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Chlorophyll A, EC,

http://www.libelium.com/smart-water-sensors-to-monitor-water-quality-in-rivers-lakes-and-the-sea/

http://www.libelium.com/products/waspmote/overview/

Note: These are just notes, have to modify the sentences to avoid plagiarism

RQs: What water quality parameters are important

What are we inferring from the parameters

How it benefits stakeholders: government, citizen, etc

How does it promote citizen science (find papers)

My research: won’t be able to sense all parameters but the parameters I’ll measure will indicate the quality to some extent and will reduce the volume of water sample required to bring back.

Drones with IoT enabled sensors for in situ measurement will allow multi-point sensing and will provide high-resolution spatiotemporal monitoring of surface water

The water surface cannot be disturbed hence can not use high-speed boats...

Drones are faster than boats?

Check https://publiclab.org/wiki/wheestat-user-s-manual

For heavy metal detection -- anodic stripping voltammetry

https://www.dfrobot.com/product-1123.html

https://www.dfrobot.com/product-1662.html?gclid=Cj0KCQiArdLvBRCrARIsAGhB\_sxVYEz\_NS02C6Apdx6sBpYn7KN9jtT2Ee2Yfohz\_ce4ElCFsYsUbCwaAnyaEALw\_wcB

**Introduction/Problem Statement/Body**

***1. Eco-Heart Index as a tool for community-based water quality monitoring and assessment***

Nobumitsu Sakai, Zeeda Fatimah Mohamad, Affan Nasaruddin, Siti Norasiah Abd Kadir, Mohammad Shahrul Amin Mohd Salleh, Abdul Halim Sulaiman, Eco-Heart Index as a tool for community-based water quality monitoring and assessment, Ecological Indicators, Volume 91, 2018, Pages 38-46, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2018.03.079.

This study uses 6 water quality parameters: pH, heavy metals, chemical oxygen demand(?), transparency, ammonia nitrogen and dissolved oxygen.

It developed the Eco-Heart Index which is economical, user-friendly, policy-relevant, and impactful universally. The measurement of the parameters is quite accurate and strongly correlated with the standard methods of measurement.

Water quality monitoring was done using Pact Test and LAQUAtwin.

Since the indicator is a heart, it is understood through cultures and community and suitable for community-based monitoring enabling the community to participate in citizen science.

The eco-heart index is strongly correlated with WQI and is more informative and attractive to drive policies.

According to Sakai et al., (2018) conventional water quality monitoring is constrained within the practitioners and quality of the water published as Water Quality Index (WQI) integrates all the measured parameters and hence individual parameters are lost. Also the numerical value of WQI is not engaging or informative enough to the laymen community. In their study

***16.*** ***Water quality monitoring strategies — A review and future perspectives (HVD style, 104 citations)***

Behmel, S., Damour, M., Ludwig, R. and Rodriguez, M. (2016). Water quality monitoring strategies — A review and future perspectives. Science of The Total Environment, 571, pp.1312-1329.

Discusses optimizing WQMPs which can be done with IoT enabled water quality sensors which are drone attachable and allows timely information production for the stakeholders

Reliable assessment of water quality through water quality monitoring programs (WQMPs) is crucial for decision-makers to understand, interpret and use this information in support of their management activities aiming at protecting the resource.

Optimizing WQMP is identifying sampling frequencies, 5) estimation of human, technical and ﬁnancial resources; (6) preparation of the logistics (e.g., ﬁeld work, laboratory work, quality control and assessment, data handling, data storing, data analysis)

One of the main challenges posed by Integrated Watershed management (IWM) is to obtain a reliable assessment of surface water quality (lakes and rivers) in a given watershed through water quality monitoring programs (WQMPs) so that decision-makers can understand, interpret and use this information in support of their management activities (for water destined for consumption, recreational and industrial use, or preservation and restoration of the ecological status)

No holistic solution exists to cover all steps of water quality monitoring

Challenges in WQMP that are relevant to my research:

continuous quality control and assessment, data storage, adequate and timely information production for the stakeholders and changes in governance. In other words, a tool that can rapidly assist the watershed manager in every aspect of a WQMP: stakeholder implication, scientiﬁc requirements, administrative requirements, and governance.

