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CLEEN WP 4.1.2

FUTURE TRENDS OF WATER QUALITY MEASUREMENTS

Environmental issues play an important role in everyday life. It is evident that efforts will be made to improve the continuous monitoring of quality of water and wastewater. Water quality measurements can be divided to the measurements of natural water, drinking water, municipal wastewater and industrial process water.

In urban water systems the future trends are widely discussed. Trends in instrumentation control and automation (ICA) and the consequences of the trends cover many topics. The use of on line sensors promotes higher environmental protection regulations and emission taxes. Also, on line sensors could remote monitoring of water purification and wastewater treatment facilities. Trends in online instrumentation mean more parameters can be measured simultaneously. Also new measurement technologies and sampling methods are developed. Trends in automation intend for example more powerful control and acquisition systems /1/.

Environment monitoring can be done by measuring different important parameters. High data quality, accessibility and cost-effectiveness are basis for developing monitoring programs. Lovett *et al*. stated thet monitoring should be considered a fundamental component of environmental science. They continue these programs to address questions and integrate monitoring into research programs that foster continual examination. Long-term support for valuable monitoring programs was also required /2/.

The use of Best Available Technique (BAT) is required at many application fields. Integrated Pollution Prevention and Control (IPPC) Directive by the European Union requires establishing operating conditions and emission limit values in permit for installations through the applications of BAT. The IPPC Directive covers the environmental aspects of production and claims to reduce emissions in the air, water and land. Energy efficiency as well as the consumption and quality of raw materials are required at the industry. By developing BAT measurement technique companies could gain wide business opportunities /3,4/.

Future trends of water quality measurements have distributed under the next titles.

MEASUREMENT TECHNIQUE DEVELOPMENT

There are wide opportunities to develop measurement techniques to water measurements. Devices should be robust and have low-energy consumption. Portable devices are broadening to different measurement

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cases for rapid analysis. Especially different elemental speciation protocols continue to receive attention. For example micro X-ray fluorescence spectrometry has been used to chemical mapping /5/.

Future trends for measurement technique development are enhanced automation and measurement sensitivity. Detection limits has to be low and reproducibility better than with conventional methods. Labor and long analysis time is replaced by automated data analysis. Measurement techniques are also expected to be environmentally friendly; in the other words, the consumption of toxic reagents at the measurement should be minimized. Many measurement techniques based on optical methods are rapid and simple /6/.

More robust and reliable sensors will be developed in the future. By keeping interferences as minimum as possible, the aim of the research will be to achieve the highest possible specificity. Robustness of the sensors is essential to avoid malfunctions. Sensors useful life is required to be long.

The use of virtual sensors will count on the help of Artificial Neural Networks (ANN). Each case has to be well trained and the most suitable algorithm chosen. Future development of biosensors will focus upon the technology of new materials especially copolymers. One significant challenge is electronic noses which are sensitive to different conditions /7/.

ON LINE

On line measurements are developed for getting real-time measurement data from the process. The use of potential techniques like biosensors and optical sensors are limited by environmental factors. Also, their life-time can be short and sometimes affected by fouling. Promising new measurement method like optical analysis technique requires further development. The optical analysis for monitoring of wastewater organic load needs improvement in measurement reliability. Also standardized validation of water quality is essential /8/.

On line methodologies have many advantages compared to official methods. Often analysis time is shortened. The required sample volume reduced because sample manipulation is minimized. Obtained information is real-time, accuracy and cost-efficiency. Automation shortens the data analysis time and gets results reliability /9/.

The on line measurement technique can be used at harsh conditions. Water quality components and water level were measured at a real-time automatic measurement station at winter season in Finland. However, the differences between the station and traditional manual water sampling analyses were observed. Sensor-based monitoring of nutrient transport during the winter season proved its benefits particularly /10/.

