APPLICATION OF INTEGRATED AUTOMATIC MONITORING SYSTEM WITH WATER SIMULATION PLATFORM ON INCREASING EFFICIENCY OF IRRIGATION WATER QUALITY MANAGEMENT

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ABSTRACT

In Taiwan, irrigation water is polluted by the discharge of industrial and domestic wastewater into irrigation channels In Changhua County, the density of industrial area is relatively high, and surrounding the agricultural land making it difficult to identify the area of pollution. This study evaluates the integration of automatic monitoring systems (AMS) and water simulation platform on increasing management efficiency of the agricultural framework by ensuring the irrigation water was free from the risks of heavy metal pollution. In this study, a heavy metal-automatic monitoring system (AMS) was equipped at the drainage channels to record real-time water quality data and the data were retrieved via the cloud system. Data collected would be imported into a "water simulation platform" to indicate possible pollution receptor regions. In this study, statistical data from the past 15 years were collected via the AMS cloud system and data from Sept-Dec 2017 were applied for simulation.

It was discovered that most water quality anomalies occurred during evening and night-time. Meanwhile, in order to determine the diffusion area of pollution, simulation via the water simulation platform was used to increase the inspection efficiency. A water simulation platform transformed from the Water Quality Analysis Simulation Program (WASP) was visualized as a user-friendly web-based system with temporal-spatial data.

Users of the platform could assess the scenarios at the irrigation area, followed by customizing the parameters according to the data received from AMS. Simulation results of Hsinzhen channel were aggregated into a comprehensive table in a form of a conversion table containing parameters needed for simulations. Thus, while determining the region, processing via the platform or by referring to the conversion table were both feasible. Huge amount of time could be saved on the process as compared to conventional methods. The integration of AMS and water simulation platform are functional tools for irrigation associations while collaborating with the government's environmental inspection units. Finally, amendments for water quality management measures could be improved and enhanced.

Keywords: Irrigation water, Automatic monitoring systems, Water simulation platform, Water Quality Analysis Simulation Program, Water quality management measures.

1. INTRODUCTION

Taiwan's agricultural land measured approximately 793,026 hectares in 2017. Changhua County is located between Wuxi River and Zhuoshuei River. To the north of the county are Pinglin River and Maoxi River, while to the west is the Taiwan Strait. The topography showed an inclination from south-east to the north-west. It is 43km long and 30km wide, presenting a figure of a triangle. Agricultural land in Changhua

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made up 59,147 hectares, which was 0.08% of the nation's total, and making up 57.3% of the county's land area. The proportion was the second highest in the nation. There is no doubt on the importance of farming activities in Changhua, where its yearly paddy production was recorded up to 201,000~263,000MT.

The organizational structure of Changhua Irrigation Association (CHIA) was divided based on their geographical characteristics, resulting in the four regions including Changhua, Babao, Beidou and Nantou irrigation areas, in which each region contains different water systems. The irrigation and drainage systems of each region are shown in Figure1.

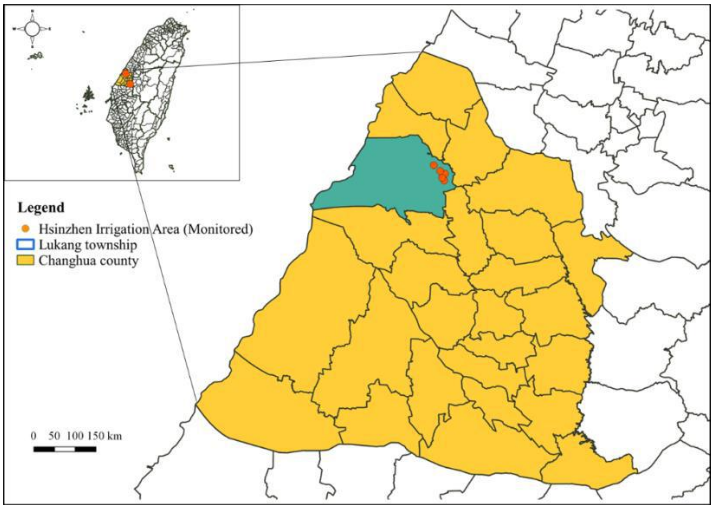

Figure 1. Hsinzhen irrigation area

Hsinzhen is a vital irrigation channel in Changhua. It was chosen as the study area of this research due to its major paddy farming production and it is located at the downstream of the county with a shoreline on the west-side. Based on the county's irrigational data, water usage were the highest during mid-March, early July and August to early November of a year, while the lowest usage was during December to January.

