Water Care System (WCS) for Numeric Water Quality Criteria (NWQC) with IoT/IoUT–Educational Implications of Sustainability Goal SDG 14

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Water Care System (WCS) for Numeric Water Quality Criteria (NWQC) with IoT/IoUT– Educational Implications of Sustainability Goal, SDG 14

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***Abstract*—In most developing countries and evolving countries, availability of potable water is scarce, and the water sources are very often unattended or unmonitored. Island states have the additional problems associated with unheeded pollution from wastewater from the industries and household as well as various ships and tankers. Some of our research efforts have been focused on environmental pollution and continuous monitoring of water quality based on turbidity, temperature, and pH. We focus on selected numeric water quality criteria (NWQC) and present NWQC monitor using an IoT (Internet of Things) and IoUT (Internet of Underwater Things) platform concept, based on already existing systems. Based on field data, some results in monitoring water quality in selected applications are presented. An IoT/IoUT platform realized for monitoring air pollution in Problem-Based Learning (PBL) projects for BSc and MSc students, working with real data and focusing on developing environmentally friendly technological solutions seemed to motivate the students. The project is then extended to the realization of continuous supervision of the waters of both developed and developing nations using IoUT. Useful IoT/IoUT based alerts can reach these "digitalized" citizens, who can thus be trained to use these NWQC data for an environmentally conscious living and to exert pressure on regulators to safeguard water resources as well as to implement proper environmentally friendly wastewater management and water care system (WCS). Some results and practices with respect to NWQC in the EU, particularly in France and Germany will also be presented in this paper. Finally, the paper addresses one of the sustainability goals of the United Nations, SDG 14, using EE (Electrical Engineering) and IT tools with innovations for environmental protection.**

Keywords—Numeric Water Quality Criteria (NWQC), IoT/IoUT for NWQC, Surveilance and Response System (SRS), digitalizing Water Care System (WCS), WHO (World Health Organization), UN Sustainability Development Goals (SDG), Health, Safety and Environmental (HSE), Problem-Based Learning (PBL)

I. INTRODUCTION

Water is the source of life and all outer space projects have the search for water as one of their most important tasks. According to the WHO (World Health Organisation), by 2025, 50% of the global population will be living in water stressed areas. Thus, global responsibility of preserving water, reusing water and of being aware of its misuse or mismanagement falls on each one of us. Each of us must be aware of the need to preserve ground water, assured of the quality of drinking water, alert to the guidelines of managing wastewater and protect the sea and lakes. EU and Norway have common water quality measures, such as temperature, turbidity, bacteria, dissolved oxygen of importance to aquatic fauna and flora, pH indicating acidic or basic nature of water, nutrients necessary for the organisms in water, ammonia from inadequately treated domestic and industrial wastewater, mercury, organic products like PCBs (Printed Circuit Boards), pharmaceuticals and personal care products, microplastics (micropollutants) etc. According to Schwarzenbach et al, 2006, there are about 70 000 known and new chemicals in various water resources including potable water, [1].

In the context of collaboration between academia and institutions within the EU, this paper presents some WCS addressing some NWQC in the countries of the authors.

Mylvaganam, Jacobsen, 1998 developed a turbidity measurement unit to be used in different water monitoring stations, partly launched along with other oceanographic instruments, transferring data via satellites to dedicated stations in Bergen and other places. Similarly, wastewater as well as remnants from the food manufacturing company Toro were analysed by Mylvaganam and his students and colleagues in conjunction with Toro's disposal of waste in farmlands in the suburbs of Bergen, including some islands, as presented in the IEEE OCEANS 1998, [2].

Korostynska et al 2012 list various sensors to monitor many of the parameters mentioned above, [3]. In recent years different surveillance and reporting systems addressing parameters associated with NWQC using IoUT for monitoring water quality have been launched and many systems for real time monitoring of water quality are available with national and international actors.

II. WHO Water Quality Guidelines

WHO has a set of guidelines based on four pillars of management, monitoring, system assessment with safety plans, [4], emphasizing the need for defining the NWQC and setting up of the necessary hardware and software, see Fig. 1. where these guidelines are illustrated.

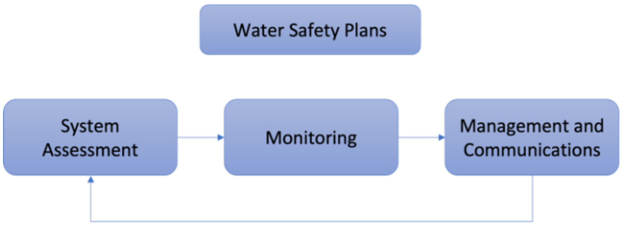

Fig. 1 WHO guidelines based on four pillars of management, monitoring, system assessment with safety plans, adapted from [4].

