Feasibility analysis of marine ecological on-line integrated monitoring system

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Abstract. The in-situ water quality sensors were susceptible to biological attachment. Moreover, sea water corrosion and wave impact damage, and many sensors scattered distribution would cause maintenance inconvenience. The paper proposed a highly integrated marine ecological on-line integrated monitoring system, which can be used inside monitoring station. All sensors were reasonably classified, the similar in series, the overall in parallel. The system composition and workflow were described. In addition, the paper proposed attention issues of the system design and corresponding solutions. Water quality multi-parameters and 5 nutrient salts as the verification index, in-situ and systematic data comparison experiment were carried out. The results showed that the data consistency of nutrient salt, PH and salinity was better. Temperature and dissolved oxygen data trend was consistent, but the data had deviation. Turbidity fluctuated greatly; the chlorophyll trend was similar with it. Aiming at the above phenomena, three points system optimization direction were proposed.

1. Preface

The impact of human offshore activities on the marine environment should not be overlooked, "2013 China Marine Environmental Quality Bulletin" pointed out: coastal seawater pollution was still serious, and it was China's marine ecological environment damage "hardest hit". Marine environmental pollution was increasing, marine ecological structure had been destroyed. Red tide and oil spills and other ecological disasters occurred frequently. Economic losses of aquaculture often occurred. In addition, sustainable development of marine economy was facing severe challenges. "National Science and Technology to revitalize the marine planning outline (2008 - 2015)" proposed that it was necessary to carry out stability test and popularization of the marine ecological environment monitoring equipment, and construct long-term ecological environment observation platform. China established ocean station in the coastal since the early 20th century. Then the country continued to invest special funds. Now we possessed more than 100 marine observatories (points) and more than 120 in-situ buoy over 6 meters. But the observation parameters were mainly based on the hydrology and meteorology, seawater ecological monitoring was almost blank. This caused the waste of platform resources. With the support of the National 863 Program, water quality sensors developed rapidly, and appeared a number of sensors which were based on optical method, spectrometer, wet chemical system, electrochemical system and so on [1]. This provided a strong hardware support for the marine ecological monitoring.

2. Current research

The development trend of marine environmental monitoring was from single parameter to multi-parameter integration. Finally, a regional Marine monitoring network was formed. The development of the regional monitoring system in abroad was earlier, such as: the America Maine Bay Ocean Observing System (GoMOOS), the Chesapeake Bay Monitoring System (CBOS), the Mexico Coast Marine Observing System (GCOOS), Norway EAWATCH EUROPE marine integrated observing system, the German MERMAID system and the small multi-parameter integrated monitoring system (Ferrybox, Integrated monitoring system construction in domestic behind foreign about 10 years. Since the 21st century, we had built "Shanghai marine three-dimensional monitoring system (demonstration area)", "Fujian sea real-time three-dimensional monitoring system" and "Pearl River estuary marine environment comprehensive monitoring system" [2, 3].

Water quality monitoring system was an important part of the regional marine monitoring network. A large number of researches had been done in domestic. The research work mainly focused on the multi-sensor data acquisition circuit and the host computer software development [4-7], establishment of evaluation model and system [8-11], integrated monitoring and management [12-14], and so on. Zhou Bing [15] proposed a water quality automatic monitoring laboratory integrated management system, his ideas were more open. Except the management of online water quality sensor, the laboratory management work was included to ensure the normal operation of the system. In recent years, the study of biological toxicity for seawater environmental assessment had rapid development [16], this development direction can't be ignored.

On the whole, in the domestic, marine water quality on-line integrated ecological monitoring system was mainly based on in-situ sensor, single parameter or multi-parameters combination. The drawbacks of this program were that the sensors were relatively discrete, not easy to maintain. In addition, the in-situ sensors which were long-term laid underwater, would be susceptible to biological attachment, corrosion, wave impact. The effect was particularly serious for optical sensors. The paper will propose a highly integrated marine ecological on-line integrated monitoring system to solve the above problems. The paper mainly introduced the system design ideas, as well as the system construction plan and the considerations. By comparing the data obtained by the in-situ sensor and the integrated system, the paper analyzed the feasibility of marine ecological on-line integrated monitoring system which was established inside monitoring station. The establishment of the integrated monitoring system would accelerate the application of independently developed water quality sensor, and form a rich marine ecological observation network system to obtain comprehensive monitoring data, and provide reliable basis for ecological disaster warning and marine environmental protection and management. This had far-reaching significance.