Despite the large amount of agricultural production in Taiwan, the irrigation water was polluted by industrial and domestic wastewater discharged into irrigation channels, where nearly 5% of the nation's irrigational water facing the risk of pollution. The CHIA carries out irrigation water sampling every 2 months, and the data showed that the water at Hsinzhen was facing Nickel pollution, where the concentration was recorded highest at its monitoring points at upstream and midstream, especially at the midstream, which a record of 1.5mg/L was inspected during a sampling in 2013. Meanwhile, the frequency of the concentration exceeded the limit value (0.2mg/L) was the highest at the Hsinzhen-2 monitoring point. On the other hand, two events happened at the Hsinzhen upstream. Channels of the study area are shown in Figure 2. In the figure, the regions in red were considered as high risk farming areas, which were located at the downstream of industrial plants. The irrigation water at the region could be polluted and thus effective management is necessary to protect the safety of water and food production.

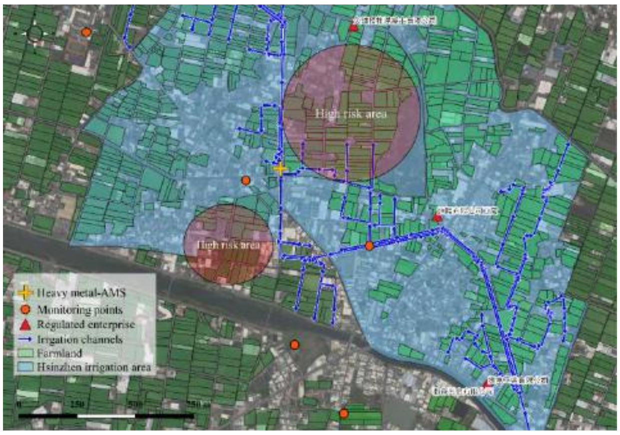

Figure 2. Channels of Hsinzhen, Changhua

This study aims to determine possible diffusion area of heavy metals pollution at Hsinzhen via new tools, which is the integration of automatic monitoring system (AMS) with a water simulation platform. At the end of the study, suitability of heavy metal's limit value would also be determined. The AMS equipped at the drainage channels could record real-time water quality data and as it was linked with the cloud system, real-time data retrieval was allowed a warning would be sent to the management units when exceed of limit value happened. Then, data would be imported into the simulation platform to indicate possible the pollution area.

Based on the reports of EPA in 2006 and 2014, the melting point of Nickel is 1453ºC, and the boiling point is 2732ºC. It was mainly used as a supplement substance in steel and metal alloy manufacturing process. Wastewater containing the pollutants would be discharged from the plating plants. The other pollutants could also found in the batteries, electronic devices, and fossil fuels. Nickel ions would bring toxic effects for human health which could kill cell organizations in human or cause allergic dermatitis. Therefore, it is vital to prevent Nickel from penetrating into the daily food production process.

2. METHODS

Water Quality Analysis Simulation Program (WASP) is a model created by the Manhattan College and was amended by the USEPA. It could be applied to determine water pollution through inputting parameters of the channel data and water quality. Data from 1 September 2017 to 31 December 2017 was collected and analyzed. Based on a Taiwan EPA report in 2013

In this study, WASP was used to simulate the water quality changes at Hsinzhen, by inserting scenarios where the channels were polluted by the wastewater discharged from the industrial regions upstream, and to determine the level of effects brought by the pollution. In order to enable instant reaction, the AMS plays an important role on sourcing the pollution since it returns frequent and continuous data of water concentration with time interval of 80 minutes. Therefore, data from the AMS could be applied to WASP for quick simulation.

Statistical data from the past 15 years were collected via the AMS's cloud-system. Normally, water quality anomalies occur during evening and night-time. Meanwhile, in order to predict the region and distance of the pollution, simulation via a "water simulation platform" was applied to significantly increase the inspection efficiency, which would be further discussed later on the next section.

The results were compared with the data collected by the environmental bureaus or irrigational associations. Besides, the model could help predict possible affected region to control the use of water, and hence to increase the effectiveness of monitoring and management tasks by the government.