WHO has a set of specifications for parameters of relevance for NWQC (Table I), reproduced from [4,5]:

TABLE I. Some Parameters of Relevance of NWQC, Slightly Modified from WHO, [18, 19].

Parameter	Level	Description
NTU	<1	Max. recommended value is 5, but preferable<1 for disinfection efficiency. (NTU- nephelometric turbidity units)
pH	6.5 - 8.5	Should be between 6.5 - 8.5
TDS	1000mg	About the weight of a small paper clip)/l. TDS (mg/l) = Conductivity (µS/cm) x factor (0.55 to 0.9); Total dissolved solids (TDS)
Aluminum	0.2mg/l	Aluminum carryover in the treated water can be checked using dedicated measurement and testing kit.
Ammonia	<1.5mg/l	Causes tastes and odour.
Copper	<1mg/l	Causes staining of laundry and as health significance <2mg/l.
Chloride	<250mg	About the weight of ten grains of rice)/l.
Chromium	<0.05mg/l	Has health significance.
Fluoride	<1.5mg/l	Has health significance.
		High hardness, no limits but can give rise to consumer complaints through scum deposition.
Iron	0.3mg/l	Iron usually occurs in ground water and the guideline value is set for aesthetic reasons as iron causes discolouring of the water.
Lead	<0.01mg/l	Has health significance.
Manganese	<0.1mg/l	Causes staining of laundry and as health significance <0.5mg/l.
Mercury	<0.001mg/l	Has health significance.
Nickel	<0.02	Nitrate (as NO3-) <50mg (about twice the weight of a grain of rice)/l. Has health significance.
Sulphate	<250mg	About the weight of ten grains of rice)/l. Gives rise to taste and causes corrosion.
Zinc	<3mg/l	Gives rise to taste and appearance.

III. Water Quality Care in Norway

Similar sensor data acquisition, transmission and fusion systems can be realized with the ubiquitous IoT offering access to sensor data, and our experience in processing environmental data in conjunction with a project in collaboration with Telemark County, USN, Telemark Hospital and SINTEF. A typical sensor data scenario with CO2 concentrations from our system is shown in Fig. 2. Fig. 3 shows the four modules, measurement station, server, web browser/cloud and personal device such as smartphone, necessary for proper functioning of Water Care System (WCS) providing Surveillance and Response Systems for enabling overview of the critical NWQC, [6].

A similar approach has been used in the water care system developed by the Norwegian Research Institute Bioforsk (Røseth et al, 2014) in collaboration with The Norwegian Public Roads Administration, dealing with construction and maintenance of public roads, motorways, and tunnels with intense focus on Health, Safety and Environmental (HSE) issues. Fig. 4 shows an array of sensors for multimodal acquisition of five parameters/measurands height, temperature, pH, conductivity, and turbidity characterising the water quality. A case study involving pH values of a historically documented water spring in a place called Farris gave the results of pH values at different heights as shown in Fig. 5. An actual incident involving acid spillage near a tunnel works near a place called Hobekken in Norway is portrayed in Fig. 6 by an unusual increase of pH values in water found in and around the tunnel. Fig. 7 shows a scenario involving SMS alert on water quality parameters to personnel responsible for environmental supervision, like the alerting services to users shown in Fig. 3.

Fig. 2. An environmental monitoring system delivering actual CO2 levels using Microsoft Azure based data fusion algorithms. Technology transfer to WCS for Numeric Water Quality Criteria (NWQC), based on Halvorsen et al, 2018, [6].

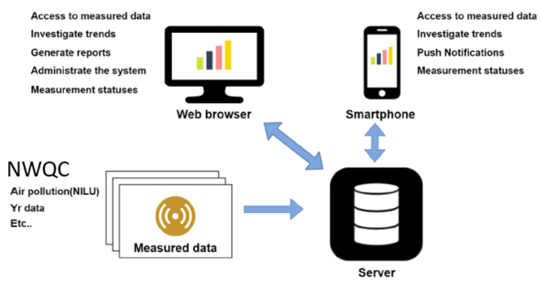

Fig. 3. The four modules, measurement station, server, web browser and personal device such as smartphone, necessary for proper functioning of Water Care System (WCS). Based on already implemented system. Including other environmental parameters.