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Applications of on line measurements are widely spread. Water turbidity can be measured by Nephelometric Turbidimeter Monitoring System (NTMS). The NTMS was used also for determining the floc size changes in flocculation for synthetic algae water suspensions /11/. One recently developed online application for pH measurement of seawater desalination was proposed by Wang *et al.* They have designed three operation modes to improve the online pH measurement by glass electrode. The measurement errors were diminished by temperature compensation, ultrasonic cleaning technology and auto-calibration. The glass electrodes service life was lengthened by these operational modes /12/.

On line applications are widely used at water treatment plants. On line membrane permeability based on the measurements of permeate flow, transmembrane pressure and water temperature was monitored in membrane bioreactors (MBR) at a centralized municipal wastewater treatment plant. The method was tested with a 250 days data set of continuous pilot operation of a municipal MBR /13/. The other application for on line wastewater monitoring is an instrument measuring biochemical oxygen demand (BOD). It has been used for controlling activated sludge process at water reclamation plant. The measurement results were good enough, so the instrument is nowadays used as a shock-load warning alarm instrument /14/.

On line quality measurements was used at a process control of a drinking water plant. Total hardness of water was measured. The use of the results did not increase the performance of the plant. Laboratory data collected for monitoring reasons was used to make a soft sensor for the total hardness. The accurate and robust soft sensor was based on a particle filter and a precise model of the process /15/.

Some examples were found to determine the quality of natural water. A sensitive on line, near real-time acetylene reduction assay was used to measure nitrogenease activity in the surface waters in the eastern Atlantic Ocean /16/. One significant part of the on line measurements is data transfer. Many measurement points are far away electricity. Data transfer can be done via wireless sensor network, as O'Flynn *et al*. has done. They used the "SmartCoast" Multi Sensor System to monitor quality of fresh water sites. The Wireless Sensor Network (WSN) platform enables in-situ chemical and physical measurements. Data was also viewed in real time via the internet /17/.

SOCIAL MEDIA

People want to get real-time data from their environment. One possibility to get data is a social media and its applications where one can get information and also add his own observations and measurements. In Finland, for example, has been developed an operations model for environment monitoring. It can be used both by private people and public authority and provides data from in situ measurements, automated monitoring platform and remote sensing. Many enterprises were developing the model by offering service

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or providing environmental data or devices. Business opportunities include also the service provision and the usage of the service /18/.

Modeling, Computation and Neural networks

Different models have been developed to estimate changes at environment. For example, Institute for Chemical and Bioengineering at Zürich, Schwitzerland, has developed the global environmental fate model of persistent organic pollutants named CliMoChem. A method for a qualitative and quantitative comparison of model and measurements has been developed to confirm model results with measurements. Although the model has been used to calculate concentrations of dichlorodiphenyltrichloroethane (DDT) and its degradation products in the environment, that kind of models will spread widely to the measurement targets where the estimates will be of great concern to environment /19/.

Today a significant measurement target is natural water where people want to know if the water quality has drop under an acceptable level. An Artificial Neural Network based model was used for on line monitoring of water quality. A large quantity of real-time monitoring data was used to improve the water quality and permit rapid responses to pollution incidents. The ANN-based model provides an effective approach to control water quality especially for environmental protection purposes /20/. Also a spectral algorithm was developed for the measurement of dissolved ozone concentrations in drinking water treatment /21/.

Water purification process was studied with Principal Component Analysis (PCA). Measured data was processed by chemometric analysis. PCA analysis helped to get a general insight of the water purification treatment. It also made possible to reveal seasonal changes influencing the process. STATIS (Structuration des Tableaux A Trois Indices de la Statistique) was employed along with PCA to obtain the knowledge about the complete water treatment process. Similar chemometric analysis could be used at many other measurement applications /22/.

Water Quality Index

Sometimes it is not consequential to know what is the exact amount of for example COD in wastewater but what is the proportional level of water quality. Modeling could bring more data from water although by modeling one cannot know the exact values of water. An Artificial Neural Network (ANN)was used to predict water quality in wastewater quality monitoring. After the water quality parameters were evaluated, a term ‘Water Quality Index’ (WQI) was introduced to summarize and report water quality. The ANN was a forceful tool to specify the WQI value ranging from 0 to 100 at different seasons /23/.

