Asian Journal of Water, Environment and Pollution, Vol. 10, No. 1 (2013), pp. 25–39.

Development and Application of the MERMAID Water Quality Monitoring Station in the Brantas River, Java, Indonesia

Friedhelm Schroeder*, Michael Boer[1] and Didik Agus Wijanarko[2]

Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research, Max-Planck-Straße 1, 21502 Geesthacht, Germany

[1]4H Jena Engineering GmbH, Mühlenstraße 126, 07745 Jena, Germany

[2]Badan Lingkungan Hidup Prov Jatim, Indonesia

✉ friedhelm.schroeder@hzg.de

Received November 5, 2012, revised and accepted November 16, 2012

Abstract: The design, development and operation of an automated water quality station at the banks of the Brantas River, Java, Indonesia is described. The objective of the work was to prove that such a station can be operated in tropical areas with trained local personnel. By designing and building a modular system within a transportable container, a generalised system that can be applied to other tropical or subtropical regions was developed. The main problem in tropical waters—biofouling of sensors—was solved by automated cleaning procedures that include pressure cleaning with acidified water and chlorination. Low maintenance requirements could be achieved by a completely automated operation and remote maintenance via phone and internet. The different components of the system—water inlet, hydraulic circuit, data management—are described in detail. The performance and the costs of the automated water quality station are discussed.

Key words: Indonesia, Brantas, river, estuary, water quality, oxygen, automated monitoring, biofouling.

Introduction

Traditional pollution monitoring in rivers is carried out by sampling and consecutive lab analyses. As a result, occurring ‘events’, e.g., illegal emissions and changes of water quality due to heavy rainfall that washes nutrients from newly fertilised fields into rivers and estuaries, can be missed completely. Such traditional monitoring methods are costly and often lack the temporal resolution required to distinguish between natural variability and anthropogenic influence. Whereas in Europe and the United States automated monitoring stations along large rivers are common, this is not the case in newly industrialising countries often due to a lack of money and often due to the complexity in maintaining such stations. From this predicament arises the problem that this technology is used mainly in countries where the industrial and domestic discharge is well regulated resulting in comparatively ‘clean’ rivers. In contrast, the water quality problems in many threshold countries are still severe. In addition, there is a general lack of knowledge about the biogeochemical cycles in tropical regions. The lack of monitoring systems that enable continuous observation of rivers is a major hindrance when it comes to understand these tropical environments.

One of these tropical rivers with a high pollution load and water quality problems is the Brantas River in East Java. The Brantas River basin in East Java, Indonesia, is the most urbanised region in Indonesia. About 16 million people are living in the Brantas catchment area and

*Corresponding Author

depend on its resources. It contains most of East Java's fresh water reservoir capacity and produces about ten per cent of the nation's rice crop. It functions as the most important source of fresh water supply in the East Java Province (Sudaryanti et al., 2001; Seno Adi, 2012; Jennerjahn et al., 2004). Currently, almost all the water of the Brantas River in the dry season is utilized and some measures for enhancing water supply are indispensable to meet the increasing water demand. Over the last two decades, the average annual water consumption per capita has doubled from 400 to 800 m^3, predominantly because of the agricultural sector, which uses about three quarters of the available water (Binnie, 1999). Meanwhile, the quality of river water has been deteriorating due to the growth of urbanization and industrialization. The total domestic load of organics is estimated to be about 330 t BOD_5 d^{-1} (Biological oxygen demand in five days = measure for the amount of degradable organic carbon content) . Nearly 500 industries directly discharge their effluents, contributing a BOD load of approximately 150 t d^{-1} (Aldrian et al., 2008).

In 2001 an Indonesian-German joint project was started that had three objectives:

1. To prove that an automated water quality station can be operated in a sustainable way in a highly polluted tropical river;
2. To operate this station in order to get more information about the water quality status of the river under varying conditions (wet/dry season etc.); and
3. To make an assessment about the water quality status with recommendations for a water quality improvement.

Here we describe the development, installation and test of a water quality station. The time series are discussed in detail in Schroeder and Knauth (This volume).

Materials and Methods

The "MERMAID" and "FerryBox" Technology

The need for automated systems to monitor chemical and biochemical variables led to the definition of the EUREKA-EUROMAR project MERMAID (acronym for: Marine, environmental remote-controlled monitoring and integrated detection) (Knauth et al., 1996a, 1996b, 1997; Schroeder, 2010) in 1990. The concept of MERMAID is a modular monitoring system, which can be mounted on a buoy, platform, pile or ferry and has numerous sensors and instruments which measure meteorological, hydrographical and biogeochemical parameters and which automatically takes samples at pre-defined conditions. It is also capable of responding to different weather and tidal conditions, any of which could influence pollution levels. State-of-the-art data management and communication software process and feed the highly accurate information back to a land-based station via radio, cellular phone or satellite link, enabling scientists to remotely observe conditions as they happen and take measures to reduce concentrations of pollutants.

As further development from the MERMAID system, a new operational tool that uses ferryboats as the carrier system for automated monitoring equipment has been developed since 2000. Such systems can be operated with lower costs than automatic buoys and have better performance with regard to biofouling. Contrary to automated buoys where in situ sensors that are sensible to biofouling have to be used due to energy constraints, FerryBoxes have a flow-through system with inline sensors that can be better protected against biofouling. The German FerryBox consists of a fully automated flow-through system with sensors and automatic analysers for the measurement of physical, biological and chemical parameters (temperature, salinity, turbidity, pH, oxygen, chlorophyll-*a*, nutrients). It provides automatic cleaning cycles and position-controlled sampling (GPS) (Petersen et al., 2007; Petersen et al., 2008).

This technology has been slightly modified for application at the banks of the Brantas River. The main challenge for this modification was to develop an effective anti-fouling system for application in tropical waters. The development has been carried out together by the GKSS Research Centre (now Helmholtz Zentrum für Material- und Küstenforschung, Geesthacht) and the industrial partner 4H Jena Engineering GmbH, Germany.

Biofouling of Sensor Systems

Biofouling is often considered as a limiting factor for ocean and river monitoring. Many potential solutions to avoid or minimise this problem have been proposed, but none of them seems to be universally applicable (Lehaitre and Compére, 2001; Manov et al., 2003; Whelan and Regan, 2006). When sensors are immersed in seawater, they are rapidly affected by unavoidable bio-fouling. The growth is a complex phenomenon since in marine environments, over 400 organisms are responsible for fouling problems. Fouling organisms may be divided according to their size into micro-organisms (or so called biofilm, slime, micro-fouling) and macro-fouling.

Among many other authors Lehaitre et al. (2001) describe the succession of fouling organisms in five main stages:

- The first event is the adsorption of organic and inorganic macromolecules immediately after immersion forming the primary film;
- The transport of microbial cells to the surface, and immobilization of bacteria on the surface;
- In the third stage, the bacterial attachment to the substratum is consolidated through extra-cellular polymer production, forming a microbial film on the surface;
- The fourth stage corresponds to the development of a more complex community with the presence of multi-cellular species, microalgae, debris, sediments, etc. on the surface; and
- The last stage is the attachment of larger marine invertebrates such as barnacles, mussels and macro-algae.

There are several publications that deal with this topic (Flemming, 2001; Delauney et al., 2002; Delauney et al., 2009; Delauney et al., 2010). Presently mainly three biofouling protection systems for oceanographic/riverine sensors have shown some reliability and are applied (Delauney and Cowie, 2002):

- Purely mechanical devices such as wipers or scrapers;
- Biocide generation systems based on the copper corrosion mechanism or tributyltin (TBT) biocide leaching; and
- Biocide generation systems based on a localized seawater electro-chlorination system or an automatic acid dispensing device.

With in situ sensors these techniques often are limited. For example, it is often difficult to apply biocides since they are swiftly swept away by local currents. Here comes the main advantage of flow-through systems such as the FerryBox or the MERMAID-Brantas system: Due to the secluded environment of the water system biocide techniques are very effective, because the flow can be stopped periodically. However, for an effective antifouling it is not only necessary to kill bacteria at an early stage before a biofilm can build up, but as well to remove dead bacteria and early stages of biofilm. This task can be accomplished by high flow-through velocities and by automated flushing procedures. One of the most effective biocides is free chlorine. For ocean applications this can be directly generated by electrolysis of seawater (Delauney et al., 2009). However, in the Brantas River the conductivity resp. the concentration of Cl- ions are not high enough. Instead, an automated hypochloride acid dispensing system has to be used.