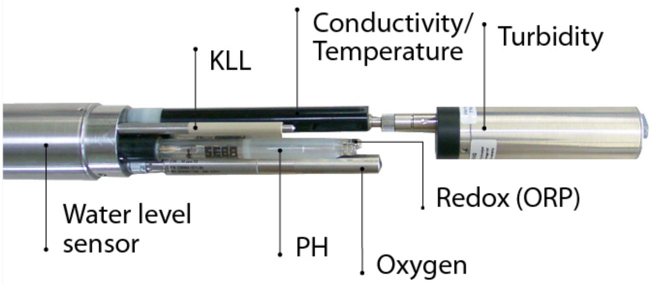

Fig. 4. Multiparameter sensor for water level, temperature, pH, conductivity ORP (Oxidation Reduction Potential) and turbidity of water. [Courtesy: https://www.seba-hydrometrie.com/].

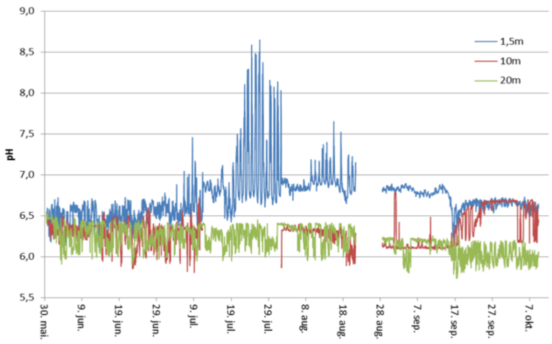

Fig. 5. Measurement of pH values at different levels in water spring in Farris, Norway during the 30.05 to 09.10.13, Courtesy: Roseth et al, 2014, [7].

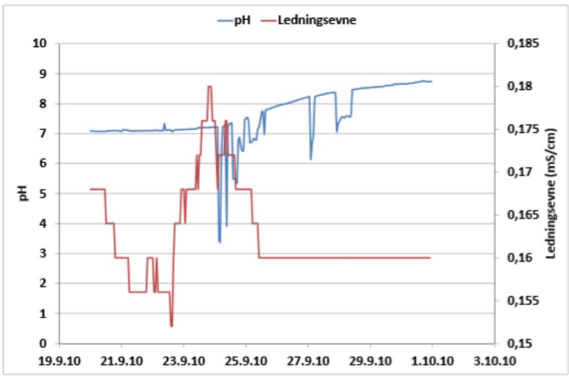

Fig. 6. Plot of monitored time series of pH and conductivity (Ledningsevne) values indicating accidental overdose of acids during construction work of tunnel near Hobekken in Norway, Courtesy: Roseth et al, 2014, [7].

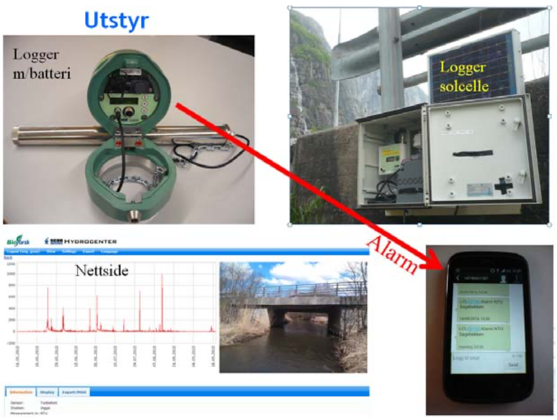

Fig. 7. Principle of SMS alert from sensor via data acquisition system (logger) to the handheld device. Cloud-based processing of the data for time series analysis and presentation to the user, Courtesy: Roseth et al, 2014, [7].

IV. Water Quality Measurements in Rezekne River in Latvia

A. *Rezekne River*

Rezekne is one of the largest rivers of the Daugava confluence basin in Latvia. The Daugava River falls into the Gulf of Riga of the Baltic Sea. Rezekne River rises in Lake Razna, the second biggest lake in Latvia and flows into the biggest lake in Latvia – Lake Lubans (Ramsar sites). The nutrient inflow into the Baltic Sea depends on both natural processes and anthropogenic human activities in the drainage area (Kiedrzyński et al. 2014, [8], [9]). For this reason, Rezekne River ecosystem quality research activities are topical not only on a local, but on a global level as well.

Furthermore, Rezekne River flows through protected natural area Raznas National Park and natural rezerve ”Lubāna Mitrājs”, which are Natura 2000 territories. However, this river has been rarely comprehensively studied. Most of Rezekne River territory consists of polders. The river works as a buffer decreasing the pressure of Rezekne River upper flow before its mouth in Lake Lubāns. Rezekne River flows through agricultural, meliorated and densely populated areas. The lenght of Rezekne River section in Rezekne city is approximately 10 km (about 6.21 mi). Knowing the magnitude of wastewaters and biogenic elements flowing in the Rezekne River, it has been stated that collected and treated wastewaters have a significant impact on the Rezekne River. In separate Rezekne River stretches the regulations for significant fish water areas are violated and some swimming areas do not meet the quality requirements in a long-term perspective, which means there is a threat that water quality is not stable and can decrease from time to time (Daugava River Basin Management Plan, 2009, [10]).

