Utilizing Total Amount Control to Manage Wastewater Discharge into Irrigation-Drainage Channels – A Case Study of Yilan Irrigation Association, Taiwan

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1. INTRODUCTION

1.1 BACKGROUND

Yilan, an agricultural county, is located in the northeastern part of Taiwan. Most of Yilan's irrigation and drainage affairs are managed by Yilan Irrigation Association (YLIA). YLIA is responsible for approximately 18,500 hectares of farming area primarily using surface freshwater as irrigation water source. The overall irrigation water quality of YLIA had been satisfactory for decades. However, since the completion of Hsuehshan Tunnel (**FIGURE 1**), which connects Taipei and Yilan and smoothens the transportation in between, Yilan has become part of Taipei's one-day-living zone, resulting in increases of touristic activities, number of residential houses, and domestic wastewater production. It was thought that much of the domestic wastewater has been discharged into YLIA's channels (namely, "wastewater discharge into channels", or simply WDIC), potentially deteriorating the irrigation water quality. However, the actual situation had not been clearly understood.

1.2 OBJECTIVES

1) to perform a thorough investigation of current WDIC status in Yilan.
2) to study the impact of intensive WDIC on the spatial variation of irrigation water quality within a selected particular region through a comprehensive on-site water quality monitoring program.
3) to propose an approach for YLIA to better manage WDIC based upon the concept of total amount control.

2. METHODS AND DISCUSSIONS

2.1 INVESTIGATION ON WDIC STATUS IN YILAN

To better understand the current WDIC status, YLIA performed a thorough site investigation to record all WDICs in its farming area in 2013. The results showed that 4,655 WDICs (mostly farming houses for residential use) had permission (through legal approval application) to discharge effluent (**FIGURE 1**), but there were 41,005 WDICs in total, mostly residential houses. The results implied that 89% of WDICs did not have approvals from YLIA, causing a significant challenge for YLIA to manage its irrigation water quality. Thus, the potential of WDICs' impact on irrigation water quality needed to be studied.

2.2 STUDY ON CHANNEL WATER QUALITY WITH INTENSIVE WDICS

With preliminary study, Lin-Ho-Yuan irrigation area was selected to be studied since there were relatively more intensive WDICs in the region (**FIGURE 2**). Sampling points were determined after site investigation of the studied area. Totally 60 sampling points were located on these channels that have number of WDICs higher than 6. In sum, Lin-Ho-Yuan area had 1,009 WDICs, and the sampling points covered the channels having totally 850 WDICs, implying that the results of sample analyses should be able to explain well the impact of WDICs on water quality. Preliminary study showed that electric conductivity (EC) and NH_3-N were more negatively impacted in small irrigation and drainage channels, possibly due to their relatively lower base flowrate. Further study of 10 representative channels with 20 sampling points and 240 samples (12 at different times for each point) showed similar results (**FIGURE 3**).

FIGURE 1. The distribution of permitted WDICs (contributed to approximately 11% of total WDICs) in YLIA's farming area.

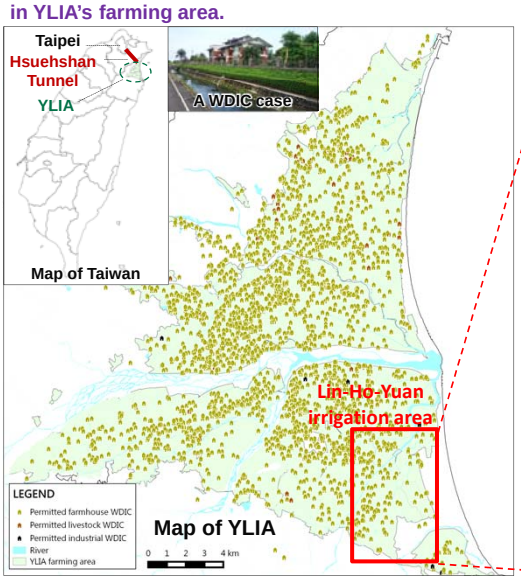


FIGURE 2. Lin-Ho-Yuan area (selected for investigation on WDICs impact on water quality).