Measurement Methods

Location of Station

The Brantas River basin is located in the east of Java island with the major river Brantas of 320 km length (Figure 1). The Brantas River has its source in mountainous regions. In the downstream region the Brantas River branches into two rivers discharging into Madura Strait called Surabaya River to the north-eastward and Porong River to the eastward as flood canal of this region. In the vicinity of the city of Surabaya the Surabaya River divides into the Mas River (Kali Mas) that flows northward and the Wonokromo River that flows eastward (Adi, this volume). The objective of this work is an assessment of the water quality of the Brantas River and its estuary. Since the water quality deteriorates extremely in the lower reaches it was decided to build a station at the junction of Kali Mas and Wonokromo River (Figure 1). The location has the advantage that it was possible to build the station on the safeguarded premises of Dinas Pengairan, one of the Indonesian partner organisations. This is helpful with respect to the problem of theft and vandalism that often prevails in these areas. The following infrastructure could be made available: Water supply from the river for measurements, electricity, fresh water for automated cleaning and telephone lines for data transfer. Since one of the aims of the project was the demonstration of the functioning of a quality-controlled automated station another benefit of this location was the existence of a water quality station some 100 metres downstream, built by the Austrian company "Verbundplan GmbH" (Gunatilaka, 1999; Marini and Weilguni, 2003; Siregar, 2004) that could be used for comparison (see below).

Design of the Station

Container

The MERMAID-Brantas water quality station should serve as a prototype that can be easily applied in different regions. Therefore,

1. it should be easy to install anywhere in the world (infrastructure provided),
2. the flexible configuration, e.g., the equipment with specific sensors, should be tested thoroughly in Germany prior to deployment, and

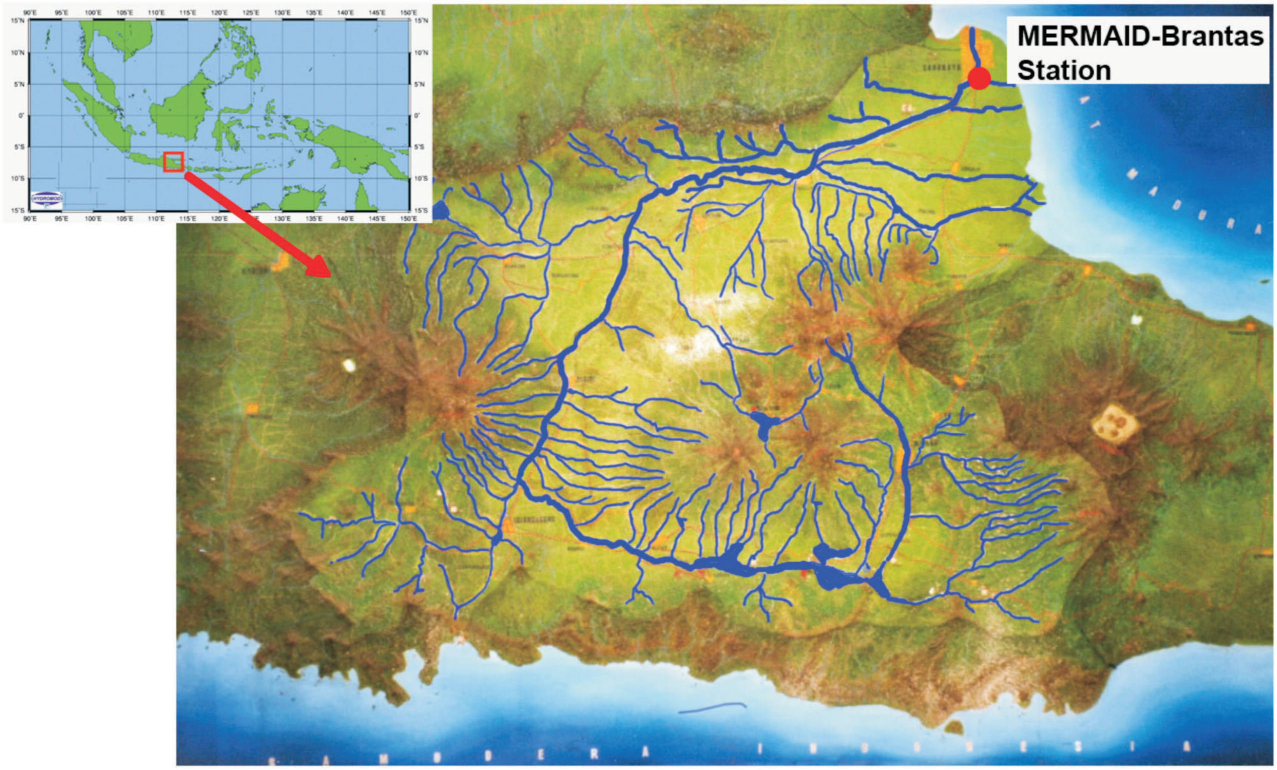


Figure 1: Catchment area of the Brantas River in Java, Indonesia. The location of the MERMAID-Brantas station is marked as a red dot.

3. the installation on location should be as easy and fast as possible.

To fulfil these prerequisites the whole system had been completely assembled in Germany inside a 10’ container and was shipped to Indonesia at the end of 2002. After only two days of installation the system was operating. In Figures 2 and 3 a photo of the measuring container on-site is shown. Due to the extreme meteorological conditions in the tropics, i.e., high sun intensity and heavy rainfall, the container is mounted on a metal-frame that itself stands on a concrete base off the ground. A simple ‘car port roof’ provides additional shelter against heavy rainfall and shades against the sun. A fence together with an alarm system (motion sensors, halogen spotlights) provides additional security.

One of the most important infrastructural prerequisites is the continuous provision of water from the river. This was carried out by means of a centrifugal underwater pump mounted on a movable frame in the river. Since it was clear from the Verbundplan station that the pump would sometimes be affected by the debris in the river a relatively cheap and robust pump was chosen that could easily be displaced. The triangular device contained a lifting body with a buoyancy ball. It was fixed at the concrete bank of the river by two hinges so that it could move up and down and follow the changing water level (Figure 4). The water level changes about ±50 cm due to manual control of two weirs upstream and downstream from this location. The system had to follow these water level changes and be robust enough to withstand the collision with drifting objects and especially the pressure of floating water hyacinth fields that move with the river current. In front of the pump is a 2 mm size mesh that prevents the intake of large particles from the river. For inspection and repair the frame can be easily yanked out of the water.

The water is pumped into the container. In Figure 5 photos from the inside of the container are shown. Besides the flow-through measuring unit described in detail below and the chemical analysers it houses a computer system with uninterruptible power supply, an air conditioning unit and several infrastructure elements.

Flow-through Measuring Unit

The MERMAID-Brantas system consists of a fully automated flow-through system with various sensors and automatic analysers. The principle is depicted in Figure 6. Water is pumped from the river into an internal water loop in which the water is circulated with a constant velocity of about 1 m s^{-1}. This lowers the tendency for building bacterial slimes on sensors and tube surfaces. A

