plants with high capacity were established on the Polish side in Swinoujscie and Miedzyzdroje, too. Altogether, the adjacent towns nowadays have to be regarded as less important sources for viruses. Despite this, a local virus release never can be excluded.

Fig. 3: Public beach in Luczyna in the Jezioro Dabie near Szczecin as well as in Stepnica close to the Odra river mouth. Refering to our results, summer tourists are subject to a serious virus infection risk in both locations.

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