3. System construction

Marine ecological on-line comprehensive monitoring system could simultaneously monitor various parameters to meet the necessary of regional marine monitoring, and obtain continuous and complete data for assessment of regional water quality or disaster warning. It is a highly integrated system, the main design idea was: "put up" as much as possible in-situ sensor from underwater, then reasonably classified, and placed in cabinet within the monitoring station or buoy, in accordance with the similar in series, the overall in parallel way, weaken the maintenance difficulty. Ultimately, the filtered water was analyzed. At the same time, the system could set measure frequency according to the change law of seawater quality parameters, and achieve sampling, analysis, pipeline cleaning, data processing and transmission automation.

Firstly, hydrodynamic unit was necessary. It overcame the tidal effects, then provided seawater samples for the system. The seawater samples were pumped into integrated monitoring system. Secondly, the system formed detect branch through reasonable pipeline design. The water quality sensor was classified according to the principle of testing and the requirement of water samples, then laid in the detection flow path. The host computer obtained the water quality analysis data through the serial port. Finally, the data was displayed in real time on the system display, and synchronously

processed and remotely transmitted to the monitoring center station or other supervisor units.

According to the above ideas, the system should contain at least the water distribution unit, various water quality sensors, data acquisition unit, control unit, data storage and transmission unit. About the water sample collection and distribution unit, the water can't be filtered for some sensors (such as turbidity sensors). Otherwise, it would cause data distortion, couldn't truly reflect the water quality of the tested sea area. However, for some sensors that use micro-channel detection (such as nutrient sensors), filtering is necessary. Otherwise, the instrument couldn't be used normally. Therefore, the allocation unit should contain at least two paths. The control unit used Advantech's small industrial computer and configuration display. The industrial computer performance was stable, with a wealth of serial resources. In addition, the use of configuration software greatly simplified the system control process, could effectively shorten the development cycle. The control unit could set the sensor running mode (continuous operation or regular operation) according to the scheduled program. When the component failed, the control unit could respond to fault diagnosis, and the fault alarm information was sent to the management center, in order to timely repair. According to the agreed protocol, the data acquisition unit obtained the data of the sensor through the serial port after receiving the completed instruction, then stored it in the storage unit. When all sensor data were acquired, the DTU module (model H7110), which was preset IP address and port number, was connected with the monitoring center station or other supervisor, then remotely transmit data using the TCP protocol.

Figure 1 showed the system workflow, with two detection branches, using parallel design. One of the branches was a loop, composed of a single parameter sensor (7, 8, 9) in series, without filtering. The other was a nutrient analyzer branch, with two-stage filter, the former using gauze, the latter using a stainless steel filter. The system had a buffer tank, PC controlled solenoid valve switching and pump start or stop during operation to achieve sensor measurement on the corresponding branch. In addition, in order to prevent the pipeline biological attachment, the system had chemical reagent cleaning and water rinse. Cleaning work could maintain the best filtration capacity, extend the service life.
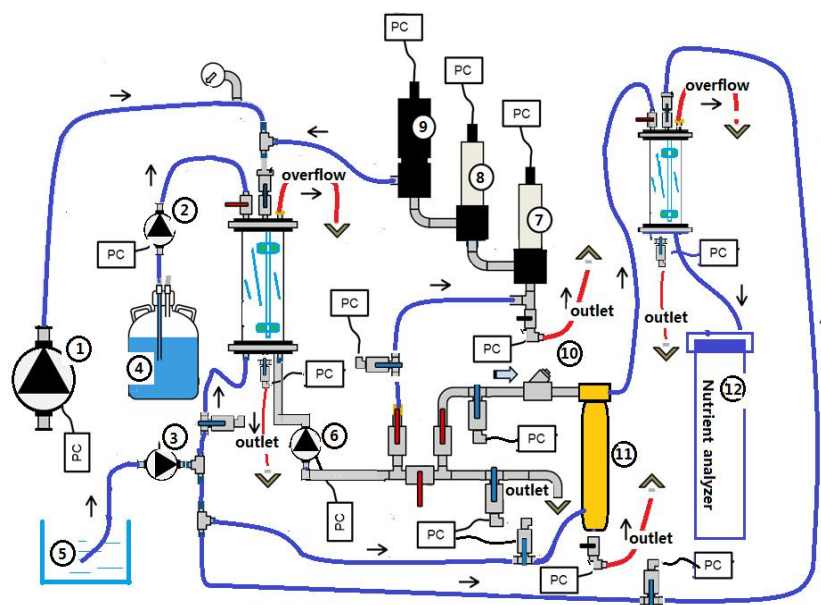

Figure 1. System workflow.