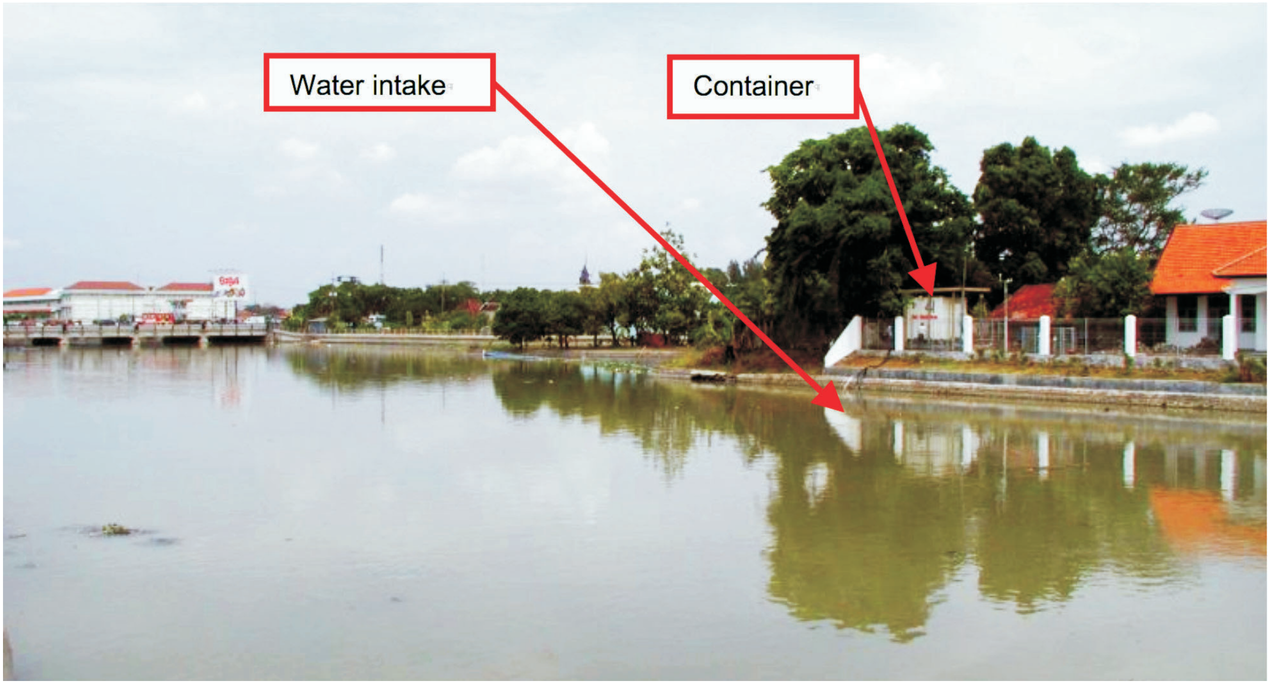


Figure 2: Photo of the MERMAID-Brantas installation site at the Wonokromo. The water intake is about two metres apart from the bank of the river.

Figure 3: Photo of the MERMAID-Brantas container.

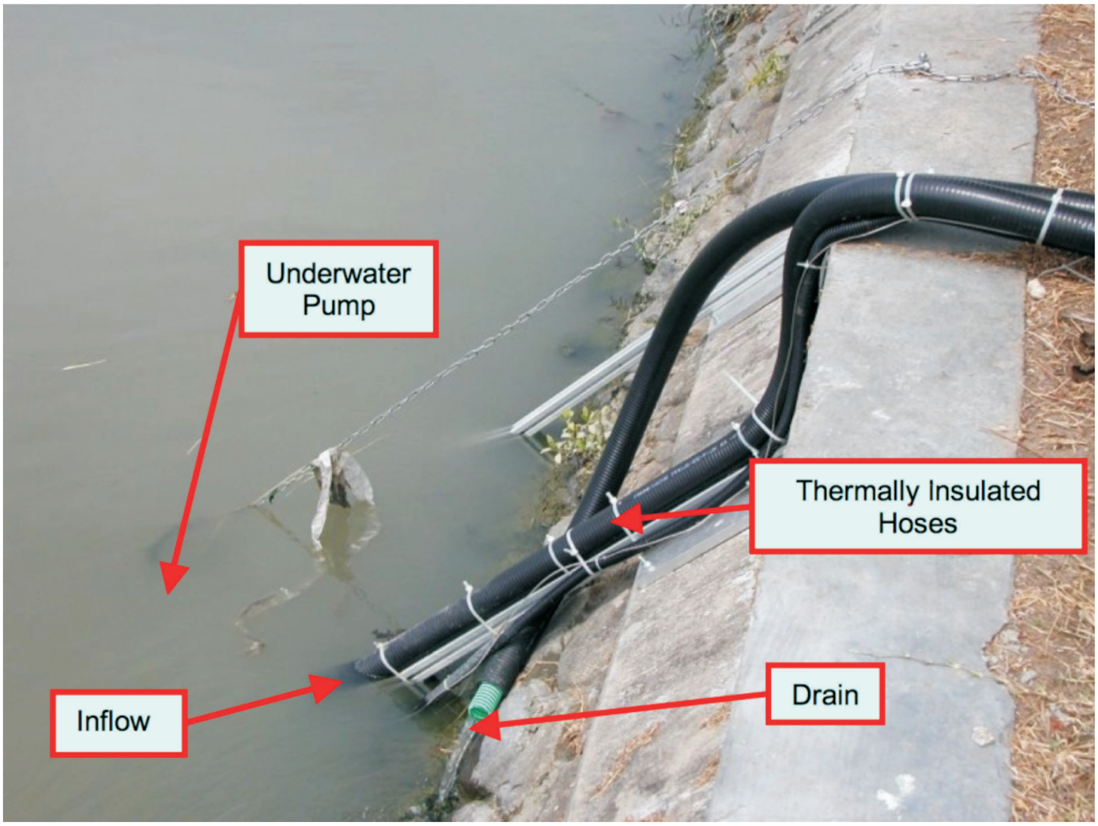
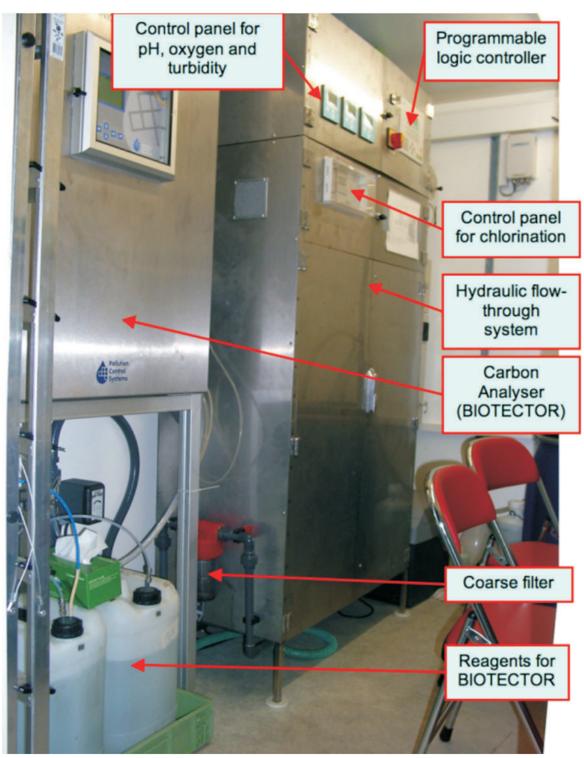
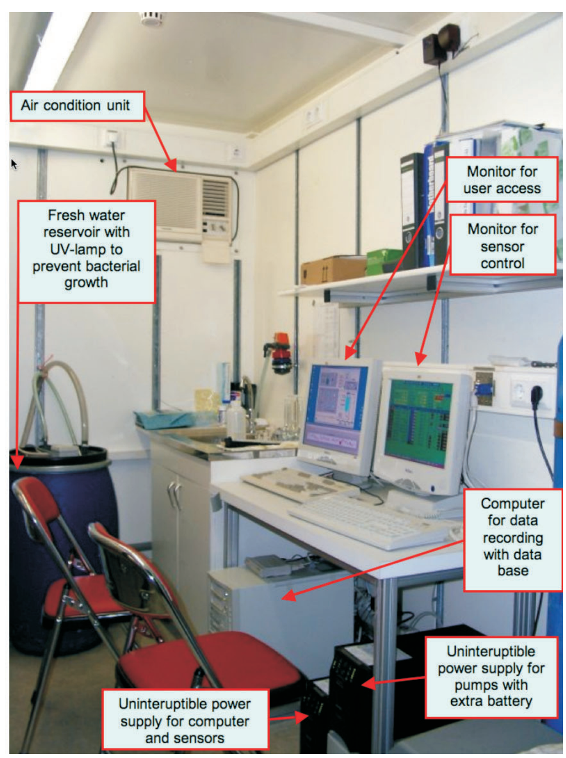


Figure 4: Photo of the sample input system.



(a)



(b)

Figure 5: Photo from inside of the container. (a) Measurement system; (b) System and infrastructure.