B. *Sampling sites and methods used in water quality monitoring*

In seasonal studies 2012 (June - August) samples were collected and the chemical and physical qualities of the Rezekne River water were investigated.

The basin of the Rezekne River occupies 2025.7km^2 (about half the area of Rhode Island, USA). The total river length is 116 km (about 72.08 mi). The Rezekne River width varies from 6 to 20 m on average, depth – 0.8 – 2.0 m. Annual average run-off of the river is 0.2 km^3, run-off is also regulated by locks of the Kaunata Lake at the river source. The river speed flow varies from 0.2 to 0.7 m/s. In the upper part of the river basin there are significant inflows from lakes, but in the lower part – from the marshes.

The pressure of dissipated pollution is found significant in 13 water objects in the Daugava River area and in the Rezekne River as well. That is mostly because of phosphorus that flows in the river. The ecological quality of the Rezekne River at this moment can be valued as moderate or bad – the main threats are diffuse and point sources of pollution (Daugava River Basin Management Plan, 2009, [9]).

The largest settlements on Rezekne Riverbanks are Rēzekne, Kaunata, Stoļerova, Ratnieki, Sprūževa, Greiškāni. In several villages the obsolete treatment plants cannot fully clear municipal wastewaters, thereby partially treated or non-treated wastewaters are discharged directly or through the drainage ditches into the Rezekne River. Rezekne city wastewater treatment plants (WWTPs) are in the Rezekne River protective areas and treated wastewaters flow in Rezekne River (Company „Rēzeknes ūdens”). Rain wastewaters and municipal wastewaters from private households, which are densely built along the riverside line and are not connected to a central sewerage system, by filtering through the grounds, are flowing into the Rezekne River within the Rezekne city area.

Downstream at Žogoti, westwards from the left riverside, there are fishponds of "Nagļi” fisheries that are filled from the Malta River, but during the fishing season are discharged in the Rezekne River, heavily polluting it with organic matters (Vanagalis et al. 2012, [11]). Near the Sakstagals village a large dolomite mining quarry is arranged with the removal of wastewaters through drainage ditch, thereby wastewaters flow in the Rezekne River. Land around the Rezekne River is widely used and due to fertile soil in upper and middle course it is especially used in agriculture. Sources of pollution in the Rezekne River are from: 1. municipal and industrial discharges, 2. overland flow from developed watersheds containing nutrients from garden fertilizers 3. additional organic debris so easily washed from urban surfaces and agricultural areas. These diverse pollutions contribute to nutrient increase through poor manure and fertilizing practices and increased erosion from plowed surfaces, thus making the overall chemical quality of water in Rezekne River worse, leading to an exacerbation of the river euthrophication process.

Fig. 8 presents the Rezekne River sampling sites from the outlet from Lake Razna to the mouth in Lake Lubans (19 sampling sites) on 16 June, 30 August 2012.

Measurements of physical - chemical parameters of river water were carried out taking samples from the banks of the Rezekne River in the upper layers (0.5 - 1 m depth). Water temperature (°C), pH, conductivity (mS cm^{-1}), dissolved oxygen (DO) (mg l^{-1}), turbidity (NTUs), oxidation reduction potential (ORP) (mV), chlorophyll-a (µg l^{-1}), blue-green algae (cell ml^{-1}) were measured with a HACH Hydrolab DS5 Sonde. Chemical oxygen demand (COD) was measured with a photometer DR-2800 manufactured by Hach Lange (USA). The number of ions in nitrates (NO_3^-), phosphates (PO_4^{3-}), ammonium (NH_4^-), sulphates (SO_4^{2-}) was defined with Hach Lange (USA) photometer DR-2800, NO3- concentration determination was used approbated in Latvia standard method LVS ISO 7890 3:2002; for PO43- determination – LVS EN 1189:2000. Total Cu and Cr were measured by using an inductively coupled plasma-optical emission spectrometry (ICP-OES) system model Optima 2100 DV from Perkin–Elmer TM.