1. Water pump; 2. Diaphragm pump; 3. Circulating pump; 4. Chemical cleaning solution; 5. Water bucket; 6. Circulating pump; 7. Sensor; 8. Sensor; 9. Sensor; 10. Gauze filter; 11. Stainless steel filter; 12. Nutrient analyzer.

4. Technical solutions

To ensure the system normal operation, the collected data was true and effective, except the

measurement of the sensor itself was stable and reliable, the system design also need to pay attention to the following questions: 1. Sampling unit must be able to fully reflect the water quality characteristics of the sampling area, a reasonable sampling point was very important. 2. Need to avoid the residual water samples causing cross-pollution, flooding the real data. 3. The sensor detection chamber on the flow path must be reasonable designed to avoid producing optical pollution, that may cause measurement distortion for optical sensor. 4. The filter system should be reasonable and reliable. The article will take Zhoushan monitoring station as an example, and present the solution of the above problems.

About problem 1, the Zhoushan monitoring station was located near the pier, often had boat in nearby, the normal tidal range within 5 meters. The sampling site should be fully considered, the water exchange was smooth, the water was even. There are two ideas for the design of the pump: submersible pump or vacuum pump. Vacuum pump could use dual-pump structure, alternating use or a failure to start another. This solution could increase the reliability of the water system, this is the advantage. But the suction of vacuum pump was limited, it couldn't be used in some large tidal stations. For Zhoushan monitoring station, the system maximum sampling height was 7-8 meters, and about 2 meters after into the room. Finally, large lift submersible pump program was used. It was made of 316 stainless steel, 15 meters lift. To overcome the tidal effects, and collect a fixed depth of water samples, a small special floating structure was designed. The submersible pump was fixed at the bottom. At the same time, sampling pipeline was reserved sufficient length to meet the needs of the tide, using U-type layout program. The floating body was easy to float with the sea wave, or suffer disturbance of the passing vessel. So it was difficult to maintain the same sampling point. Therefore, the system design drew on the design ideas of the temperature and salt wells, using PE / UPVC pipe to construct an artificial sampling well. The well could fix and protect floating components. Without affecting the strength of the sampling well, the sidewalls should be as much as possible to drill water exchange holes. This could ensure that water quality uniform inside and outside of the sampling well. Sampling well and floating body design shown in figures 2 and 3.

Figure 2. Sampling wells.   **Figure 3.** Floating body.

The solution to the problem 2 was: Firstly, optimized the flow path design, all pipelines outlet slightly lower than inlet, reduced unnecessary turning, as far as possible using vertical pipe layout, shorten the length of the horizontal pipeline. The bottom of the system designed water collection cavity. The water samples centralized discharged from it. In order to avoid the solenoid valve failure, the overflow pipeline design was necessary. Secondly, open all the solenoid valves before each measurement, using the fresh seawater to wash the last detection residual samples, and ensure that the data were valid in real time.

For the problem 3, the bottom of the detection chamber to the optical sensor head (such as water quality multi-parameter sensor) should reserve sufficient distance, at least 12 cm. In order to reduce air

bubbles, water samples should inject from below and discharge from above.

For the problem 4, the filtration system used multistage filtration. Submersible pump set primary filtration, filtered out algae, weeds and so on. The secondary filter was set according to the requirements of the sensor. For example, the pre-filtration of the nutrient sensor used 0.45 micron filter diameter. Prior to the use of powder sintered stainless steel filter. The strength was high, the pressure at the dead end was strong, the higher recoil pressure ensured that washing effect was better.

5. Comparison experiment

After the system was built, we carried out mass experiment to study the feasibility of the system installed in Zhoushan, respectively using the ALEC sensor and the nutrient analyzer (independent research and development). The two kind instruments were laid in different flow paths, the former didn't need filter, the latter need filter twice. The test protocol was that each instrument prepared two sets, one set placed in the sampling well, the other set placed in the system. Figures 4-9 showed the data for the ALEC multi-parameter, obtained at 2016.5.20 evening and the morning of 5.21. Figures 10-14 showed the data obtained by the nutrient analyzer.
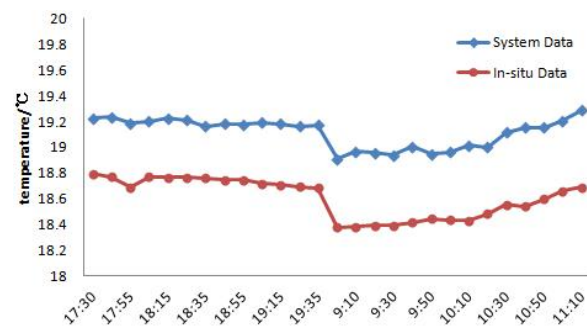