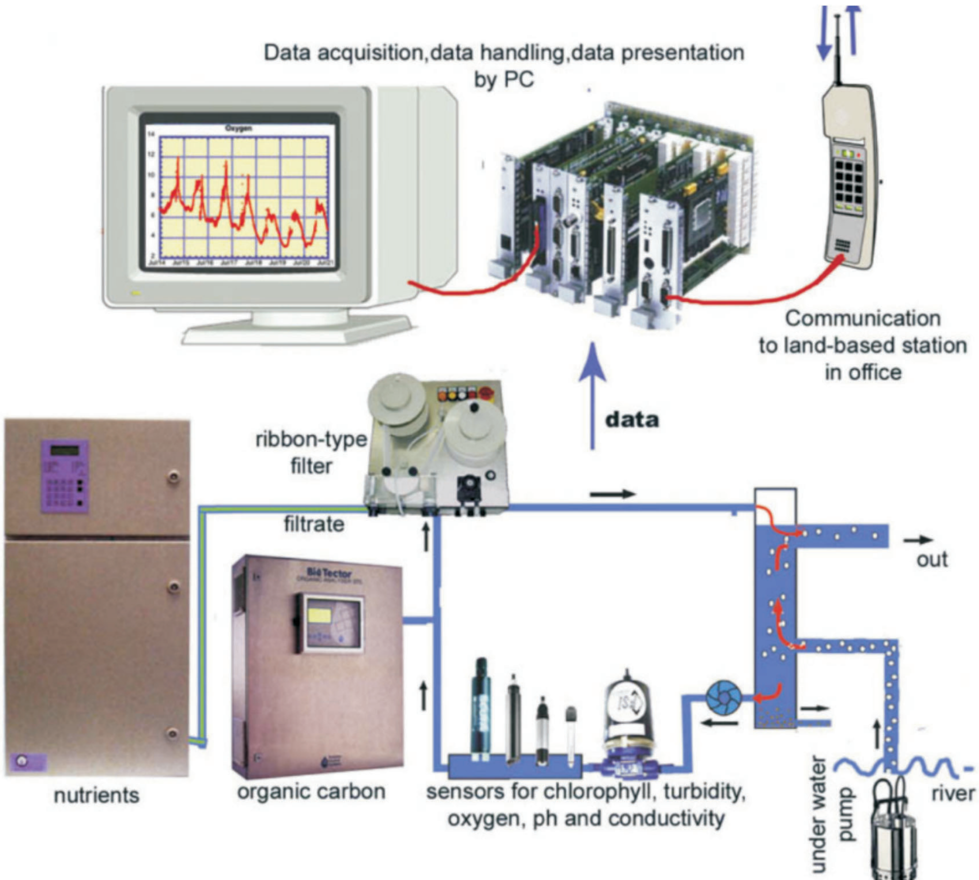


Figure 6: Scheme of the MERMAID-Brantas system.

small part of the water is filtered by a ribbon-type filter for automated nutrient analysis. The system contains motor valves and control sensors, e.g., for pressure and flow, for automatic operation. For a reliable unmanned operation the system is supervised by an industrial programmable logic controller (PLC, Siemens SIMATIC Controller S7) which can shut off the system in case of very severe errors and controls automated cleaning cycles. This controller was chosen due to its industrial-type reliable operation in comparison with more unreliable standard PCs. Acquisition, storage and transfer of data to shore is controlled by an industrial standard PC (Pentium II). Data can be transferred to a land-based station in the office and the system can be remotely operated by telephone or mobile phone.

A more detailed description of the system is presented in Figure 7. The system consists of a main circuit with a debubbler chamber that is filled via valves V1 and V2 and serves for the removal of air bubbles. The pump P2 circulates the water within this loop. In order to maintain a constant pressure of about 200 mbar in the loop the pump is regulated via an electronic frequency converter from a pressure sensor. This has the advantage to keep flow to the secondary circuit module and to the chemical analyser modules constant under all conditions, even when the flow in one of the by-passes changes. All flows are measured by inductive flow meters FXL5000-Mini from ABB (Fl1: total inflow; Fl2: flow of filtration unit; Fl3: flow TOC analyser, Fl4: main flow, Fl5: secondary circuit flow). All these 'house keeping data' are recorded for debugging purposes and can be reached per internet for remote maintenance. Figure 8 shows a photo of the hydraulic loop before it was installed inside the stainless steel cabinet shown in Figure 5a.

Automated Cleaning and Chlorination

The most important traits of the modified FerryBox unit are the automated cleaning and antifouling systems. The cleaning system consists of three stages:

1. The coarse mesh of 2 mm in front of the pump prevents the intake of large debris.
2. An easily cleanable sieve with a mesh size of about 0.5 mm in the intake pipe captures smaller particles and grease. The sieve and the mesh can automatically be back-flushed with freshwater for cleaning and can be easily removed for manual cleaning.

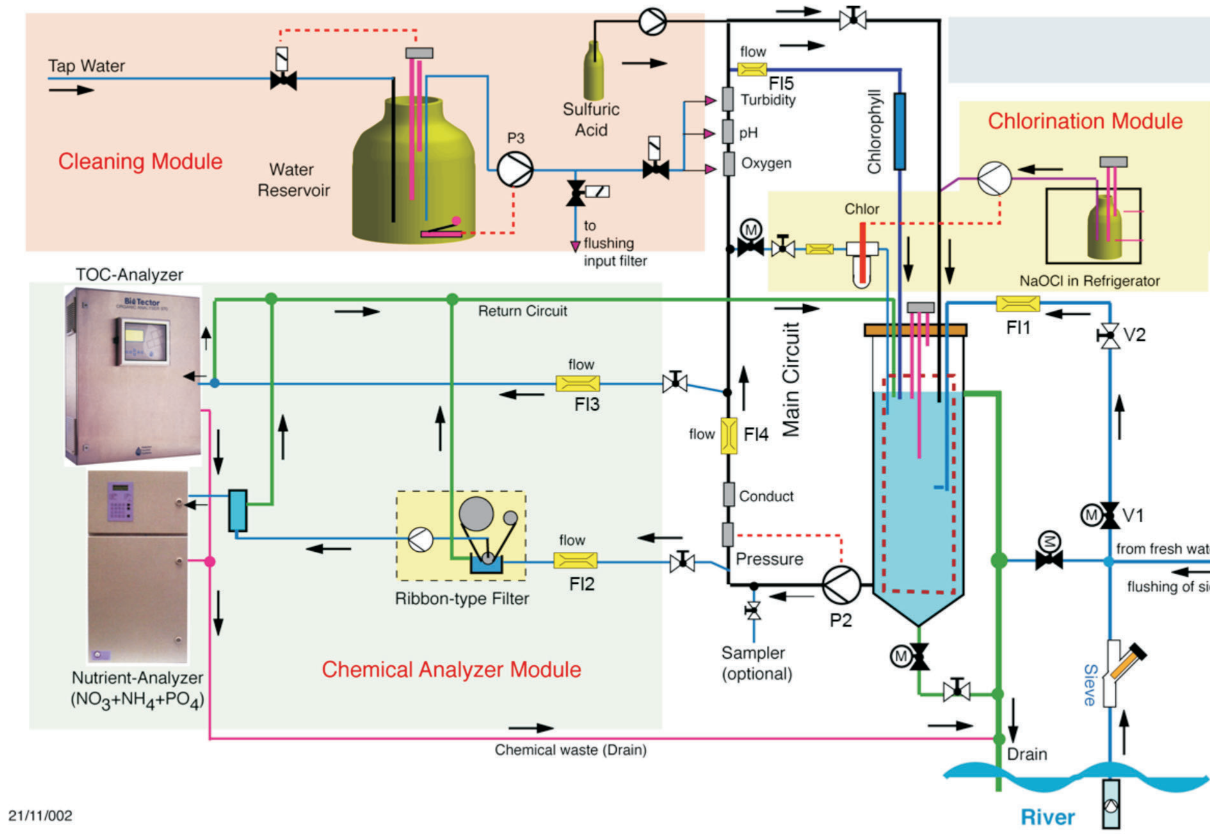


Figure 7: Detailed drawing of the hydraulic loop.