***27. On-line water quality monitoring on Brantas river East Java Indonesia***

23 online water quality monitoring stations have been built to provide accurate, real-time continuous data

Very old paper and equipment

The data os needed tp establish an effective decision tool for the management of river basin. Continuous monitoring allows immediate action in case of emergency. Furthermore, long-term evaluation of

the data quality results in improves in predictive capabilities based on modeling techniques and

thus providing important support for decision-makers.

Water quality monitoring is required to ensure standards and criteria set by government and regulatory agencies for river water with respect to the specific use for e.g. drinking, industrial, irrigation etc.

A well planned and managed water quantity and quality measuring network can serve as a valuable tool for predicting shifts or trends. The objectives of the On-line Water Quality Monitoring have been defined in accordance with:

water use,  obtaining baseline data and inventories,  regulation and guideline for development,

 law enforcement,  water quality and quantity modeling, and basis for water discharge permit development.

Modeling of hydrological events combined with a Hydrological Information System and a Decision Support System will strengthen the development of the overall water management tasks in the

Brantas River Basin.

Parameters: pH, temperature, conductivity, dissolved oxygen, turbidity, orthophosphate, and ammonia.

* **UAV for Water Sampling**

***2. Can drones be used to conduct water sampling in aquatic environments? A review***

H.T. Lally, I. O'Connor, O.P. Jensen, C.T. Graham, Can drones be used to conduct water sampling in aquatic environments? A review, Science of The Total Environment, Volume 670, 2019, Pages 569-575, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2019.03.252.

Research stated that 330ml of water samples is insufficient for sampling and research needs to be done to demonstrate the accuracy of drone collected data from real-time off the shelf probes and cost-benefit analyses are required before water sampling programs use drones.

Research has shown the potential of drones to collect water samples and Physico-chemical data from aquatic bodies. Advances in sampling payloads, incorporating off-the-shelf probes and capturing water successfully has been done but the key limitations of water sampling drones are a small volume of water, low rate of a successful capture, legislative restrictions, inconsistencies between water chemical properties obtained using drone vs traditional methods and with the level of reliability and accuracy.

Proposed solutions are modifying larger drones with greater payload capacity, technological development to ensure successful water capturing, planning fieldwork and employing real-time Physico-chemical probes (Song et al., 2017).

Application of off-the-shelf drones  (Detweiler et al., 2015; Ore et al., 2013, 2015; Song et al.,

2017; Terada et al., 2018) [CHECK], advancements in incorporating off-the-shelf multi-meter probes (Koparan et al., 2018b; Song et al., 2017) Check Bringing un-manned aerial systems closer to the environment (Related to this paper).

***6.  Autonomous In Situ Measurements of Noncontaminant Water Quality Indicators and Sample Collection with a UAV (HVD style) (2019, 2 citations)***

***(Check this for statistical tools for sensor analysis- paired t-test)***

Koparan, C., Koc, A., Privette, C. and Sawyer, C. (2019). Autonomous In Situ Measurements of Noncontaminant Water Quality Indicators and Sample Collection with a UAV. *Water*, 11(3), p.604.

UAV assisted autonomous water sampling system (UASS) developed in this study was equipped with three water sampling cartridges and sensor nodes for in-situ measurements of water quality at different depths.

The system allows rapid sampling from difficult to access water bodies (inaccessible and dangerous water bodies) with relatively low costs and can operate without intense training for practitioners. It lowers operational cost and is useful for monitoring water reservoirs, lakes, rivers, and ponds periodically/ after natural disasters.

Parameters: Temp, EC, pH, DO.

***7. In Situ Water Quality Measurements Using an Unmanned Aerial Vehicle (UAV) System***

Koparan, Cengiz; Koc, Ali B.; Privette, Charles V.; Sawyer, Calvin B. 2018. "In Situ Water Quality Measurements Using an Unmanned Aerial Vehicle (UAV) System." Water 10, no. 3: 264.

An UAV-assisted water quality measurement system was developed for in situ water quality measurement and the hexacopter was assembled with floatation equipment. The UAV carried out multipoint sampling and the data was used to interpret the spatial distribution of measurement in the pond. The sensors have good accuracies and the percent differences were below 4%.

Landing and lifting from the water surface avoided the need for additional sensors for hovering and the main limitation is the flight duration.