Figure 4. Turbidity.
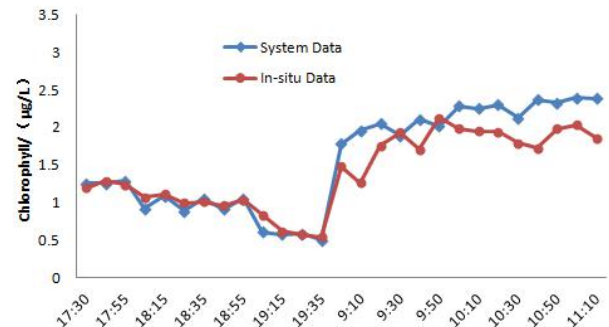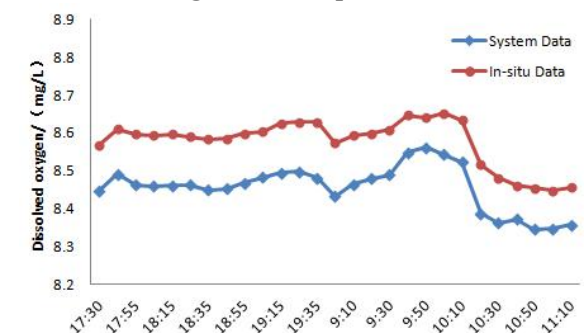

Figure 5. PH.

Figure 6. Temperature.

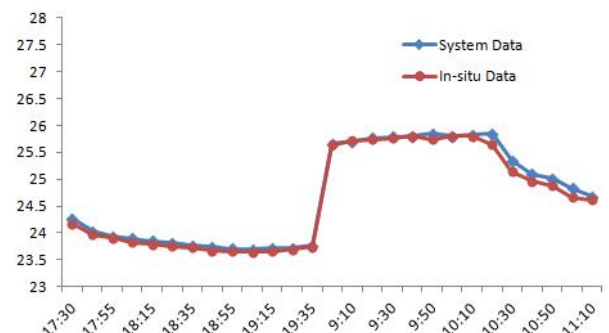**Figure 7.** Chlorophyll.
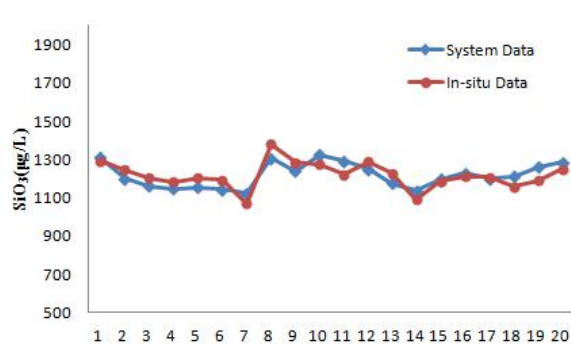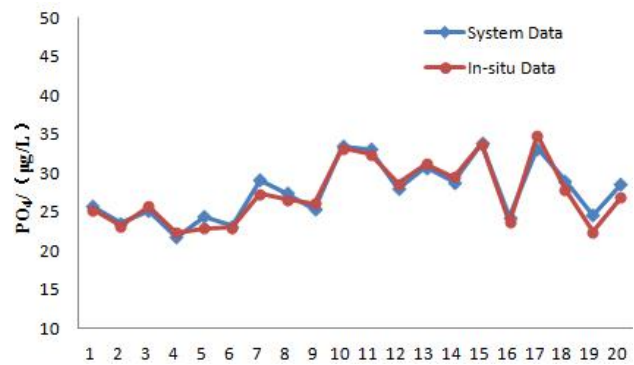

