FerryBox – A New System for Automatic Measurement of Biological-Chemical Parameters from Ferry Boats

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Abstract - A new operational tool which uses ferryboats as carrier system for automated monitoring equipment has been developed. Such systems can be operated with much less costs than automatic buoys and have better performance with regard to biofouling. Currently the systems are tested in an EU project in which eight ferry routes are used for a comparison of different European "FeryBoxes".

The "German FerryBox" presented here consists of a fully automated flow-through system with sensors and automatic analysers for the measurement of oceanographic and chemical parameters, among which are nutrients and algal properties. It provides the possibility of automatic cleaning cycles and position-controlled sampling (GPS). Data can be transferred to shore and the system can be remotely operated via mobile phone. The system has been installed on the ferry Cuxhaven (DE) - Harwich (UK) and is in operation since November 2001. Results from first year experience demonstrate the function and applicability of the ferry system.

I. INTRODUCTION

The contamination of coastal waters with nutrients and toxic substances is of growing concern in European countries. For an assessment of the water quality of these regions operational monitoring programs have been implemented. In this context the main aims of water quality monitoring are:

- preventing the potential danger to human health
- assessing the impact of anthropogenic substances on aquatic ecosystems
- documenting the present state of water pollution
- showing the efficiency of water protection measures by means of emission values.

Looking at the present practise of monitoring of rivers, coastal areas and shelf seas it is evident that operational monitoring is mainly carried out by manual sampling during ship cruises and following analyses in the laboratory. In the "official" monitoring programs for the North Sea this is carried out three to six times per year, which is not enough to observe the spatial extensions of phenomena such as algal blooms, which have a typical random short time distribution. Information about spatial distributions therefore is strongly hampered by a fixed station strategy [1].

Whereas sampling is the only feasible method for counting biological species and the analysis of trace contaminants, such as heavy metals or organic micropollutants, there are other, complementary methods for the automatic unattended measurement of standard oceanographic parameters, such as temperature, salinity, currents, and in some cases other parameters including turbidity, oxygen, nutrients and chlorophyll fluorescence. These automated measurements are mainly carried out from different types of moored buoys or other fixed marine stations [2], [3], [4], [5].

There are many advantages of these operational systems on buoys among which are the assessment of short-term events (storms, fresh water discharge etc.) and production of consistent long-term time series with high temporal density. However, there are also some serious disadvantages in that they provide only point measurements and often data gaps occur due to biofouling of sensors and maintenance difficulties due to difficulty of accessing stations during bad weather. The operational costs are high due to maintenance by ship cruises.

Based on all these problems and limitations, it seems logical to investigate which role ships of opportunity could play [5]. There are many routes for ferryboats and "ships-of-opportunity" which run quite frequently. Already 60 years ago the "Continuous Plankton Recorder (CPR)" [7] has followed the idea of using scientific equipment on such ships for continuous recording of environmental data. This method has now been improved and shows an impressive data set of semi-quantitative phytoplankton data over the world oceans.

Within the last years some more sophisticated systems had been implemented on ferry boats which allow more precise measurements of temperature, salinity and chlorophyll [8], [9], [10], [11], [12].

Applying such measuring systems on ferry boats or ships-of-opportunity has several advantages:

- the system is protected against harsh environment, e.g., waves & currents etc.,
- biofouling can be more easily prevented (inline sensors),
- no energy restrictions (in contrast to buoys),
- easier maintenance when ferry comes back "to your doorstep"
- lower running costs since the operation costs of the ship do not need to be calculated
- instead of point measurements (buoys) transects yield much more information.

Within the GOOS (Global Ocean Observing System) and

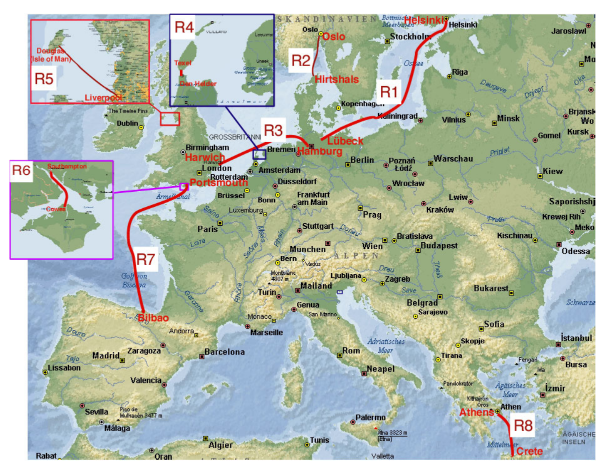

Fig. 1. EU project "FerryBox" and the involved ferry routes

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EuroGOOS Framework we have started initiatives to develop automatic measuring systems for bio-oceanographic parameters.

As a measuring platform ferries on regular routes offer a cheap and reliable possibility to obtain regular observations on near surface water parameters. Present activities are both nationally and internationally EU funded. Some of these tools and methods are currently being developed and tested in the EU project "FerryBox", in which eight ferry routes will be used for a comparison of different European "FerryBoxes" (Fig. 1). More information about the project is available under: *http:\\www.ferrybox.org*.