Offline, saved in a SD card

Parameters: Temp, EC, DO and pH are the most common parameters of impairment of water quality in river, lakes etc

***8.  Bringing Unmanned Aerial Systems closer to the Environment***

Carrick Detweiler, John-Paul Ore, David Anthony, Sebastian Elbaum, Amy Burgin & Aaron Lorenz (2015) Environmental Reviews and Case Studies: Bringing Unmanned Aerial Systems Closer to the Environment, Environmental Practice, 17:3, 188-200, DOI: [10.1017/S1466046615000174](https://doi.org/10.1017/S1466046615000174)

This research studies an aerial water sampler that flies to remote locations and dips a pump into water to collect samples for lab analysis.

The spatiotemporal resolution of these datasets will enable policymakers to better measure the impact of policies.

The key finding is water properties measured by these novel systems correlate with water properties measured by traditional sampling techniques

***~~9.  Autonomous Aerial Water Sampling (HVD style, 37 citations)~~***

~~Ore, J., Elbaum, S., Burgin, A. and Detweiler, C. (2015). Autonomous Aerial Water Sampling.~~ *~~Journal of Field Robotics~~*~~, 32(8), pp.1095-1113.~~

~~(Ore, Elbaum, Burgin & Detweiler, 2015)~~

~~Water sampling (spatially separated and high frequency) is crucial in managing freshwater resources and maintaining public health.~~

~~The aerial water sampler has the potential to increase speed and range at which scientists obtain water samples while reducing cost and effort~~

~~The system developed in the study can be used by water scientists to improve the spatial scale and temporal resolution of water sampling.~~

***10. UAV Assisted Automated Remote Monitoring and Control System for Smart Water Bodies***

P. S. Perumal, A. S. A. Raj, B. M. S. Bharathi, G. M. Raju and K. Yogeswari, "UAV Assisted Automated Remote Monitoring and Control System for Smart Water Bodies," *2017 Second International Conference on Recent Trends and Challenges in Computational Models (ICRTCCM)*, Tindivanam, 2017, pp. 116-120.

doi: 10.1109/ICRTCCM.2017.85

The proposed system has floating sensor that measures water quality

And the UAV uses LIDAR to monitor water level and capacity which are transmitted directly to the field control unit. The field control unit is connected to several sensors including water quality and rain fall sensor. The field control unit  sends all this data to remote monitoring and control station wirelessly where the data is preprocessed and validated which is then classified and transformed into knowledge

* **Hybrid UAV for Water Sampling**

***13. Design of Amphibious Vehicle for Unmanned Mission in Water Quality Monitoring Using Internet of Things (HVD style 8 citations)***

Esakki, B., Ganesan, S., Mathiyazhagan, S., Ramasubramanian, K., Gnanasekaran, B., Son, B., Park, S. and Choi, J. (2018). Design of Amphibious Vehicle for Unmanned Mission in Water Quality Monitoring Using the Internet of Things. Sensors, 18(10), p.3318.

This study developed an unmanned amphibious vehicle that integrated multi-rotor UAV and hovercraft

The payload is 7kg and operation of 25 minutes and had IoT based water quality measurement sensor that connected to a 4G wifi hotspot and transferred the data to google firebase.

The amphibious system also could collect 500ml of water through a suction pump attached to the end effector of a robotic arm.

Hardware consumed 7.58W of power and the data transmission took 11ms. Saturation time for turbidity and pH was 65ms and 26 ms respectively.

Parameters measured: turbidity, DO, pH, EC \*\*Uses DF robot sensors

* **Wireless distributed sensor networks water quality sensors**

***17. Development of embedded wireless network and water quality measurement systems for aquaculture (HVD style, 9 citation)***

Vaddadi, S., Sadistap, S. and Kumar, P. (2012). Development of embedded wireless network and water quality measurement systems for aquaculture. *2012 Sixth International Conference on Sensing Technology (ICST)*.

No mention of water quality sensor accuracy

This study developed portable water quality measurement installed on a floating platform which is powered by a rechargeable dc battery with solar panel and it communicates with central unit wirelessly through ZigBee wireless communication to transfer data for remote monitoring. The remote station has a PC with ZigBee wireless communication and internet to upload the data to the cloud. (Quite clunky)

The system is anchored to a pole or tree so it remains in the same location and is weatherproof.