Since there was no irrigation water control area at Hsinzhen and its irrigation water was influenced by wastewater from a number of factories upstream, information of registered factories were collected. The historical data from the monitoring points (location where the CHIA carry out sampling tasks) were analyzed. The following scenarios were designed to narrow down possible situations at the concerned regions:

Scenario 1: Wastewater was not discharged into the irrigation channels but anomalies occurred occasionally (current situation)
Scenario 2: Wastewater was not discharged into the irrigation channels but Nickel concentration was at the boundary of limit value
Scenario 3: Wastewater discharged into the irrigation channels and the amount of pollution needed to be assessed.
Scenario 4: Testing with the historical data to calculate the amount of accumulated pollution

The scenarios were designed based on the real situation happened in Hsinzhen, and to determine how the tools could assist in protecting water quality at the high risk region.

3. RESULTS

As WASP is a program that requires a series of parameter input, it takes time to obtain results. In order to enable more instant results of the pollution, a WebGIS platform was built through results obtained from WASP, and visualized as a user-friendly web-based system with temporal-spatial data. The platform could act as a tool to help simulate region of the pollution region as shown in Figure 3. It was created using languages including Javascript, HTML5 and CSS3 and integrated with open street map and Geojson format, and the grid data was obtained via Ajax for the visualization of results. The measurements of drainage systems were written into the platform, including drainage structures, water velocity and volume of the channels. One of the most impressive function of the platform was that users could generate results by simply changing parameters based on the events happened.

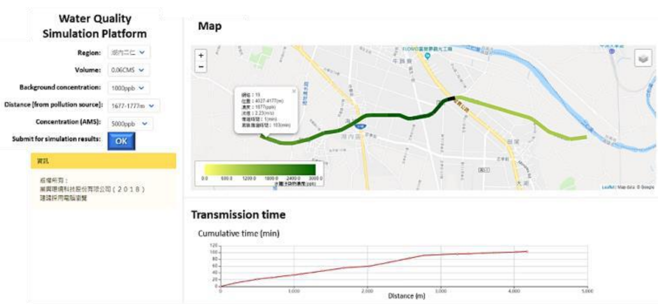

Figure 3. Water quality simulation platform

As seen from the Figure, the platform showed background information of the channels and the results were demonstrated with functions on switching the type of map. Most importantly, the concentration results shown on the maps displayed explicit risky region and the possible affected region downstream clearly. On the other hand, values were extracted from the AMS data, as shown in Figure 4.

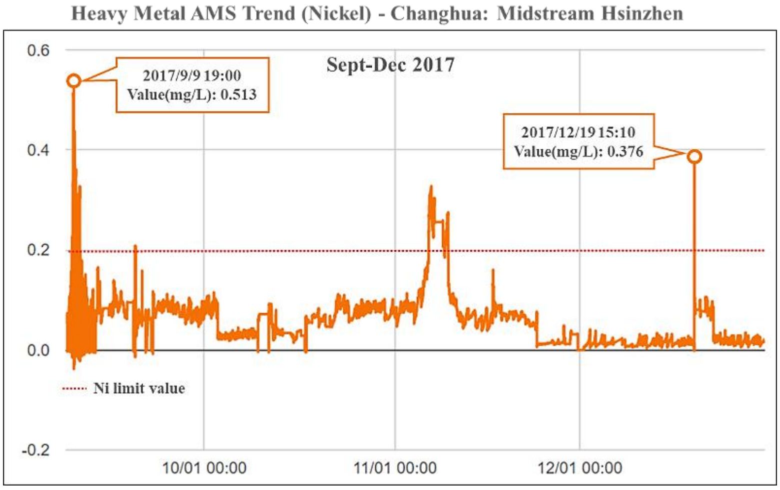

Figure 4. Trend of Nickel recorded by the heavy metal AMS at Hsinzhen

The average value of Nickel during Sept-Dec was 0.062mg/L and the standard deviation was 0.056mg/L. The highest value was 0.513mg/L during 7pm on 9 Sept, which was at least double the limit value. The AMS recorded a total of 591 counts of limit exceeds. Pollution events occurred at different time of a day, thus applying WASP model and the platform to predict the pollutant was needed. Results of each scenario are presented below.