II. MATERIAL AND METHODS

The "German FerryBox" consists of a fully automated flow-through system with different sensors and automatic analysers. Fig. 2 shows a schematic drawing of the German FerryBox system and the measured parameters.

Water is pumped into the ship from an inlet in front of the ships cooling system. A debubbling unit removes air bubbles, which may enter the system during heavy seas. At the same time coarse sand particles which may be introduced in shallow harbours and which settle and tend to block the tubes are removed as well. Coupled to the debubbler is an internal water loop in which the seawater is circulated with a constant velocity of about 1 m/s. The velocity decreases the tendency for build-up bacterial slime on sensors and tube surfaces. A small part of the water is filtered by a ribbon-type filter for automatic nutrient analysis (this type of filter regularly provides new filter material avoiding bacterial processes which may influence the concentration of nutrients). For a reliable unmanned operation the system is supervised by an industrial programmable logic control which can shut-off the system in case of errors and operates automatic cleaning cycles, e.g., in harbour. Data acquisition, data storage and data transfer to shore is controlled by an industrial standard PC (Pentium II). Data can be transferred to shore and the system can be remotely operated by GSM (mobile phone).

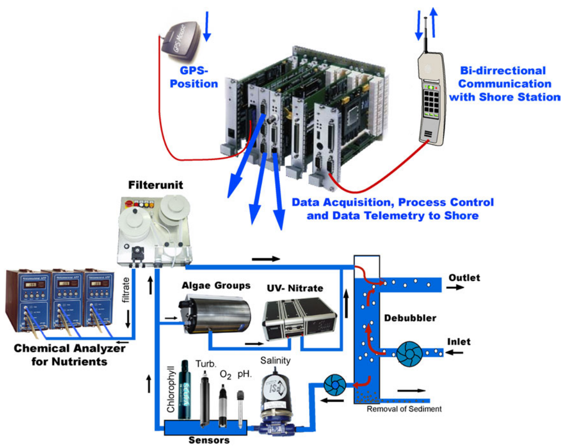

Fig. 2. Schematic drawing of the German FerryBox system

Biofouling is prevented by cleaning of the sensors with fresh water and rinsing with acidified water or under severe conditions (tropics) by chlorination. Sometimes clogging of the water inlet in the ship interface by debris or fish causes problems. Since all flow rates are monitored and controlled by the system in such cases an automatic pressure back-flushing cycle is initiated which clears the inlet.

Of the used sensors especially the analysers for nutrients and the sensor for algal groups should be mentioned:

Nutrient analysis is carried out by chemical analysers which automatically perform the same colorimetric reactions as are applied in standard marine chemistry in the laboratory.

In addition a new optical method for nitrate determination is under test: By measuring the spectrum of sea water from 200 nm to 400 nm and applying a multi-component analysis to the known spectra of nitrate, bromide and humic substances nitrate can be measured quantitatively in the range from about 1 µmol/l to 100 µmol/l (automatic change of cuvette length).

Algal groups are measured by sequential excitation with five LED's (blue, green, yellow, orange & red) and measurement of the emitted fluorescence signal [13]. By careful calibration phytoplankton with distinctive different pigment patterns can be distinguished, e.g. green algae, blue-green algae and diatoms. The instrument is now being tested during the cruises. In regular intervals samples are taken and plankton is counted and chlorophyll measured by HPLC for comparison. The first installation of the system has been taken place on the ferry between Hamburg (Cuxhaven) and Harwich and is under test since November 2001. The ferry route covers the southern part of the North Sea and crosses the waters flowing from the English Channel to the North.

III. RESULTS AND DISCUSSION

Since November 2001 measurements were obtained regularly. Fig. 3 shows the DFDS ferry route and the results from one transect in May 2002:

In the temperature curve the higher temperatures at the coastal waters (Cuxhaven and English coast) can be seen. The salinity curve near Cuxhaven shows the fresh water outflow of the river Elbe, whereas the decrease near Harwich is only marginal. It is also evident that lower salinities are observed along the Dutch coast compared to the English Channel due to fresh water influence of the Ijsselmeer and the river Rhine. Near Harwich a high turbidity is measured which is characteristic of the coastal areas at the English coast. The total chlorophyll concentration shows two maxima, one near Cuxhaven and one between the English Channel and the Dutch coast. The maximum near Cuxhaven is typical for the first spring bloom in front of the Elbe estuary. The main reason for this could be the high nutrient concentrations in combination with the relatively moderate turbidity (light availability). In this peak diatoms are dominant; however green algae are also present. The second chlorophyll peak at the Dutch coast is a mass occurrence of algae in this area in spring. Here, green algae and diatoms are both prevailing.

The pH varies between 7.9 and 8.4 pH units. Near the Elbe estuary (Cuxhaven) the values are lower due to the fresh water input. However, other low values can be found near Harwich where the freshwater influence is negligible. Since the oxygen concentrations here are low, turbidity is high and ammonium is high as well, one may guess that oxygen consumption processes of re-suspended sediments contribute to these lower pH values. As expected, pH and oxygen also show maxima at the chlorophyll peaks, thereby reflecting the higher primary productivity of these areas.