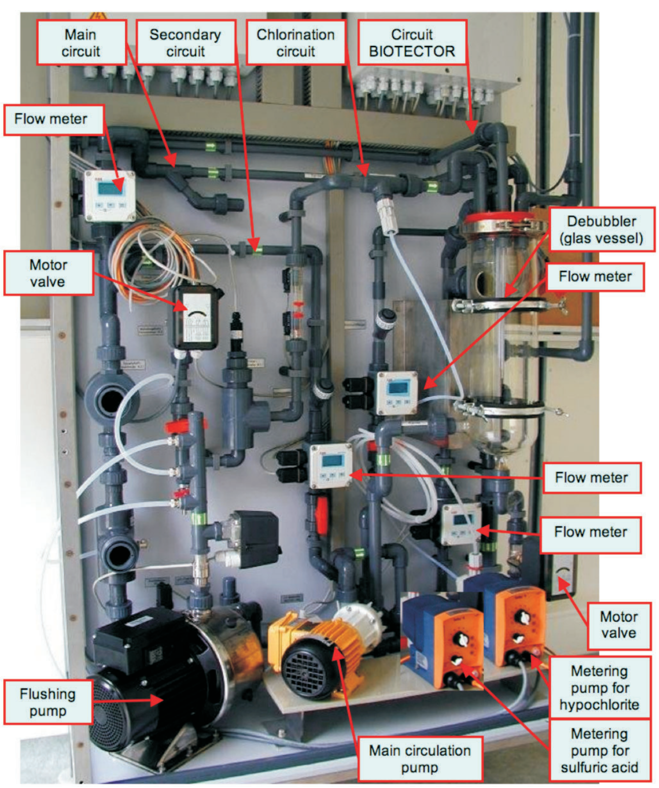


Figure 8: Photo of the hydraulic loop (removed from its stainless steel cabinet).

3. For automatic cleaning of the hydraulic circuit and sensors the water is drained from the system after stopping the pumps and the sensors are cleaned by a combination of tap water and sulphuric acid with a pH of 2 that is directly injected on the sensors by pump P3 (Figure 7). Due to the low pressure of the public drinking water supply in Indonesia an additional pump had to be used. After two minutes of pressure cleaning the system is filled with acidified water and circulated in all circuits for another five minutes. All these procedures are carried out and controlled by the industrial programmable logic control unit.

Since under the tropical conditions the biofouling pressure is very high, additional chlorination was used that kills all bacteria in the system. This is achieved by injecting 0.5-1 ml of sodium hypochlorite solution (12% free chlorine) into the system. The resulting concentration of free chlorine is controlled by a chlorine-sensitive electrode with electronic controller (system MECLE-5 by MECOTEC, Elmshorn, Germany) that actuates the pump in order to keep the free chlorine concentration between 5 and 10 ppm. After cleaning and chlorination the system is drained again and flushed with tap water. The whole cleaning/chlorination cycle is initiated once a day at midnight local time. During the cleaning the recording of data is suspended.

Process Control

Another important feature of the MERMAID-Brantas system is the safe automated operation. This is achieved by the industrial programmable logic controller (PLC) that monitors the main hydraulic processes with different sensors, e.g., flow meters in each hydraulic circuit, a pressure sensor and level indicators in the debubbler vessel and in the water reservoir. The PLC supervises the conditions and initiates motor valves in case of errors. For example, when the main pump in the river fails, it is shut off, the input valve is closed, the river water in the system is drained and replaced by clean tap water. By this procedure a contamination of the sensors is prevented. The PLC detects leaks and blockages by monitoring all flows and reacts by switching the correct valves. All important elements (pumps, valves, sensors) are coupled to a second uninterruptible power supply that maintains the power long enough to bridge a power failure of the public system that occurs sometimes during thunderstorms in rainy season for about 15 minutes. After this time a defined shut-down of the system with tap-water flushing occurs. By providing controlled flow conditions that are continuously monitored the data quality is high and errors due to changing hydraulic conditions can be prevented.

Sensors and Chemical Analysers

The following sensors are installed in the MERMAID-Brantas station:

Conductivity:	4-conductor cell MECON-4R, MECOTEC, Elmshorn, Germany
Oxygen:	Membrane-covered electrode COS4 with electronic unit liquisys M COM 223, Endress & Hauser, Germany
Turbidity:	180° scattering at 800 nm, liquisys M CUM 223, Endress & Hauser, Germany;
pH:	Glass electrode orbsint CPS11 with electronic unit liquisys M CPM 223, Endress & Hauser, Germany
Chlorophyll:	Fluorescence WETStar(Chl) from WETLabs, USA

The automated analysis of total organic carbon (TOC) and total inorganic carbon (TIC) are carried out by a BioTector analyser (BioTector Analytical Systems Ltd, Ireland). A range from 0-5 mg C l^{-1} is used. For nutrient analysis the water is filtered by a ribbon-type filter (Bandfilter Type 12, Metrohm). The analyses are carried out by an industrial-type online-analyser for the parameters ammonium nitrate+nitrite and o-phosphate (Micromac C, Systea, Italy).

MERMAID Data System

The MERMAID data system consists of a sensor controller (marine station controller, MSC), a land station and several slave stations. The details are described in (Knauth et al., 1996a, b).

The following hardware was used:

Sensor controller: Single board computer with Intel 80386 processor under DOS operating system.

Land stations (master and slave): Standard computer with Pentium II processor under operating system Windows NT.

The tasks of the sensor controller are:

1. Recording of data (1 sec interval)
2. Averaging of data (flexible, standard: 1 min interval);
3. Automated control of sensors via the PLC
4. Initiating cleaning and chlorination cycles via the PLC
5. Logging all events from the housekeeping sensors
6. Transfer of data to land station in container via RS232

The various sensors and analysers ('devices') are hierarchically organised. An excerpt of the tree diagram is shown in Figure 9.

The tasks of the land station are:

1. User interface to MSC for control of the system
2. Data storage in an Oracle data base
3. Data retrieval from data base
4. Flexible data presentation for user access
5. Data export for further data evaluation with specialised software
6. Transfer of data to all remote slave stations via modem

Since the Indonesian partner institutions needed online access to the data, four slave stations in Surabaya, Malang and Jakarta were installed (Figure 10). The tasks of the slave stations are:

1. Holding an actual copy of the data base
2. Data retrieval from data base
3. Flexible data presentation for user access.
4. Data export for further data evaluation with specialised software

Infrastructure

Due to the tropical conditions, often temperatures of 36°C with upto 98% humidity are prevailing in Surabaya that would reduce the lifetime of standard electronic components and computer parts. Therefore, an air

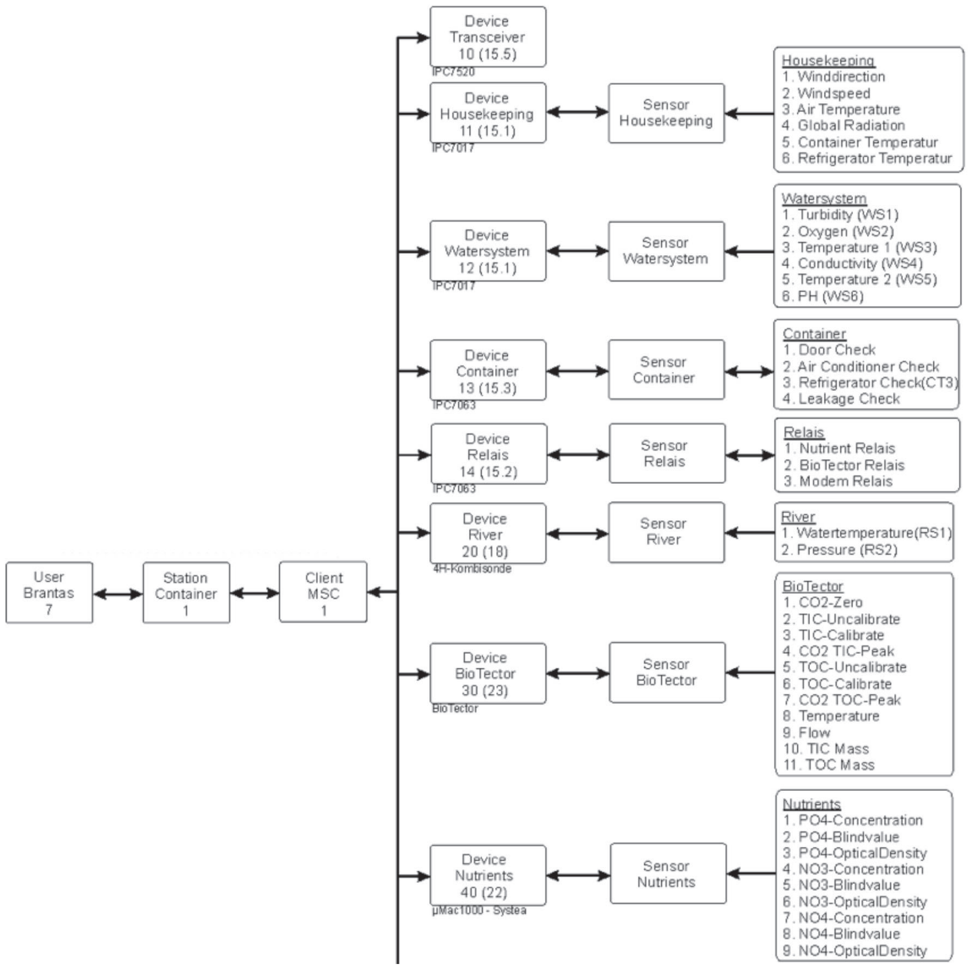


Figure 9: Excerpt from the hierarchical configuration tree of the programme.