Figure 8. Dissolved oxygen.
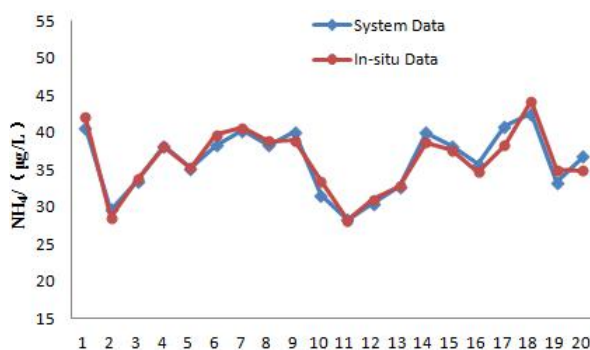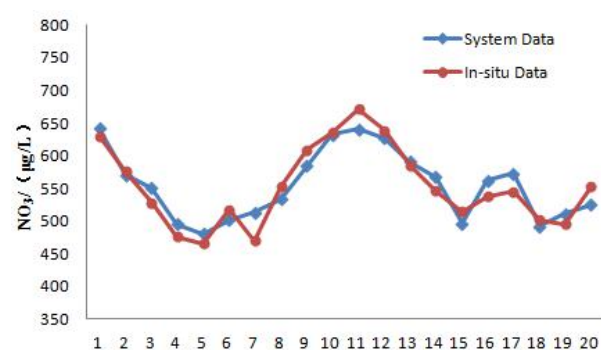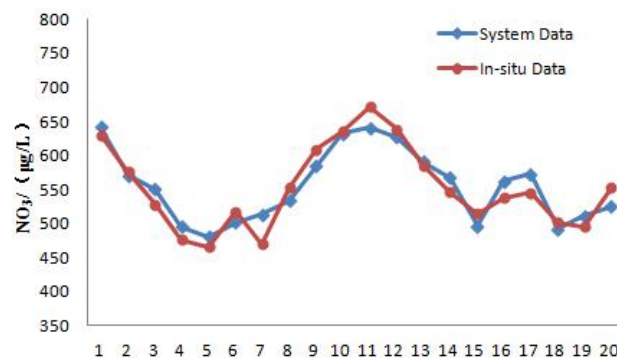

Figure 9. Salinity.

Figure 10. SiO$_3$.

Figure 11. PO$_4$.

Figure 12. NH$_4$.

Figure 13. NO$_3$.

Figure 14. NO$_2$.

Through the data comparison, we found PH and salinity data consistency was very good. Although the temperature and dissolved oxygen data trend was consistent, but the system temperature data higher than situ data 0.4-0.5℃, the system dissolved oxygen data lower than situ data 0.1-0.15 mg/L, the turbidity and chlorophyll data on 5.20 was consistent, but more volatile on 5.21.

The temperature data phenomenon may have two reasons: 1. The sampling well was constructed by the black PE pipe, which was easy to absorb heat causing temperature rise. The flow hole of the sampling well may be poorly designed. 2. Under the action of the submersible pump, the seawater was subject to shock and friction. Perhaps was the result of combination of two factors. The reason for dissolved oxygen data may be the occurrence of escape during the sample and measurement process. Turbidity and chlorophyll data on 5.20 were obtained in the evening, no fishing boat passes, the water was relatively stable, while the data on 5.21 were affected by fishing boats and passenger ships. A mass of muddy water was around the monitoring station, the water quality was uneven. Obviously, the

chlorophyll data had similar fluctuations with turbidity.

SiO_3 salt instrument performance indicators was ± 5% error, while figure 10 showed 15% of data exceed the error, the maximum deviation was 6.03%. PO_4 salt instrument performance indicators is ± 3% error, while figure 11 showed 20% of data exceed the error, the maximum deviation was 7.82%. NH_4 salt instrument performance indicators was ± 5% error, while figure 12 showed 15% of data exceed the error, the maximum deviation was 6.53%. NO_3 salt instrument performance indicators was ± 5% error, while figure 13 showed 10% of data exceed the error, the maximum deviation was 9.04%. NO_2 salt instrument performance indicators was ± 3% error, while figure 14 showed 10% of data exceed the error, the maximum deviation was 3.64%.

6. Conclusion

Feasibility analysis showed that the same kind of nutrient data was consistent, limited by the number of samples and the stability of the nutrient analyzer itself, need long-term verification. The consistency of pH and salinity data in the multi-parameter was good, the temperature data obtained by the system was 0.4-0.5 ℃ higher than in-situ. The dissolved oxygen data obtained by the system was 0.1-0.15 mg/L lower than in-situ. Turbidity and chlorophyll data was not ideal, turbidity volatility was large, causing chlorophyll fluctuations. In general, the marine ecological on-line integrated monitoring system was feasible. The system need to be optimized, optimization direction: 1.Reasonably set the submersible pump and circulating pump flow rate, reduce air bubbles. 2. Improv the sampling well program, open more exchange holes without affecting the strength of well. In addition, may consider removing the sampling wells, using open sampling program. 3. Adjust the measurement process, increase the emptying time to ensure that there is no residual water sample or recoil tap water.

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