Environmental characteristics of the Rezekne River at the surveyed sites are presented in Table II. None of the studied parameters except copper (Cu^{2+}), chromium (Cr^{3+}) and ammonium ions (NH_4^-) exceeds Regulation No. 118 of Cabinet of Ministers of the Republic of Latvia - Regulations Regarding the Quality of Surface Waters and Groundwaters. Concentration of Cu in 17 sampling places exceeds the allowed average concentration per year (MCY) (0.009 mg l^{-1}) and in 2 sampling sites exceeds regulation No. 118 regarding cyprinid waters (< 0.04 mg/l). Concentration of Cr in 14 samples exceeds MCY (0.011 mg l^{-1}) according to the Regulation No. 118. Concentrations of Cu^{2+}, Cr^{3+} metal ions gradually increase from the source of the Rezekne River, reaching peak at the inflow into the Lake Lubans. Concentration of NH_4^- ions in all samples does not exceed the upper limit according to regulation No. 118 related to the cyprinid (freshwater fish) waters (< 0.78 mg l^{-1}) and exceeds the target value (< 0.16 mg l^{-1}). The Rezekne River pH ranges from 6.9 to 8.8 and corresponds to the Regulation No. 118- limit for cyprinid fish waters 6.5-8.5. The levels of phosphate, conductivity, and chlorophyll increase from the Rezekne River source to the river mouth as shown in Fig. 9 and Fig. 10.

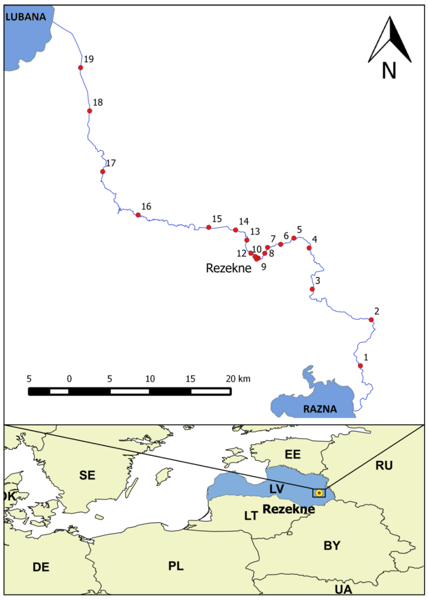

Fig. 8. Sampling sites in the Rezekne River during the expedition of 2012–2013.

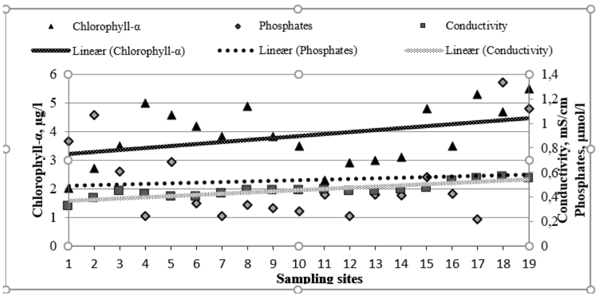

Fig. 9. Conductivity, chlorophyll-a, phosphate concentration in the Rezekne River during June 2012.

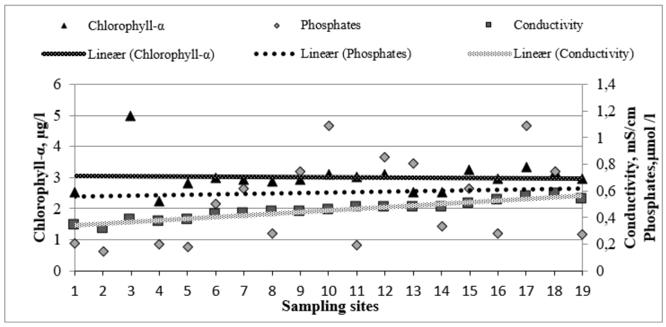

Fig. 10. Conductivity, chlorophyll-a, phosphate concentration in the Rezekne River during August 2012.

TABLE II ENVIRONMENTAL CHARACTERISTICS OF THE REZEKNE RIVER AT THE RESEARCHED SITES IN THE CONTEXT OF ASSESSING NWQC

Parameter	Minimum	Maximum	Mean value	Standard deviation
Temperature, ∘C	6.9	24.0	17.5	7.6
pH	6.9	8.8	8.1	0.2
Conductivity, µS cm^{-1}	320	570	422	134
DO, mg l^{-1}	3.3	12.1	10.1	3.9
ORP, mV	303	355	320	14.6
Chlorophyll-α, µg l^{-1}	2.02	5.52	3.62	0.91
Blue-green algae,cell ml^{-1}	147	1059	428	277
Turbidity, NTUs	1.6	28.6	8.0	13.0
COD, mg l^{-1}	10.7	32.0	20.8	1.8
SO_4^{2-}, mg l^{-1}	7.0	9.9	8.5	7.8
NH_4^-, mg l^{-1}	0.23	0.72	0.41	0.22
PO_4^{2-}, mg l^{-1}	0.02	0.19	0.07	0.07
NO_3^-, mg l^{-1}	1.11	5.50	3.51	2.26
Cu, mg l^{-1}	0.007	0.045	0.019	0.012
Cr, mg l^{-1}	0.007	0.012	0.011	0.005