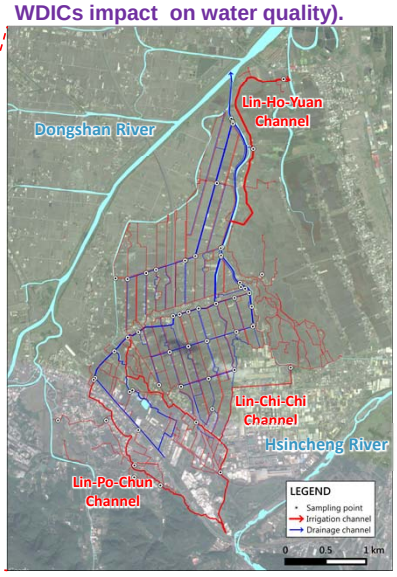
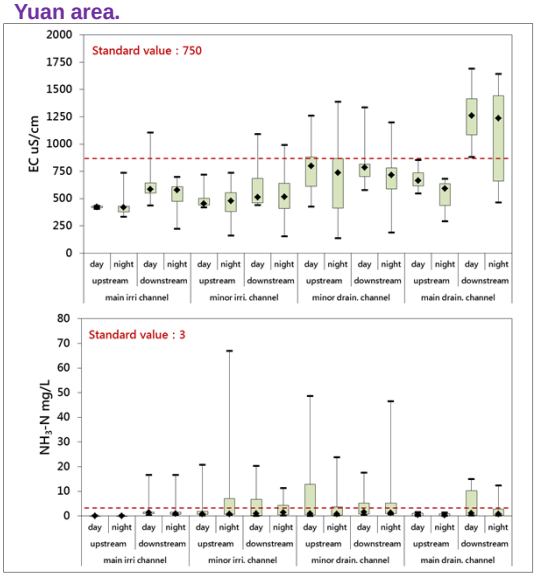


FIGURE 3. EC and NH3-N of different types and channel at different locations and times in Lin-Ho-Yuan area.



3. CONCLUSIONS

1) It was found that most WDIC cases occurred at small drainage channels, and consequently the downstream large drainage channels could have been significantly impacted especially with total nitrogen concentration easily exceeding irrigation water quality standard of 3 mg/L.
2) The results implied that farming regions using irrigation return flow from large drainage channels might have unsatisfactory irrigation water quality if there are intensive WDIC cases upstream.
3) A simple mathematical model was proposed in this study to determine the acceptable number of WDIC cases in a certain region with reasonable assumptions, which would be helpful for YLIA's WDIC management to mitigate further deterioration of the irrigation water quality while potentially utilizing nutrients from domestic wastewater in irrigation return flow for farming.

$$N_{p,U}=[Q_0(C_s-C_0)]/[q_p(C_p-C_s)] \qquad Q_0=Aq_0r$$

$N_{p,U}$: Upper limit of WDICs of a channel
Q_0: Base flowrate
C_s: Standard water quality
C_0: Background water quality
q_p: Average WDIC effluent flowrate
C_p: Average WDIC effluent quality

A: channel watershed area
q_0: irrigation flowrate per unit area
r: irrigation water return flow ratio

4) Giving that q_0 of 0.001 cms/ha, r of 20%, C_s of 3 mg/L (using NH_3-N), C_0 of 0.02 mg/L (background NH_3-N in Hsincheng River), q0 of 1 cmd, C_p of 50 mg/L (effluent NH_3-N), it was found that the upper limit of WDIC per acre is approximately 1.
5) Lin-Ho-Yuan area showed that numbers of WDICs had passed over the upper limit calculated (**TABLE 1**). This explained why channel water quality in this area easily passed the standard of NH_3-N.

TABLE 1. Comparison of estimated and actual WDICs in Lin-Ho-Yuan's sub zone; results showed that actual WDICs had passed the estimated, implying that water quality had high potential of exceeding standard.

Name of Lin-Ho-Yuan sub zone	Area (ha)	Q_0 (CMS)	$N_{p,U}$ (Using NH_3-N as criteria)	N_p Actual WDICs
Lin-Ho-Yuan small drainage	5	0.001	5	~8
Lin-Po-Chun 1st mid drainage	38	0.0076	42	136
Lin-Chi-Chi mid drainage	90	0.018	99	110
Lin-Ho-Yuan Nanfu 1st mid drainage	33	0.0066	36	163
Lin-Ho-Yuan Nanfu 2nd mid drainage	49	0.0098	54	81
Lin-Ho-Yuan Nanfu 3rd mid drainage Lin-Ho-Yuan Nanfu 4th mid drainage	102	0.0204	112	213
Lin-Po-Chun main drainage	198	0.0396	217	~400
Lin-Ho-Yuan main drainage	475	0.095	520	~900