Downsides: Requires multiple sensors for multipoint sensing.

***Parameters measured: DO, pH, temperature, EC and environment pressure***

***21. Grid-based wide area water quality measurement system for surface water (hvd)***

***(Konyha, 2016)***

Konyha, J. (2016). Grid-based wide-area water quality measurement system for surface water. *2016 17th International Carpathian Control Conference (ICCC)*.

This study developed a surface water monitoring network for measuring surface water such as lakes and rivers

It provides a forecast of the possible spread of contamination

The system consisted of a solar-powered communication station/column  which was connected to the submersible sensor carrier. The column was responsible for communication with other measurement column and with server via GPRS

Calibration was done using Bluetooth and an accompanying Android app was developed.

Parameters: ORP, pH, EC, temp, DO, NO3- ion, CL- ion

***22. Automated Water Quality Survey and Evaluation Using an IoT Platform with Mobile Sensor Nodes(HVD, 14 citations)***

(Li et al., 2017)

Li, T., Xia, M., Chen, J., Zhao, Y. and de Silva, C. (2017). Automated Water Quality Survey and Evaluation Using an IoT Platform with Mobile Sensor Nodes. *Sensors*, 17(8), p.1735.

This study developed an IoT platform with solar-powered mobile sensor nodes (MSN) for spatiotemporal quality evaluation of surface water. An online water quality index was developed to interpret the large quantities of online measurements. Environmental telemonitoring.

The shortcoming of deploying a single station is the lack of the ability to provide high resolution of spatiotemporal monitoring over large geographical areas.

Multi-sensor nodes so multiple nodes are needed which is expensive

Multi-sensor nodes connected wirelessly to a base station which has internet access through GPRS/3G/4G

 Multiple mobile sensor nodes were positioned uniformly to travel along the planned path such that each objective sampling location could be visited within the time interval requirement. The proposed sensor scheduling and path planning algorithm was designed for the application scenario of automated water quality monitoring.

The platform provided a cost-effective (Really?), fast, deployable and easily maintainable solution for high-resolution spatiotemporal telemonitoring of water surfaces

Parameters measures: Temp, pH, DO, EC, ORP

No mentions of price or accuracy of sensors

* **Development of water quality sensors**

***3. A Low-Cost System for Real-Time Water Quality Monitoring and Controlling using IoT***

K. Gopavanitha and S. Nagaraju, "A low-cost system for real-time water quality monitoring and controlling using IoT," *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*, Chennai, 2017, pp. 3227-3229.

doi: 10.1109/ICECDS.2017.8390054

This paper measured drinking physicochemical parameters of water like temperature, turbidity, conductivity, pH and flow in real-time using a Raspberry pi. It mentions that it is a low-cost system but there’s no mention of the cost. The data was displayed in the backend and the solenoid valve was remotely controllable. This is useful in the water distribution system, industries, and aquafarming.

***14.  Design of online data measurement and automatic sampling system for continuous water quality monitoring (HVD style, 9 citations)***

Wiranto, G., Mambu, G., Hiskia, Hermida, I. and Widodo, S. (2015). Design of online data measurement and automatic sampling system for continuous water quality monitoring. *2015 IEEE International Conference on Mechatronics and Automation (ICMA)*.

Doesn’t mention price or accuracy of the sensors

Continuous water monitoring system wirelessly using XBee and graphical display of parameters. The system also collects 20ml of water sample when the value of DO and pH exceeded a certain set threshold. NOT CONNECTED TO THE INTERNET

Parameters: DO, pH, temperature

***24. Modeling, Development & Analysis of Low Cost Device for Water Quality Testing (HVD style)***(Indu and Choondal, 2016)

Indu, K. and Choondal, J. (2016). Modeling, development & analysis of low cost device for water quality testing. *2016 IEEE Annual India Conference (INDICON)*.

With existing techniques, the general public is not aware of the potability of water. Lack of accurate and efficient low-cost systems are also a result of poor awareness.

Developed low-cost water-sensor that measures four parameters costing 60 USD

Modeled, developed and analyzed low-cost water quality testing device.