V. WATER QUALITY DURING THE COVID-19 PANDEMIC

Reports in scientific platforms and popular media indicate that both air and water quality improved during the period of two years dominated by Covid-19 and the associated lockdowns imposed by many nations lasting extended periods during the pandemic. The parameters of Table I used in assessing the quality of water showed a clear indication of improvement in many countries, [12]. During the period of the Covid-19 pandemic, there have been reports on improved water quality in Venice, with an increase of aquatic life. Central Pollution Control Board (CPCB) of India, [13], also reported a considerable improvement of water quality during the pandemic, [13], and has links to real-time monitoring of water quality in sites located in several rivers and lakes in India.

VI. IOUT AND EDUCATION IN EE & IT

United Nations has water quality as one sustainability development goals (SDG). Internationally, there is a strong movement to address the SDGs in academia, industries, and other organizations. With the combined contents of EE, IT and environmental awareness in addressing IoUT and NWQC in education, the SDG 14 can also be addressed successfully. One of the main goals of UN SDG 14 is preventing and significantly reducing water pollution of all kinds, from land-based activities, including marine debris and nutrient pollution. In recent years, the awareness of plastics and microplastics in lakes, rivers and oceans have created an urgent need for dedicated IoUT solutions to combat this problem. The topic of IoT is also under focus in the International Telecommunication Union (IT as discussed in different applications related to digitalizing water for smart cities also addressing WCS, [14]. The growing implications of IoUT and their applications in diverse sectors are discussed in [15] and [16]. This approach has also some positive influence in contributing to STEAM+ in tertiary educational strategies for attracting all genders to EE and IT courses, [17]. Students and staff of this community should try to contribute to these initiatives and the SDG of the UN. Fig. 11 shows a scenario of integrating SDG 14 in an EE-curriculum, supporting the vision of the UNESCO, a strategy increasingly adopted by many leading universities.

The approach of incorporating technical and environmental topics in EE-curricula enables reflective practice in a course adopting PBL with groups of students working with different aspects of the same problem related to WCS and NWQC. Stand-alone ocean buoys have been in use for many decades and new applications with a network of intelligent buoys are emerging for professional shipping and sports activities along the coasts with IoT/IoUT with 5G-networks and Satellite communications [22]. Using animal-borne sensors, taking care of animal welfare, a new technology is evolving exploiting the possibilities offered by IoT/IoUT in performing measurements in oceans, lakes, and rivers, [23].

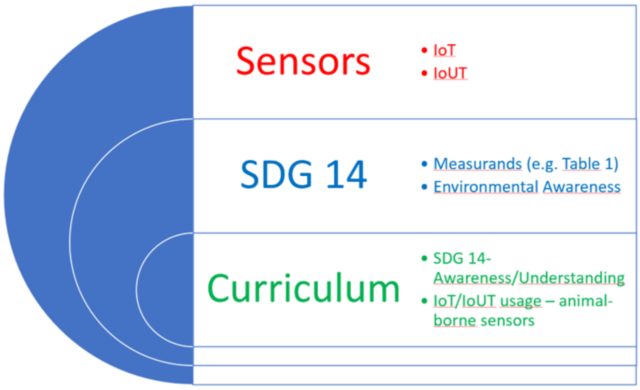

Fig. 11. Integration of SDGs in curricula, R&D and other technical, social and economic activities. SDG 14. SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development, [21].

VII. CONCLUSIONS

It is interesting to see the increasing technological push addressing measurands relevant for NWQC based on the effects of the industries, agriculture, and maritime activities. The Environmental Protection Agency (EPA) has been actively involved with the development of Water Quality Surveillance and Response Systems (SRM) and guideline for their functions. A system delivering valuable and timely information is essential as shown in Fig. 12.