Within the ferry profile the nitrate concentrations are varying between 0.1 and 90 µmol/l (1.5-1400 µg-N/l) and the ammonium concentrations vary between 0.1 and 1.3 µmol/l (1.5 - 18 µg-N/l). The largest nitrate concentrations are measured near Cuxhaven due to high nitrate input from the river Elbe. Near the English coast the largest ammonium concentrations are found whereas nitrate is slightly enhanced.

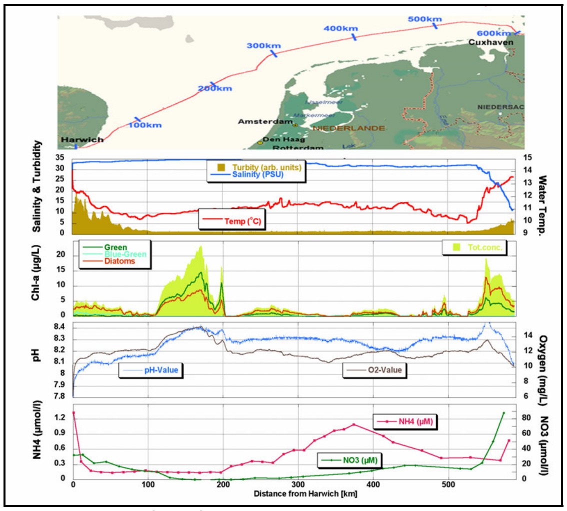

Fig. 3: Route of the ferry and data measured on a transect from Harwich to Cuxhaven at 13th of May 2002

One result which demonstrates the potential of FerryBox systems to detect phenomena which have previously been missed is the broad maximum of ammonium between km 300 and km 430, which can be found during most ferry cruises in spring and summer. The origin of this is currently unclear.

In Fig. 4 a contour plot of the chlorophyll concentrations from Harwich to Cuxhaven is shown for the time interval between January and November 2002. On the vertical axis the time is depicted; the horizontal axis shows the distance from Harwich.

As can be seen, until the end of February no algal growth exists. This starts between km 180 and km 220 in early March. Later in April plankton growth occurs along the whole Dutch and German coast. In early May this bloom breaks down, leaving only the patches at km 150 and km 560 - as already shown in Fig. 3. Later in June and July higher algae concentrations are only found at the Dutch and German coast and from August to October more or less no more blooms are detectable.

From the chlorophyll data it is evident that due to the patchiness taking samples from research ships would only be successful if the cruise had been carried out at the "right" times and at the "right" locations. On the other hand, stationary (fixed) buoys would only by chance detect these

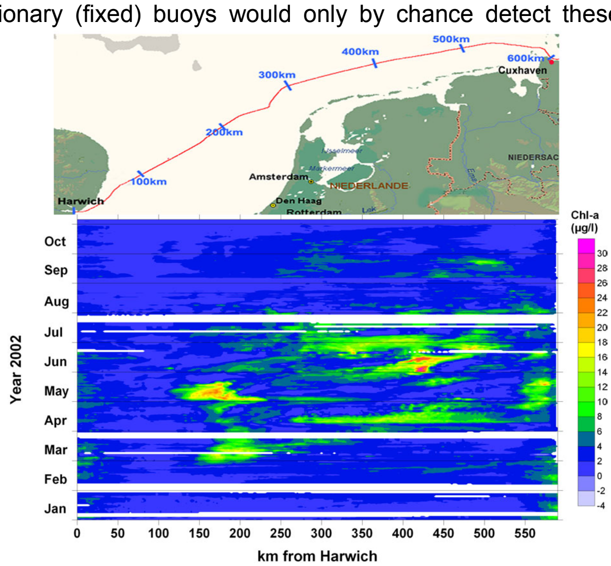

Fig. 4: Chlorophyll concentrations between January to November 2002 on the transect Cuxhaven - Harwich

algal blooms if they had been anchored within the area of the bloom. Contrary to this, transects with ferries have a greater chance for the assessment of algal blooms. If these measurements are combined with satellite measurements-as we plan to do in the very near future with ENVISAT- the "fate" of algal patches even can be followed. In the case of Fig. 4 this means that one can decide if the algal bloom broke down or was drifting out of the region. Simultaneously the ferry data can be used for calibration of satellite data (in situ truth).

Since in the North Sea the satellite coverage is poor due to clouds, a numerical model could be used for further improvement of the assessment of algal blooms.

IV. CONCLUSIONS

It could be shown that ferry boats or ships-of-opportunity equipped with automated systems for water quality measurements are a suitable tool which can supplement existing "conventional" monitoring in coastal areas and shelf seas.

However, integrated monitoring strategies which are carried out by combining sampling from ships, automatic fixed stations, automated ferry systems, remote sensing and numerical models do not only require good concepts and strategies in order to achieve the maximum of information with the minimum of resources, but also requires suitable tools to merge the different types of data (different spatial and temporal scales).

After completion of the different EU projects strategies should be developed which demonstrate how future integrated marine monitoring systems can be operated and show the benefits of enhanced coverage and information density.

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