After modeling in multisim, Implementation was done on hardware and results were compared with available products on market. The deviations of pH, EC, TDS were 0.04, 0.07 and 0.07 respectively

Future recommendations to make IoT based water monitoring device

Parameters: pH, TDS, EC, Temp

***28. Smart Sensor Device for Detection of Water Quality as Anticipation of Disaster Environment Pollution (3 citations)***

Population growth and the pace  of development have  resulted in environmental degradation,  especially the quality of surface water or groundwater.

Potable water has certain standard indicators,  namely: indicators of physical, chemical, and biological.

The threshold parameter pH = 6.5 - 8.5, TDS <1000ppm, turbidity <5 NTU, and the water temperature  =  ±  3C  than  the  air  temperature.  Precision test of sensors has been carried out and each sensor has a  good precision,  with an average percentage error for sensor pH  =  1.46%,  sensor  TDS  =  1:09%,  turbidity  sensor  =  2:00%,  and  a water  temperature  sensor  =  0.83%.  Determination of water

Quality using fuzzy logic,  divided into three categories:  water quality is good,  less good and bad.

Used XBee module and ATmega2560 with GPS transmitted wirelessly and stored locally

Parameters: temp, TDS, Turbidity, pH

***29. Smart technology for water quality control: Feedback about use of water quality sensors***

For early detection of contamination in water distribution networks distributed sensor networks were used which performed well compared to laboratory tests

The traditional methods frequently used, are based on laboratory analyses  and take several days.  To prevent earlier water quality degradation, real-time monitoring is required.

Used sensors- S::CAN

Parameters: Total organic carbon, dissolved organic carbon, pH, conductivity

***31. Automatic Measurement and Reporting System of Water Quality Based on GSM***

D. Mo, Y. Zhao and S. Chen, "Automatic Measurement and Reporting System of Water Quality Based on GSM," *2012 Second International Conference on Intelligent System Design and Engineering Application*, Sanya, Hainan, 2012, pp. 1007-1010.

doi: 10.1109/ISdea.2012.595

Key Findings:

Made automatic measurement and reporting system of water quality parameters based on GSM through SMS. It also incorporates data analysis to notify the management to action if there is something abnormal.

They made temperature, conductivity, pH, turbidity by themselves

Parameters: pH turbidity, temperature, conductivity, dissolved oxygen

Limitations

No comparison with standard measurement system or accuracy levels. Never discusses the accuracy. Says inexpensive, no mention of the price!

* **Water Sampling UnderWater Robots**

***4. A  WATER  QUALITY  MONITORING  ROBOT***

P. Osborne, E. Hoffman, R. Lovelady, R. Holloway and R. Ferguson, "A Water Quality Monitoring Robot," *OCEANS 81*, Boston, MA, 1981, pp. 512-516.

doi: 10.1109/OCEANS.1981.1151651

Submerged buoy

Water quality monitoring system (submerged buoy) is developed which replaces costly manual methods with automated in-situ measurements.

Can provide early warnings of water pollution, quantitative results for regulatory actions and data for scientific studies.

Manual methods of measurement are expensive and prone to human error and manual data collection is not practical around the clock. But, continuous monitoring is essential to the causes and effects of isolated events (?)

Automated measurements provide important scientific and cost advantages over manual methods

Parameters: Temperature, pressure, conductivity, pH, ORP(Redox), Dissolved O2, Fluoride, Turbidity

***11. Design and Field Testing of Water Quality Sensor Modules Designed for Round-the-Clock Operations from Buoys and Biomimetic Underwater Robots (2 citation, book chapter)***

Park J., Sohn J., Kim S., Park J. (2013) Design and Field Testing of Water Quality Sensor Modules Designed for Round-the-Clock Operations from Buoys and Biomimetic Underwater Robots. In: Lee S., Yoon KJ., Lee J. (eds) Frontiers of Intelligent Autonomous Systems. Studies in Computational Intelligence, vol 466. Springer, Berlin, Heidelberg

This study developed new water quality sensors which can provide high-resolution data consistently and is attachable and deployable to underwater robots and buoys

No mention of price, error rate is around 4.95% for pH, 2.65% for DO, 10.19% for turbidity, 5.2% for temp and 2.17 for EC

Parameters: Turbidity, DO, pH, EC, temp

***12. Design and Implementation of a Robotic Dolphin for Water Quality Monitoring (7 citations)***

J. Liu, Z. Wu and J. Yu, "Design and implementation of a robotic dolphin for water quality monitoring," *2016 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, Qingdao, 2016, pp. 835-840.

doi: 10.1109/ROBIO.2016.7866427

This paper proposes a bio-inspired robotic dolphin for autonomous water quality monitoring using onboard sensors including inertial navigation system, GPS, depth sensor, infrared and replaceable water quality multiprobe.