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Wastewater quality can be monitored and classified by treating the collected data with a series of supervised pattern recognition techniques. Business opportunities can be found not only from measurement techniques but also from automation of data analysis. The measurement and data analysis method provide a good approximation of realistic concentrations in wastewater. Wastewater effluents have been classified by the method. It also enables a rapid interference of treated wastewater quality and a robust assessment of treatment process state /24/.

WATER REUSE

In semi-arid areas of the world the treated wastewater was made a reliable alternative source in water resources management. Treated municipal wastewater was used for irrigation when water quality was measured to be high enough for the purpose. Proper management of wastewater irrigation and periodic monitoring of quality parameters were required to ensure reuse of wastewater. Surface of semi-arid areas will increase simultaneously with global warming /25/.

CONCLUSIONS

From the researcher point of view future trends of water quality measurements are on line measurements and modeling. Restrictions in legislation are a challenge for the companies developing measurement techniques. Demand of the use of Best Available Technique (BAT) will spread. On line measurements are rapid but in future all variables should be measured even faster without use of hazardous chemicals. More and more environmental measurement data will be available at Internet. Also, virtual and soft sensors will be used widely, and the robustness of the sensors will be essential.

SOURCES

1 Haeck, M. & Wiese, J., Trends in instrumentation, control and automation and the consequences on urban water systems, *Water Science & Technology,* 2006, 54(11-12), 265-272, Abstract.

2 Lovett, G.M., Burns, D.A., Driscoll, C.T., Jenkins, J.C., Mitchell, M.J., Rustad, L., Shanley, J.B., Likens, G.E. & Haeuber, R., Who needs environmental monitoring?, *Frontiers in Ecology and the Environment,* 2007, 5(5), 253-260.

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3 Kocabas, A.M., Yukseler, H., Dilek, F.B. & Yetis, U., Adoption of European Union's IPPC Directive to a textile mill: Analysis of water and energy consumption, *Journal of Environmental Management*, 2009, 91, 102-113.

4 Gavrilescu, M., Teodosiu, C., Gavrilescu, D. & Lupu, L., Strategies and practices for sustainable use of water in industrial papermaking processes, *Engineering in Life Sciences,* 2008, 8(2), 99-124.

5 Butler, O.T., Cook, J.M., Harrington, C.F., Hill, S.J. Rieuwerts, J. & Miles, D.L., Atomic spectrometry update. Environmental analysis, *Journal of Analytical Atomic Spectrometry,* 2007, 22, 187-221.

6 Su, Y., Li, X., Chen, H., Lv, Y. & Hou, X., Rapid, sensitive and on-line measurement of chemical oxygen demand by novel optical method based on UV photolysis and chemiluminescence, *Microchemical Journal,* 2007, 87, 56-61.

7 Bonastre, A., Ors, R., Capella, J.V., Fabra, M.J. & Peris, M., In-line chemical analysis of wastewater: present and future trends, *Trends in Analytical Chemistry,* 2005, 24(2), 128-137.

8 Bourgeois, W., Burgess, J.E. & Stuetz, R.M., On-line monitoring of wastewater quality: a review. *Journal of Chemical Technology and Biotechnology,* 2001, 76, 337-348.

9 Postigo, C., Lopez de Alda, M.J. & Barceló, D., Fully automated determination in the low nanogram per liter level of different classes of drugs of abuse in sewage water by on-line solid-phase extraction-liquid chromatography - electrospray-tandem mass spectrometry, *Analytical Chemistry,* 2008, 80(9), 3123-3134.

10 Koskiaho, J., Lepisto, A., Tattari, S. & Kirkkala, T., On-line measurements provide more accurate estimates of nutrient loading: a cesa of the Ylaneenjoki river basin, southwest Finland*, Water Science & Technology,* 2010, 62(1), 115-122, Abstract.