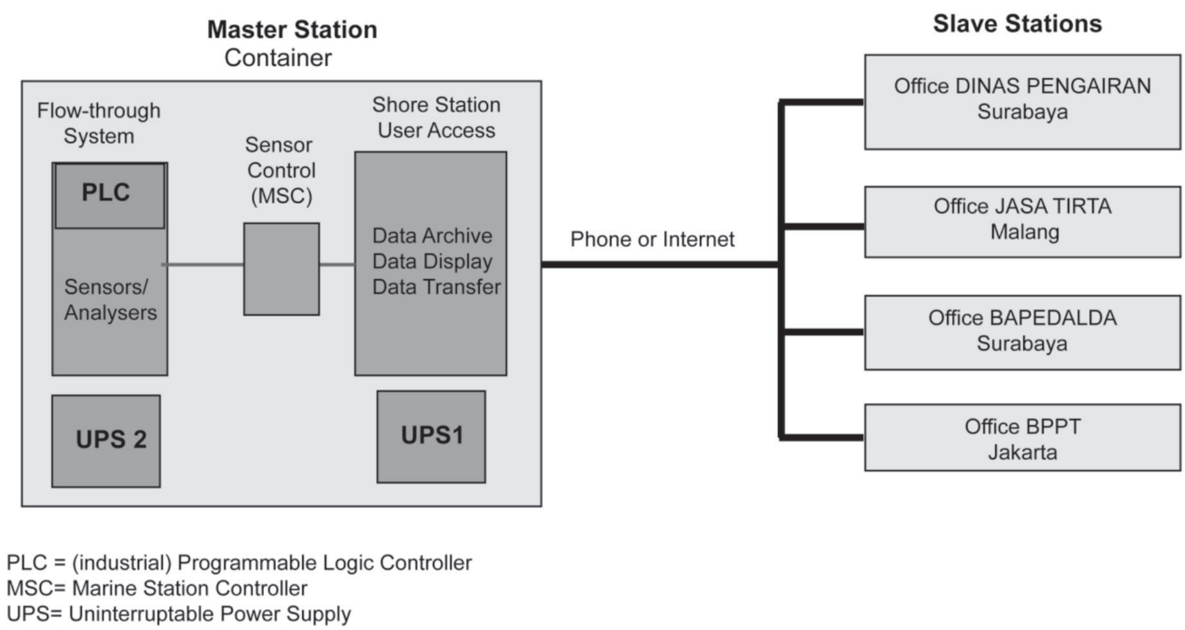


Figure 10: Scheme of the MERMAID-Brantas data system.

conditioning system kept the inside of the container below 25°C. Theft and vandalism, a severe problem in the city, could be prevented by three measures: First, the container is located on the premises of Dinas Pengairan that are locked at night and manned by security service personnel. Second, the container site is fenced off and third, a burglar alarm system with motion sensors and flood light immediately alarms the guards. During the nine years of operation no attempt of theft or vandalism occurred.

Severe tropical thunderstorms often occur in tropical areas during the rainy season. During the first year only surge protection devices in the main sensor and model lines were used as lightning protection measures which is the standard lightning protection in Europe. However, during the first rainy season several electronic components had to be replaced due to over voltage damage. Only by redesigning the whole electrical grounding this problem could be solved by installing deep buried earth leads at all four corners of the container, 16 mm^2 connecting cables and by using additional surge protectors in front of sensitive electrical components. Especially during the rainy season power blackouts often occur in Surabaya. The power interruption lasts between a few minutes and one to two hours when land lines are destroyed during a thunderstorm. To prevent uncontrolled shut-down of modules two uninterruptible power supplies (UPS) are used in the measuring station in the container. One UPS protects the land station for one hour and provides a controlled shut-down afterwards. The second UPS has a larger battery. It buffers the flow-through system and the river pump for about 20 min. After this period the flow-through unit is automatically filled with tap water before the system is shut down. All slave stations have a standard UPS to bridge a power failure of 30 min.

Results and Discussion

Station Performance

The automated station has been operated by local personnel for nine years without any severe problems. During this time the following main replacements had to be carried out:

- The main river pumps had to be replaced four times (costs ≈ 200 € per pump).
- Due to normal deterioration, the pH sensor had to be replaced six times.
- Due to water leakage some components of the Systea nutrient analyser had to be replaced on site.
- After six years of continuous operation the disc of the main computer and a telephone modem had to be replaced.
- In the initial phase several electronic components had to be replaced due to electrical surge after a heavy thunderstorm. After improvements of the lightning protection this did not occur again.

Regular weekly to bi-weekly maintenance comprised:

1. Check of the input system in the river, where sometimes debris had to be removed.
2. The hydraulic system was cleaned, wear parts such as the membrane for the oxygen electrode were checked and replaced if necessary and chemicals for chlorination, for nutrient analyses and for the carbon analyser were changed. Every month the oxygen bottle for the carbon analyser was replaced.

In total, the hydraulic system was not very much affected by soiling from the river water. In one case, large amounts of palm oil residue that were illegally discharged upstream into the river heavily contaminated the coarse mesh in front of the hydraulic loop and slightly contaminated the walls of the loop. Figure 11a shows a photo of the contaminated mesh that was totally covered by palm oil. In Figure 11b a photo of the contaminated debubbler is shown. The only effect that can be seen is the brownish colour of the glass wall. However, due to the high flow velocities the palm oil never poisoned the sensors. In contrast to the Verbundplan station 100 m downstream that was heavily affected, the MERMAID-Brantas system could be cleaned within two hours.

In general, due to the fast flow and the automated cleaning the data of the MERMAID station are much more reliable than those of the Verbundplan station. In Figure 12 data comparison between the two stations in May 2003 is shown. While the water temperature is directly comparable with a constant offset of about 0.5 °C, the difference between the oxygen concentrations varied. Especially at the end of May the oxygen concentrations at the Verbundplan station decreased, presumably due to biofouling problems. The correct values of the MERMAID station were checked with independent measurements. The effectiveness of the cleaning mechanism in the MERMAID station is shown in Figure 13. As can be seen, after the cleaning cycles that are depicted in gray (these data are normally masked in the data base) the oxygen concentrations are not affected. During daylight the concentrations reached about 2 mg l^{-1} due to primary production and decrease to near-zero values in the night. A more detailed

Figure 11: Photos of a palm oil pollution incident. (a) the internal coarse filter covered with palm oil residues; (b) the debubbler (slight brown covering).

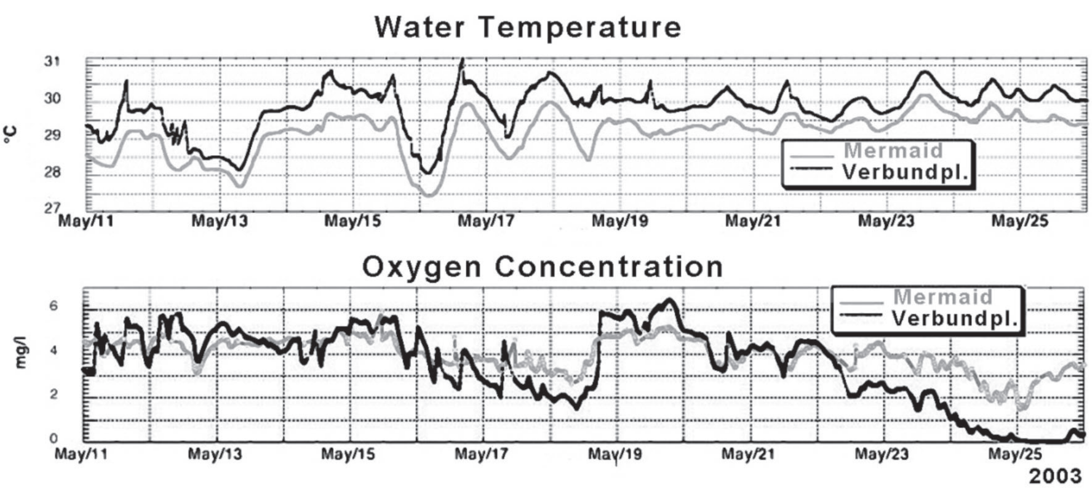


Figure 12: Comparison between data from the Verbundplan station (black) and the MERMAID-Brantas station (gray), that are 200 m apart.