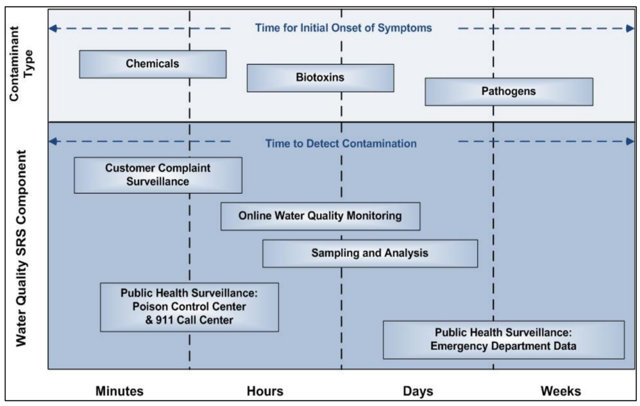

Fig. 12. Health Consequences and Detection by Surveilance and Response System (SRM) Components with their response times, [18].

EPA also has suggested a dashboard design meant to help users to assess the parameters of relevance, like those discussed in Table I, for assessing the NWQC, as reproduced in Fig. 12, from [18]. The technology involved in the development of such SRS systems is by nature interdisciplinary and encourages collaboration of actors in EE and IT sectors. The diverse types of technologies and users are illustrated in Fig. 12, which shows the main actors and services needed for an effective SRS in the context of checking water quality against NWQC.

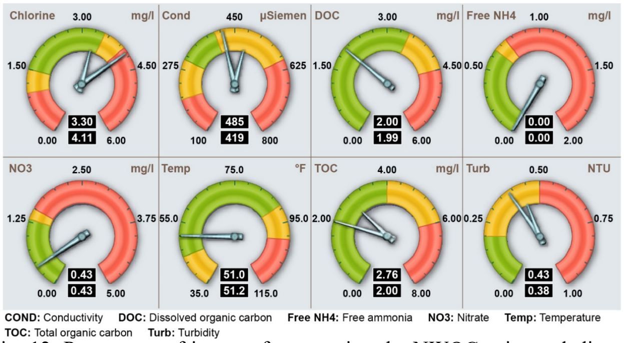

Fig. 12. Parameters of interest for assessing the NWQC using a dedicated Surveilance and Response System, as envisoined by EPA Water Security Division, [18].

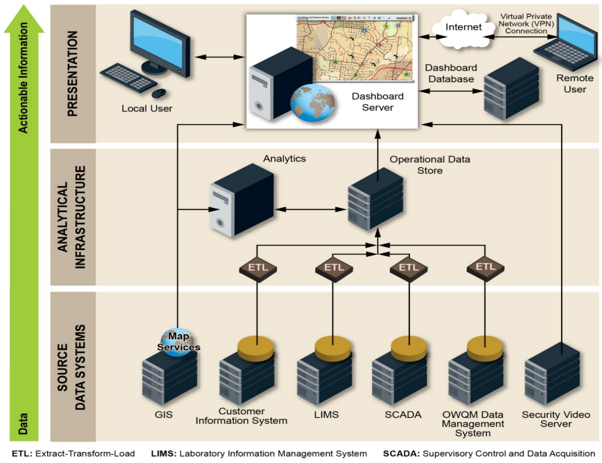

Fig. 13. Schematic of a system for the integration of different services and sectors for SRS in the context of assessing NWQC, [19], integrated with Geographical Information System (**GIS**). The shown schematic allows the different push services available in different mobile Apps, such as WhatsApp, Facebook etc.

It is appropriate to refer to a Norwegian initiative using IoT/IoUT with underwater wireless communication technologies along the coast of Norway for the benefit of marine based technologies with focus on HSE involving major industrial and academic actors, with the Department of Physics and Technology of University of Bergen as the host, [24].

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References

[1] Schwarzenbach, R.P., Escher, B.I., Fenner, K., Hofstetter, T.B. , Johnson, C.A., U. von Gunten, U., Wehrli, B. 2006 The Challenge of Micropollutants in Aquatic Systems, Science, 313, 1072 -1077.

[2] Mylvaganam, S., Jacobsen, T., 1998 Turbidity Sensor for Underwater Applications: Sensor Design and System Performance with Calibration Results, DOI: 10.1109/OCEANS.1998.725727 Source: IEEE Xplore , Conference: OCEANS '98 Conference Proceedings, Volume: 1

[3] Korostynska, O., Mason, A., Al-Shamma'a, A., 2012 Monitoring of Nitrates and Phosphates in Wastewater: Current Technologies and further Challenges, International Journal on Smart Sensing and Intelligent Systems, Vol. 5, No. 1,149-176.

[4] World Health Organization, "Water and sanitation", 2022. [Online]. Availible : https://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation. [Accessed: Mai, 2, 2022].

[5] World Health Organization, "Water Sanitation and Health", 2022. [Online].Availible:https://www.who.int/water_sanitation_health/water-quality/guidelines/en/. [Accessed: Mai, 2, 2022].