11 Cheng, W.P., Chen, W.Y., Yu, R.F. & Hsieh, Y.J., The relationship between particle size and turbidity fluctuations in coagulation process, *Journal of Residuals Science & Technology,* 2010, 7(2,) 87-94, Abstract.

12 Wang, H., Wu, K., Hu, S., Liao, Y.B., Wang, A., Wamg, T. & Ishii, Y., Online pH measurement technique in seawater desalination, *Proceedings of SPIE,* 2009, 7508 (Advanced Sensor Technologies and Applications), 75080F/1-75080F/8, Abstract.

13 Joss, A., Bohler, M., Wedi, D. & Siegrist, H., Proposing a method for online permeability monitoring in membrane bioreactors, *Water Science & Technology,* 2009, 60(2), 497-506, Abstract.

14 Iranpour, R. & Zermeno, M., Online biochemical oxygen demand monitoring for wastewater process control-full-scale studies at Los Angeles Glendale wastewater plant, California, *Water Environment Research,* 2008, 80(4), 298-307, Abstract.

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15 Van Schagen, K.M, Bakker, M., Rietveld, L.C., Veersma, A.M.J. & Babuska, R., Using on-line quality measurements in drinking water process control, *Proceedings – Water Quality Technology Conference and Exposition,* 2006, tues5#1/1-tues5#1/14, Abstract.

16 Staal, M., te Lintel Hekkert, S., Brummer, G.J., Veldhuis, M., Sikkens, C., Persijn, S. & Stal, L.J., Nitrogen fixation along a north-south transect in the eastern Atlantic Ocean, *Limnology and Oceanography,* 2007, 52(4), 1305-1316, Abstract.

17 O'Flynn, B., Martínez-Català, R., Harte, S., O'Mathuna, C., Cleary, J., Slater, C., Regan, F., Diamond, D. & Murphy, H., A wireless sensor network for water quality monitoring, *32nd IEEE Conference on Local Computer Networks,* 2007, 815-816.

18 Anttila, S., Nykänen, M., Koponen, S., Kuitunen, P., Kallio, K., Pyhälahti, T., Vakkilainen, K. & Kairesalo, T., Water quality service for lakes, *BALVOIS 2010 – Ohrid, Republic of Macedonia* – 25, 29 May, 2010.

19 Schenker, U., Scheringer, M & Hungerbühler, K., Investigation the global fate of DDT: Model evaluation and estimation of future trends, *Environmental Science & Technology,* 2008, 42, 1178-1184.

20 Yang, W., Nan, J. & Sun, D., An online water quality monitoring and management system developed for the Liming River basin in Daqing, China*, Journal of Environmental Management,* 2008, 88, 318-325.

21 Van den Broeke, J., Ross, P.S., van der Helm, A.W.C., Baars, E.T. & Rietveld, L.C., Use of on-line UV/VIS-spectrometry in the measurement of dissolved ozone and AOC concentrations in drinking water treatment, *Water Science & Technology,* 2008, 57(8), 1169-1175, Abstract.

22 Stanimirova, I., Polowniak, M., Skorek, R., Kita, A., John, E., Buhl, F & Walczak, B., Chemometric analysis of the water purification process data, *Talanta*, 2007, 74, 153-162.

23 Hore, A., Dutta, S., Datta, S. & Bhattacharjee, C., Application of an artificial neural network in wastewater quality monitoring: prediction of water quality index, *International Journal of Nuclear Desalination,* 2008, 3(2), 160-174, Abstract.

24 Tsoumanis, C.M., Giokas, D.L. & Vlessidis, A.G., Monitoring and classification of wastewater quality using supervised pattern recognition techniques and deterministic resolution of molecular absorption spectra based on multiwavelength UV spectra deconvolution, Talanta, 2010, 82, 575-581.

25 Jawad Alobaidy, A.H.M., Al-Sameraiy, M.A., Kadhem, A.J. & Majeed, A.A., Evaluation of treated minucipal wastewater quality for irrigation, *Journal of Environmental Protection,* 2010, 1, 216-225.

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