Scenario 1: The average value of Nickel after 2007 (0.0375mg/L) was substituted as the initial concentration in the simulation. Results are shown in Figure5. Since there was no confluence along the channel of the study area, the concentration changes were affected merely by settlement and re-suspension of water. As the settlement velocity was as low as 4.04x10^(-5)m/s, the influences brought to the water body was insignificant.

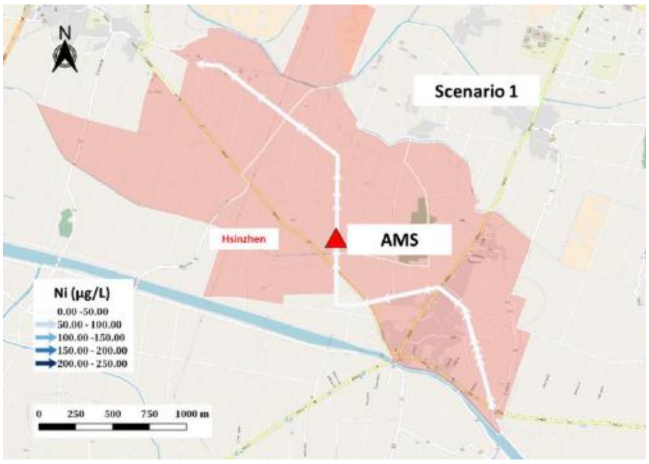

Figure 5. Scenario 1 results

Scenario 2: Nickel concentration at upstream Hsinzhen was high and was at the boundary of the limit value, thus the average value of 0.218mg/L was substituted. The settlement was unable to reduce the concentration to a safety level, thus as seen in Figure 6, the concentration was low along the simulation region. Therefore, water pollution events were found in the past.

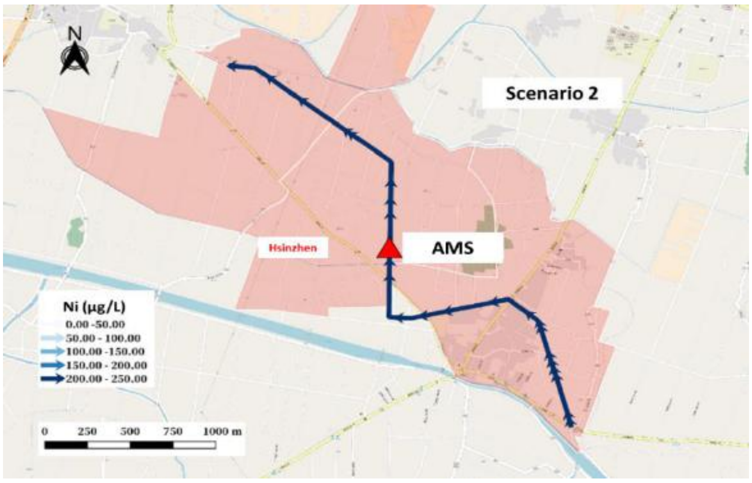

Figure 6. Scenario 2 results

Scenario 3: There were five regulated factories located at the upstream, based on the governmental data. However, waste water were not found discharging into the irrigational channels as found during a field inspection. Nevertheless, factories' information collected could therefore be applied into the model simulation. Nickel's limit value for wastewater discharge was 1mg/L. According to the issuance volume, 0.228kg of Nickel was released into the irrigation system. While the channel contained 0.3CMS~1CMS during irrigational seasons, simulation showed that the concentration would increase for approximately 0.00873mg/L at 0.3CMS and 0.00263mg/L at 1CMS. Based on the model simulation, these factories could bring the least influence to the water and only contribute 4%~5% of the amount of limit value.

Scenario 4: To determine the effects of pollution brought to the channels, data from the monitoring points of the streams were collected as shown in Table 1. Results showed that Nickel's concentration at the midstream on 20 November 2013 was significantly higher than the others, and on 5 June 2013 the downstream was higher than the others. Other than that, no other anomaly was noted.