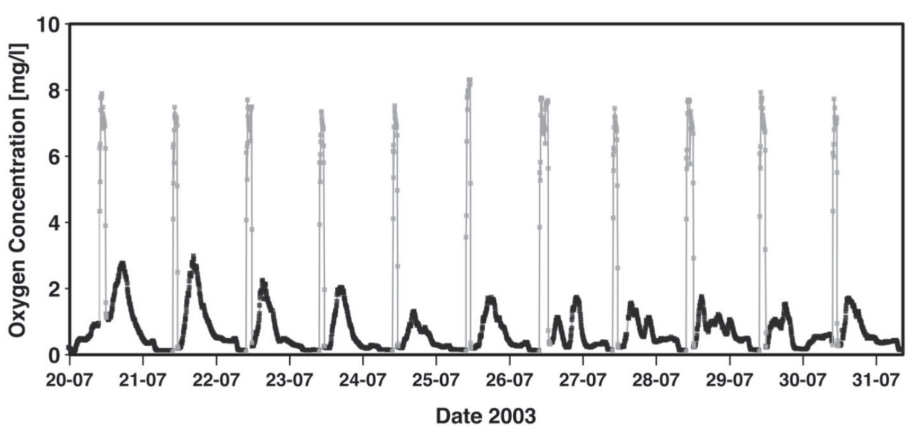


Figure 13: Data example for oxygen in July 2003. Black: Oxygen concentrations as they are stored in the data base. Gray: Oxygen concentrations during cleaning cycles that normally are masked in the data base.

description of the processes can be found in Schroeder and Knauth (this volume).

Running Costs

Averaged over 10 years the material expenses were about 500 € per month. This includes costs for water, electricity, telephone lines and chemicals. For maintenance eight technician-hours and four scientist-hours per month were enough to maintain the station and obtain good data. Only in the first two years when automated total organic carbon analyses required pressure bottles of ultra-clean oxygen the material expenses were about 800 € per month. Later the carbon analyses had been terminated.

Data Example

This publication deals with the technical details of the MERMAID-Brantas station in Surabaya. A detailed description and discussion of the obtained data is given in Schroeder and Knauth (this volume). As an example the time series of oxygen data from the years 2003 to 2008 are presented. In Figure 14 the freshwater discharge at the Wonokromo River is depicted on top and the oxygen concentrations are shown below. The discharge changed between 7 $m^3 s^{-1}$ during dry season (white areas) and upto 100 $m^3 s^{-1}$ during wet season (gray areas). The same temporal pattern can be seen in the oxygen concentrations in the lower part. During dry season the concentrations fluctuated on a daily basis between zero at night and 3-4 mg l^{-1} during the day (compare Figure 13). During wet season the minima seldom reached values below 1 mg l^{-1} (night) and were mostly above 2-3 mg l^{-1} during daytime. However, apart from this general scheme there are numerous fluctuations that may be caused by variations in cloud coverage, river currents and oxygen consumption by organic pollution. A detailed analysis of the time series can provide insight into the processes that control the water quality of the Brantas River.

Conclusions

Within a public-private partnership an automated water quality station for tropical rivers has been developed. By proper design it was possible to avoid biofouling

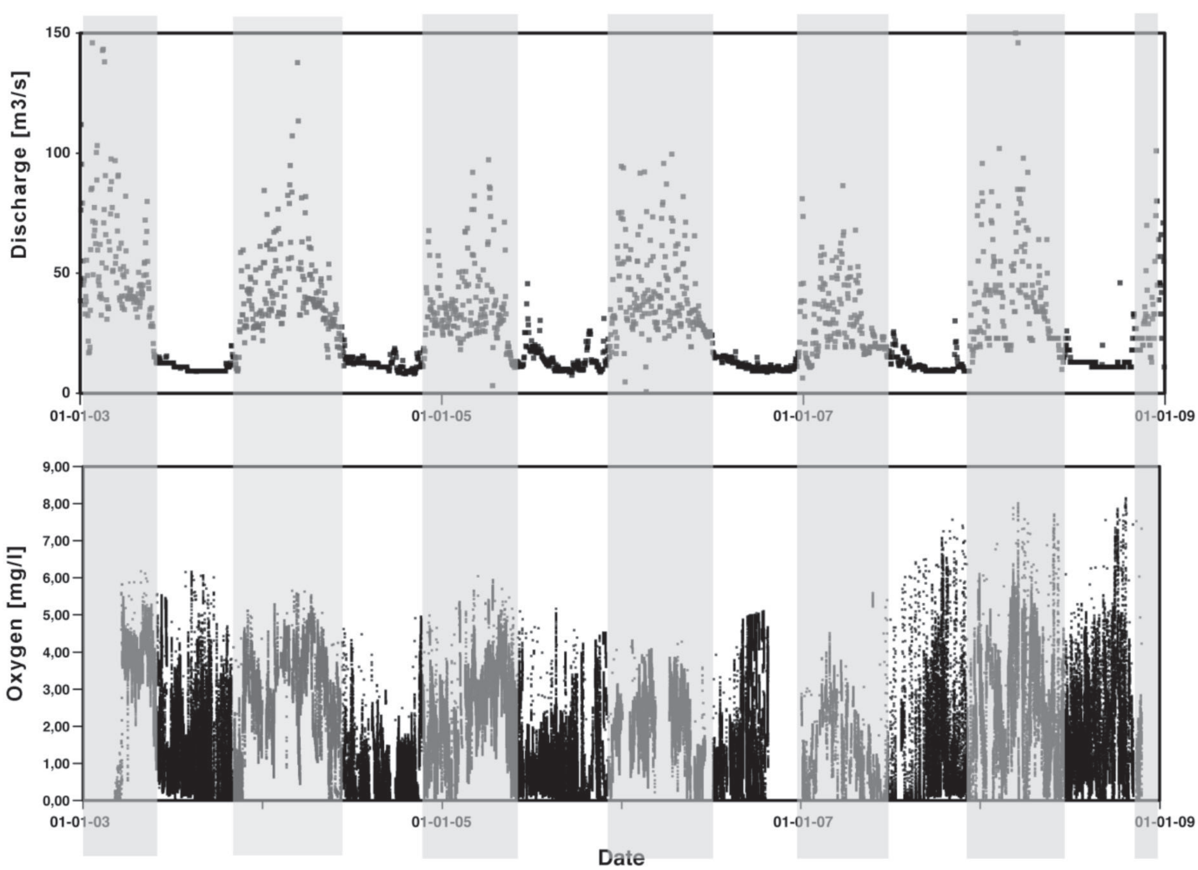


Figure 14: Time series for freshwater discharge (top, data from Jasa Tirta Corporation Malang) and oxygen (bottom) for the years 2003 to 2008. In gray the wet and intermediate seasons are indicated. Data averaged to ten minutes.

problems that under normal circumstances precludes the long-term operation of water quality devices in these regions. Within nine years of operation with local staff it could be proven that a long-term operation is possible at moderate cost. The local personnel carried out weekly cleaning, calibration and minor maintenance. Only replacement of electronic parts was carried out by German engineers. Software updates could be implemented by remote maintenance. In the last years this was much improved with the arrival of high-bandwidth internet connections in Surabaya.

As demonstrated by Schroeder and Knauth (this volume), time series with a high temporal resolution (minutes) from such a station can provide insight into many processes and allow the monitoring of water quality with a much better reliability than weekly or monthly manual samples with consecutive lab analyses. This is a prerequisite for an improved water quality management.

Acknowledgements

The project has been carried out within the framework of the Indonesian-German bi-lateral collaboration on marine science SPICE (Science for the Protection of Indonesian Coastal Marine Ecosystems). It has been financed by the German Federal Ministry for Education and Research (BMBF, Förderkennzeichen 02WU0057). We thank the ministry, the Projektträger PT-DLR and the International Bureau for financial support. In addition, we thank the Indonesian institutions BPPT, BAPEDAL, JASA TIRTA, Dinas Pengairan and Badan Lingkungan Hidup Prov Jatim for their support.