***30.System Design of Water Quality Monitoring Robot with Automatic Navigation and Self-test Capability (low citation, not a great paper)***

Water quality data communication module installed to an underwater robot for water quality monitoring

In order to further confirm the accuracy of this system, the experiment also selected the XZ–0111  type  and  5B-3B  type  multi-parameter  water  quality  analyzer  for  reference

Distance between underwater robot and the wireless communication of the shore-based facility is the bottle neck

Communication delay between robot and the shore-based facility is long

Long term underwater navigation pollutes the robots and reduces the accuracy of the sensors

Parameters temp, turbidity, blue/green algae, chlorophyll A, DO, pH and ORP

***15. ROV-based acquisition system for water quality measuring (HVD style)***

Hidalgo, F., Mendoza, J. and Cuellar, F. (2015). ROV-based acquisition system for water quality measuring. *OCEANS 2015 - MTS/IEEE Washington*.

Designed and implemented (remotely operated underwater vehicle) ROV-based water quality monitoring through the acquisition of oceanographic parameters and can be used in rivers, lakes and oceans. It used other sensors along with a multiprobe sensor

*Used a multiprobe to measure water parameters like temperature, DO, Specific conductance, salinity, pH, depth, turbidity*

***26. Water quality data measurement and analysis system equipped in underwater navigation robot (hvd)***

Hongmin, G. et al. (2013) ‘Water quality data measurement and analysis system equipped in underwater navigation robot’, Sensors and Transducers, 155(8), pp. 128–135.

This study introduces water quality measurement and analysis system equipped in underwater robot

It measures water quality data of the current position and tags it to its latitude and longitude. The underwater robot floats to the water surface and transmits the date to the shore-based facility

Experiments were carried out to asses the accuracy of the data collected by an underwater robot and the measurement errors were always within ±  5  % when compared to water quality analyzers

Parameters: temp, turbidity, blue-green algae, chlorophyll, DO, pH, ORP.

* **USV water sampling**

***18. Development of Unmanned Surface Vehicle for Smart Water Quality Inspector (HVD)***

(Siyang and Kerdcharoen, 2016)

Siyang, S. and Kerdcharoen, T. (2016). Development of unmanned surface vehicle for smart water quality inspector. *2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*.

Water quality monitoring for water resource management has become increasingly important with climate change, growing population and increase in standards of living

Traditional water measurement methods carried out in the laboratory cannot help much with making timely and informed decisions.

The available real-time water quality sensors are of a fixed location platform and not mobile. This study attached it with USV to solve this problem and provides continuous and autonomous measurements at reduced cost.

It transmits data wirelessly to the ground station using Xbee which is then sent to the internet through the PC

Cost of sensors/ accuracy not mentioned. Used Atlas Scientific sensors (hence can look up price)

Parameters measured: temp, pH, DO, oxidation-reduction potential (ORP) and EC

***19. Development of unmanned surface vehicle for water quality monitoring and measurement.***

(Yang et al., 2018)

Yang, T., Hsiung, S., Kuo, C., Tsai, Y., Peng, K., Peng, K., Hsieh, Y., Shen, Z., Feng, J. and Kuo, C. (2018). Development of unmanned surface vehicle for water quality monitoring and measurement. *2018 IEEE International Conference on Applied System Invention (ICASI)*.

Traditional methods are accurate but time-consuming and hence it leads to a slow response in response to pollution/ natural disaster

Many researchers implemented IoT but the cost is High and mobile phone signal coverage is low

This paper developed UAV which carries a mobile water quality sensor to perform real-time scan of water qualities. It also developed a communication relay via UAV to solve for low mobile signal coverage

Parameters: ARK sensor System from AQUAS [4] is selected, and measurements are as follow:

1) Chlorophyll-a ,  Chl-a, 2)  Dissolved oxygen, 3) Electrical conductivity , 4) Potassium ion, 5) pH, 6)temperature and 7)Turbidity

Used ARK sensor system to measure water quality

***25. Telesupervised Remote Surface Water Quality Sensing***

(Podnar et al., 2010)

Podnar, G., Dolan, J., Low, K. and Elfes, A. (2010). Telesupervised remote surface water quality sensing. *2010 IEEE Aerospace Conference*.