Table 1. Values of Ni at Midstream Hsinzhen

Sampling date	Upstream(mg/L)	Midstream(mg/L)	Downstream(mg/L)
2013/11/20	0.125	1.501	0.111
2013/6/5	0.06	0.06	0.13
2013/7/24	0.079	0.099	0.108
2013/9/25	0.05	0.07	0.09
2014/3/25	0.024	0.019	0.023
2015/1/29	0.046	0.05	0.051
2015/3/9	0.055	0.047	0.044
2015/5/11	0.031	0.032	0.009
2015/7/8	0.029	0.031	0.029
2015/9/8	0.015	0.013	0.017
2016/5/9	0.02	0.02	0.016
2017/2/15	0.042	0.046	0.067
2017/5/10	0.023	0.02	0.02

In order to provide an additional functional tool to enhance the sourcing mission, a post-simulation combination table was created, (Table 2). The table consisted of different groups designated via simulations, where users could determine possible pollutant location by the interpolation method by using the table. On a whole, units which were urged to determine area of pollution in a limited time after receiving warning from the AMS could either manipulate the model simulation platform or apply the table. With this tool, concerned units could manipulate the water usage at the irrigation area to avoid the crops being irrigated with polluted water.

Table 2. Combination table for simulation results

	Concentration obtained from AMS (mg/L)	Predicted distance of pollution (m)
Scenario: Wastewater discharged into drainage system; Heavy metal: Ni	>1	0-50
	0.75~1.0	151-300
	0.50~0.75	301-450
	0.25~0.50	451-600
	0.01~0.25	601-750

During the simulation, pollutants were input at the first, eighth, fifteenth and twenty-second hours for one hour, and records of the AMS showing the concentration changes over time were collected. It showed that the higher the initial concentration the larger the decreas in level, indicating that the diffusion capacity is directly proportional with concentration, as higher the concentration, the larger the diffusion capacity, resulting a faster decrease of the gradient. The AMS changes results are shown in Figure 7.

Based on the scenarios, four levels of initial concentrations of Nickel were planned and the time span for pollution release was set for an hour with a volume of 0.5CMS. The concentration changes of the AMS were observed, with concentration input of 0.2 mg/L, 0.25 mg/L, 0.3 mg/L and 0.35mg/L.

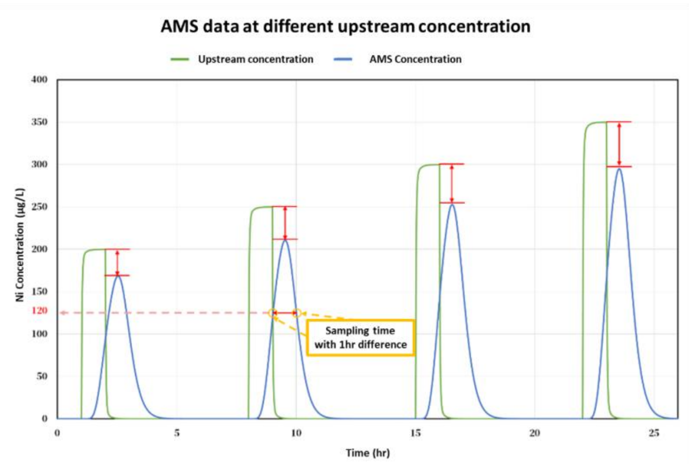

Figure 7. Heavy metal concentration's relativity graph

4. CONCLUSIONS AND RECOMMENDATIONS

During events of pollutions, Nickel concentration would decrease over time and changed through the transfer process. The AMS were equipped close to the midstream at a distance of 2300m from the upstream where a huge area of farmland was located downstream. If Nickel exceeded the limit value (0.2mg/L), AMS could merely protect the farmland at the lower region via sending warning signals to the environmental units. In order to remain the safety of food production at high risk area via effective protective instrument, a more stringent heavy metal limit value is recommended. In this case, if 0.17mg/L is observed at the downstream, it indicates that the water has reached 0.2mg/L. Warning could be sent immediately to prevent the pollution of adjacent farmland. The function of AMS could then be utilized to its greatest value.

In conclusion, while indicating the receptor of a certain case of pollution, the simulation platform or a quick reference to the interpolation table were both feasible and helpful. It could be concluded that a large amount of time would be saved on sourcing the distance of wastewater pollutant as compared to conventional methods. The integration of AMS and water simulation platform are functional tools for suitable for irrigation associations as they could receive anomalies in time and react immediately. Then, it would assist duties for environmental inspection units if simulation results were reported. Finally, department of irrigation or CHIA could achieve improvements and amendments on management measures to ensure the safety of food production.

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