References

Adi, S. (2012). History of development and attendant environmental changes in the Brantas River basin, Java, Indonesia, since 1970. This volume.

Aldrian, E., Chen, C.-T.A., Adi, S., Prihartanto, Sudiana, N. and S.P. Nugroho (2008). Spatial and seasonal dynamics of riverine carbon fluxes of the Brantas catchment in East Java. *J. Geophys. Res*., **113:** G03029, 5-13.

Binnie & Partners (Overseas) Ltd. (1999). Surabaya River pollution control action plan study, vol. 2. Main report, Redhill, UK.

Delauney, L., Compere, C. and M. Lehaitre (2010). Biofouling protection for marine environmental sensors. *Ocean Sci*., **6:** 503-511. doi:10.5194/os-6-503-2010

Delauney, L. and P. Cowie (2002). Biofouling Resistant Infrastructure for Measuring, Observing and Monitoring. BRIMOM Report, Project number EVR1-CT-2002-40023.

Delauney, L., Compere, C., Coail, J.Y. and G. Guyader (2009). Biofouling protection for marine underwater observatories sensors by local chlorination. Geophysical Research Abstracts, Vol. 11, EGU2009-10234.

Flemming, H.-C. (2001). Biofouling in water systems – Cases, causes and countermeasures. *Appl. Microbiol. Biotechnol*., **59:** 620-640. doi:10.1007/s00253-002-1066-9.

Gunatilaka, A. (1999). What does the future hold for Brantas River (Indonesia)? – A common concern and commitment. Proc. Int. Symp. 'Hydropower into the Next Century – III', Gmunden, Austria, Oct. 1999. Int. J. Hydropower & Dams, 189-199.

Jennerjahn, T.C., Ittekkot, V., Klöpper, S., Adi, S., Sutopo, P.N., Sudiana, N., Prihartanto, Yusmal, A. and B. Gaye-Haake (2004). Biogeochemistry of a tropical river affected by human activities in its catchment: Brantas River estuary and coastal waters of Madura Strait, Java, Indonesia. *Estuar. Coast. Shelf Sci*., **60:** 503-514.

Knauth, H.-D., Schroeder, F., Menzel, R., Thurow, S., Marx, S., Gebhart, E., Kohnke, D. and F. Holzkamm (1996a). The German Operational Monitoring Network: Present State and New Technology. Oceanology 96, Brighton, Conference Proceedings. Spearhead Exhibition Ltd., New Malden, Vol 3.

Knauth, H.-D., Schroeder, F., Kohnke, D. and F. Holzkamm (1996b). Coastal Monitoring Network – Remotely controlled German system alerts operators to METOC events, provides monitoring and analysis data – New Technologies. *Sea Technology*, **37:** 33-43.

Knauth, H.-D., Schroeder, F., Menzel, R., Marx, S., Gebhart, E., Kohnke, D. and F. Holzkamm (1998). EUROMAR-MERMAID: Experimental Operation of the Prototype Network. *German Journal of Hydrography*, **49(2/3)**.

Lehaitre, M. and C. Compère (2001). Biofouling and Underwater Measurements. Chapter 11 from Final Report of "Bros – Biofouling Reduction on Optical Systems, MAST III Project", p.18.

Manov, D.V., Chang, G.C. and T.D. Dickey (2003). Methods for Reducing Biofouling of Moored Optical Sensors. *J. Atmos. Oceanic Technol*., **21:** 958-968.

Marini, G.W. and H. Weilguni (2003). Hydrological information system based on on-line monitoring – From strategy to implementation in the Brantas River basin, East Java, Indonesia. *Water Sci. Technol*., **47:** 189-196.

Petersen, W., Colijn, F., Hydes, D. and F. Schroeder (eds) (2007). FerryBox: From Online Oceanographic Observations to Environmental Information. EuroGOOS Publication No. 25, EuroGOOS Office, SMHI, 601 76 Norrköping, Sweden.

Petersen, W., Wehde, H., Krasemann, H., Colijn, F. and F. Schroeder (2008). FerryBox and MERIS: Assessment of coastal and shelf sea ecosystems by combining in situ and remotely sensed data. Estuarine, *Coastal and Shelf Science*, **77:** 296-307.

Schroeder, F. and H.-D. Knauth (2011). Time-series of water quality data of the Brantas River, Indonesia. (This volume.)

Schroeder, F. (2010). MERMAID Opens Prospect of Cleaner Seas with Pollution Early Warning System.

To be found online at url:

1. EUREKA Publications 2010: Online: http://pressitt.com/smnr/MERMAID-OPENS-PROSPECT-OF-CLEANER-SEAS-WITH-POLLUTION-EARLY-WARNING-SYSTEM/1954/
2. Science Daily: http://www.sciencedaily.com/releases/2010/07/100709101920.htm,
3. CORDIS Wire: http://cordis.europa.eu/wire index.cfm?fuseaction=article.Detail&rcn=23388

Siregar, M.R.T. (2004). On-line water quality monitoring on Brantas river, East Java, Indonesia. Semiconductor Electronics, 2004. ICSE 2004. IEEE International Conference. Dec. 7-90 2004, p 42-46.

Sudaryanti, S., Trihadiningrum, Y.B., Hart, Davies, P.E., Humphrey, C., Norris, R., Simpson, J. and L. Thurtell (2001). Assessment of the biological health of the Brantas River, East Java, Indonesia using the Australian River Assessment System (AUSRIVAS) Methodology. *Aquatic Ecology*, **35:** 135-146.

Whelan, A. and F. Regan (2006). Antifouling strategies for marine and riverine sensors. J. Environm. Monitoring, 8: 880-886 (online at http://pubs.rsc.org). doi:10.1039/b603289c.

Asian Journal of Water, Environment and Pollution

Volume 8 Number 3 **July – September, 2011**

Contents

Editorial i

❑ *Snapshot* ii

Factors Affecting Denitrification Rate in Barato Lake, Hokkaido, Japan
Pawan Kumar Jha and Minagawa Masao 1

Agricultural Intensification in South Asia and Its Contribution to Greenhouse Gas Emission: A Review
Nani Raut, Bishal Kumar Sitaula and Roshan Man Bajracharya 11

Ecological Enumeration of Tree Vegetation and Their Contribution in Removal of Atmospheric Pollution Load: A Case Study in an Industrial Complex of Western Orissa, India
P.C. Mishra, N. Behera, S.P. Mishra and Kumarmani Meher 19

Recovery and Utilization of Sulphur Dioxide from Exhaust Flue Gases to Control SO_2 Emission at Thermal Power Plant, Rajasthan
Arun Kumar Sharma, Shveta Acharya and Rashmi Sharma 29

Regionalization of Storm Duration for Determining Derived Flood Frequency Curve: A Case Study for Victoria in Australia
Khaled Haddad and Ataur Rahman 37

Oil-Water Separation from Waste Oily Mixture by Physical Treatment
V.K. Srivastava and Chintan Pathak 47

Nickel Recovery from Spent Ni/Al_2O_3 Catalysts Using Nitric Acid Solution
Rachit Oza, Nikhil Shah and Sanjay Patel 51

Old Coal Mine Workings Shaping to Cataclysm – A Study at Jharia and Raniganj Coalfields
Amar Prakash and K.B. Singh 59

Water Quality Status of Kabini River in and around Nanjudeswara Temple in Nanjangud, Mysore
J. Mahadev, Syed Akheel Ahmed, Srikantaswamy and Satish S 67

Effect of Oxidative Stress Injury and Antioxidant Status in Malignancy
Arpita Chatterjee and Gopeswar Mukherjee 75

❑ *Short Notes*

Evaluation of Unprocessed Municipal Solid Waste Composition in Different Wards of Pallavaram in Pallavapuram Municipality Area in Chennai
N. Raman and D. Sathiya Narayanan 79

Studies on Pollution in River Chambal: Zooplankton in Relation to Water Quality
D.P. Singh 83

Microbial Denitrification of Ground Water – Batch Study
Archna, R.C. Sobti and S.K. Sharma 89

❑ *Special Feature*

An Update on Recent Natural and Man Made Disasters in Japan
N. Madhavan 95

Environment News Futures 107