This study presented a fleet of autonomous robot sensor boats (RSB) developed for lake and river fresh water quality assessment. It used a multi-sensor water sonde (expensive) to asses water quality in small recreational lakes and carried tests over 3 months in clear vs hair algae-laden and before and after heavy rain. It is important because runoff water after heavy rainfall might be polluted with man-made pollutants like fertilizer and waste materials

The boats were controlled using Multilevel Autonomy Robot Telesupervison Architecture (MARTA) and the paper mostly discussed about that architecture

The RSB relayed to a data server where the boats and realtime data were monitored.

Proved the telesupervision architecture for surface water quality sensing and conducted in situ sensing task

Parameters: temp, pH and DO

* **Water Quality Monitoring using boats/ Ships**

***5. Automatic cruise system for water quality monitoring (cit: 0) HVD style***

Zhu, C., Liu, X., Chen, H. and Tian, X. (2018). Automatic cruise system for water quality monitoring. International Journal of Agricultural and Biological Engineering, 11(4), pp.220-228.

Zhu, C., Liu, X., Chen, H., & Tian, X. (2018). Automatic cruise system for water quality monitoring. *International Journal Of Agricultural And Biological Engineering*, *11*(4), 220-228. doi: 10.25165/j.ijabe.20181104.2658

The range of fixed-point measurement of water quality monitoring is limited and multipoint is expensive. Sage-Husa adaptive Kalman filter was used to correct error in GPS positioning. The ship was equipped with water quality parameters acquisition module, GPS module, and GPRS-DTU packet data transmission module. It can widen the measurement range, lower cost and widely used in aquaculture and river management systems and emergency water pollution.

This study carried out a comparison between single and multipoint measurements.

Single point measurement cannot reflect overall water quality in large culture areas (fish pond). Android mobile client was developed which enables collection from any point

Params measured: real-time measurement of dissolved oxygen, pH, temperature and ammonia-nitrogen content in water

***23. Mobile sailing robot for automatic estimation of fish density and monitoring water quality.***

(Koprowski et al., 2013)

Koprowski, R., Wróbel, Z., Kleszcz, A., Wilczyński, S., Woźnica, A., Łozowski, B., Pilarczyk, M., Karczewski, J. and Migula, P. (2013). Mobile sailing robot for automatic estimation of fish density and monitoring water quality. *BioMedical Engineering OnLine*, 12(1), p.60.

The robot can be remotely monitored and it detects fish density detecting the fish spatial location and it also measures quality of drinking water for human consumption. Measures physicochemical properties of water.

It developed a low-cost remote-controlled boat model (catamaran type due to greater stability of sailing) with local data archiving

The robot was used to monitor reservoirs that supply drinking water

No mention of what parameters or accuracy

***20. Experimental evaluation of an Autonomous Surface Vehicle for water quality and greenhouse gas emission monitoring (36 citations hvd)***

(Dun and Grinham, 2010)

Dun, M. and Grinham, A. (2010). Experimental evaluation of an Autonomous Surface Vehicle for water quality and greenhouse gas emission monitoring. *2010 IEEE International Conference on Robotics and Automation*.

Catamaran

This study evaluated experimentally an ASV capable of navigating complex inland water reservoirs and measuring a range of water quality properties. A solar-powered catamaran was used capable of profiling water columns while moving and the data collected by the ASV complemented with existing manual monitoring campaigns with improved spatial and temporal monitoring of water storage.

It is also directly integrated with a reservoir scale floating sensor network to allow data download and adaptive sampling strategies.

The role of the ASV is to autonomously navigate and continuously collect WQ information and relay back to the shore in real-time

Doesn’t talk about the accuracy of the sensors or how data is transferred

The continuous monitoring of these nodes enables early detection of events such as algal blooms

Parameters: A typical sensor payload for the ASV consists of an Optical Methane Detector (OMD, Heath Consultants, Texas), YSI Sonde (measuring temperature, conductivity, chlorophyll,

turbidity, dissolved oxygen)