[6] Halvorsen, H-P., Grytten, O.A., Veel Svendsen, M., Mylvaganam, M. 2018 Environmental Monitoring with focus on Emissions using IoT Platform for Mobile Alert — EAEEIE, The 28th EAEEIE Annual Conference, Reykjavík.

[7] Roseth, R., Johansen, Ø., Leikanger, E., Nytrø, T.E., Tveiti, G., Rise, Ø., Skarbøvik, E. 2014 On-line målinger av vannkvalitet i vegutbyggingsprosjekter – erfaringer, The Norwegian Public Roads Administration, Bioforsk Rapport 9(5)14

[8] Kiedrzyński, M., Urbaniak, M. , Magnuszewski , A., Wyrwicka A., Zalewski M., 2014 . Point sources of nutrient pollution in the lowland river catchment in the context of the Baltic Sea eutrophication. Ecological Engineering 70: 337–348.

[9] Kiedrzyńska, E., Jóźwik., A, Kiedrzyński, M., Zalewski, M., 2014 . Hierarchy of factors exerting an impact on nutrient load of the Baltic Sea and sustainable management of its drainage basin. Marine Pollution Bulletin 88(1-2): 162-173

[10] Daugava River Basin Management Plan, 2010-2015/ in Latvian: Daugavas upju baseina apgabala apsaimniekošanas plāns 2010. – 2015.gadam/, 2009. Source: http://www.meteo.lv/upload_file/ 09_upju_baseinu_apsaimniekosana/2009-12-22/Daugava/ VIDMPlan_Daugava.pdf

[11] Vanagalis, A., Razmus, P., Meidus, E., Teirumnieka, Ē. 2012. Investigation of water quality of Rezekne River. International Scientific Practical Conference Environment. Technology. Resources. 16: 347-354

[12] Khan, I., Shah, D., & Shah, S. S. 2021 COVID-19 pandemic and its positive impacts on environment: an updated review. International journal of environmental science and technology : IJEST, 18(2), 521–530. https://doi.org/10.1007/s13762-020-03021-3.

[13] Central Pollution Control Board (CPCB), "Water Pollution" 2019. [Online]. Available: https://cpcb.nic.in/water-pollution/. [Accessed: Mai, 2, 2022].

[14] Daniel Paska, "Digitalized Water for Smart Cities", 2018. [Online]. Available: https://www.itu.int/en/journal/002/Pages/03.aspx. [Accessed: Mai, 2, 2022].

[15] Kao CC, Lin YS, Wu GD, Huang CJ. A, 2017, Comprehensive Study on the Internet of Underwater Things: Applications, Challenges, and Channel Models. Sensors (Basel); 17(7):1477. doi: 10.3390/s17071477. PMID: 28640220; PMCID: PMC5539468.

[16] Jahanbakht, M., Xiang, W., Hanzo, L., Rahimi Azghadi, M. 2021 "Internet of Underwater Things and Big Marine Data Analytics—A Comprehensive Survey," in *IEEE Communications Surveys & Tutorials*, vol. 23, no.2, pp.904-956, doi: 10.1109/ COMST.2021.3053118.

[17] Timmerberg, J. Halvorsen, H-P, Viumdal, H, Mylvaganam, S. 2021 "Sustainability Awareness through STEAM+". Nordic Journal of STEM Education. 5. 10.5324/njsteme.v5i1.3974.

[18] EPA Water Security Division, 2015, Water Quality Surveillance and Response System Primer, United States Environmental Protection Agency.

[19] EPA Water Security Division, 2019, Dashboard Design Guidance For Water Quality Surveillance and Response Systems, United States Environmental Protection Agency.

[20] One Planet Summit, "One Ocean Summit", 2022. [Online]. Available: https://www.oneplanetsummit.fr/en. [Accessed: Mai, 2, 2022].

[21] United Nations, "UN 2023 Water Conference", 2022. [Online]. Availible : https://sdgs.un.org/conferences/water2023. [Accessed: Mai, 2, 2022].

[22] Jet Engineering, "5G at Sea", 2022. [Online]. Available: https://jet-eng.co.uk/5g-at-sea/. [Accessed: Mai, 2, 2022].

[23] March, D. et al, 2019, Towards the integration of animal-borne instruments into global ocean observing systems, Global Change Biology, Volume 26, issue 2, P586-596 , DOI: 10.1111/gcb.14902.

[24] Centere for Research-based Innovation, "SFI Smart Ocean", 2022. [Online]. Available: https://sfismartocean.no. [Accessed: Mai, 2, 2022].