# INVESTIGATION, ASSESSMENT AND OPERATION MANAGEMENT OF THE REUSE OF AGRICULTURE RETURN WATER IN TAIWAN

Chien-Pang Liu[1], Wen-Hao Tesi[2], Kuo-Cheng Hsien[3] and Fang-Tse Tao[4]

## Abstract

Controlling the amount of total water usage and sustainable use are major considerations for water resource management policy in Taiwan. Following these considerations, water resource diversification usage is a major direction for water resource development. We examine the possibilities of irrigation water reuse, including site investigation and evaluation for the quantity and quality of the return water, and the water treatment technique and cost analysis. The research result could be help to enhance the usage efficiency of the irrigation water in Taiwan.

## Introduction

Controlling the amount of total water usage and sustainable use are major considerations for water resource management policy in Taiwan. Following these considerations, water resource diversification usage is a major direction for water resource development.

According to recent research, the amount of return water from rice paddies is 2.6 to 3.0 billion cubic meter per year in Taiwan, which is about 25% ~ 30% of all total irrigation water. Most of the drainage water flows into downstream drainage systems and eventually into the sea. Owing to the shortage of water resources in Taiwan, we have been examining ways to collect and recycle the remaining water from the end of the irrigation drainage. This research includes water quantity, quality, potential users, water treatment and techniques for return water collection.

[1] Manager of Hydraulic and Ocean Department , Sinotech Engineering Consultant
E-mail: liupang@sinotech.com.tw ; Tel: 886-2- 27698388-11210 ; Fax: 886-2- 8761-1595

[2] Technical Manager of Hydraulic and Ocean Department , Sinotech Engineering Consultant
E-mail: wenhao@mail.sinotech.com.tw ; Tel: 886-2- 27698388-11247 ; Fax: 886-2- 8761-1595

[3] Senior Engineer, Hydraulic and Ocean Department , Sinotech Engineering Consultant
E-mail: kch@mail.sinotech.com.tw ; Tel: 886-2- 27698388-11238 ; Fax: 886-2- 8761-1595

[4] Senior Engineer, Hydraulic and Ocean Department, Sinotech Engineering Consultant
E-mail: taur@mail.sinotech.com.tw ; Tel: 886-2- 27698388-11233 ; Fax: 886-2- 8761-1595

## Water quantity of agriculture return flow

1. Figure 1 shows the process of return flow from the paddy farm. The water budget equation for the paddy farm can be described as $I \times [1 \div (1+S2)] + ER = ET_{crop} + DP + \triangle S + O$, where I denotes the irrigation flow, O denotes the return flow, ER denotes effective rain, ETcrop

denotes evaporation, DP indicates the deep percolation, △S indicates the change in the amount of water stored in the pond, and S2 indicates loss rate.

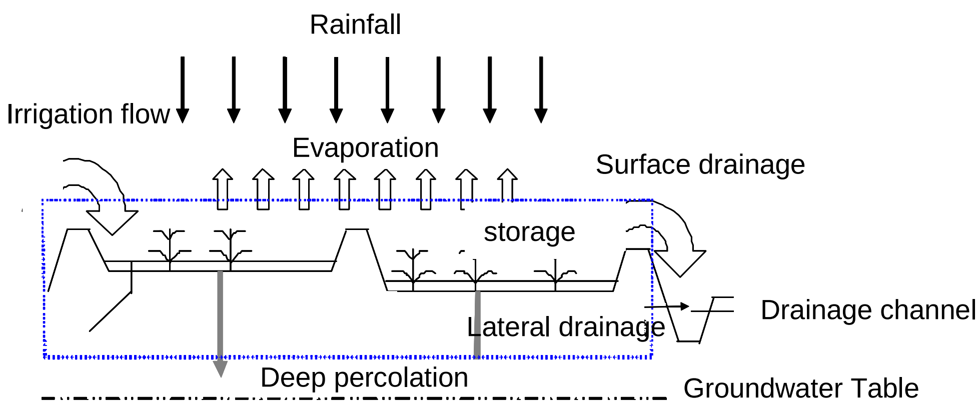



**Figure 1. Water balance in paddy farm**

Calculation results show the average return flow from 2002 to 2007 at about 1.82 billion cubic meters per year in Taiwan. This is separated into 15 irrigation associations as shown in Fig 2. The return water on the eastern side is higher than on the western side of Taiwan, but it is not stable--80% and 90% exceedence probability of return flow is almost near zero in many irrigation areas. Many factors could influence the stability of return water, such as hydrology, water resource of irrigation, groundwater, irrigation methods, irrigation channel distribution, and so on; however, the major reason influencing stability is that farmers do not get water from rivers in non-irrigation seasons in many irrigation areas.

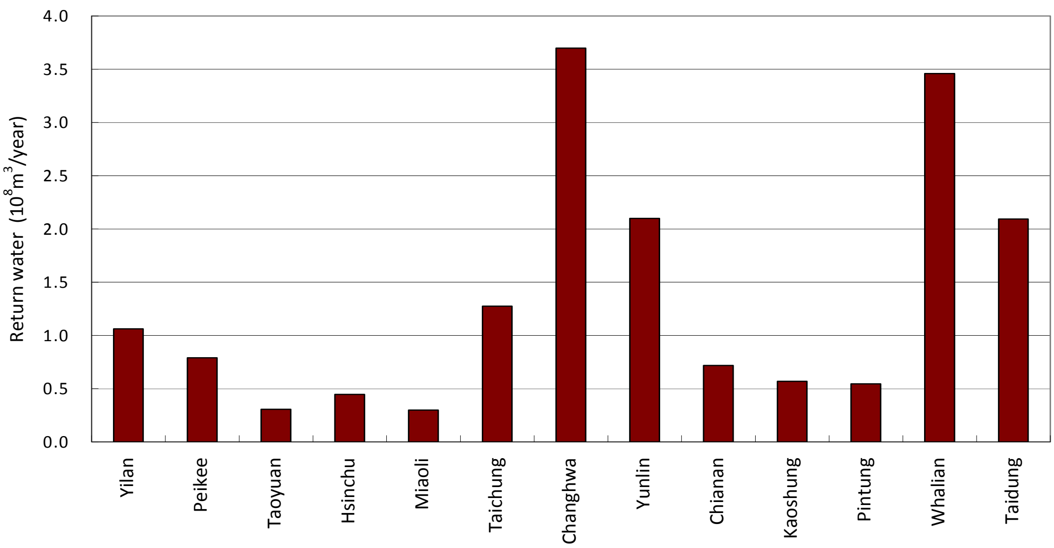



**Fig 2.** Return water in Taiwan

## Water quality of return flow

The return flow sampling plan was based on a monthly sampling of irrigation periods in 42 sites during the crop season. The water quality assay of the return flow included pH, conductivity, total dissolved solids, suspended solids, biochemical oxygen demands, chemical oxygen demands, total nitrogen, total phosphorus, turbidity, total bacteria count, E. coli, nitrate, nitrite, TKN, alkalinity, total hardness, chloride, sodium adsorption ratio and heavy metals. Our findings were as follows:

We found that all the agriculture return flows were slightly contaminated by domestic sewage and animal husbandry wastewater. On the other hand, in Nantou, Changhua, Yunlin and Pingtung, the main contamination may have been from farmland fertilizer. In the Tainan area, flows were slightly contaminated by industrial wastewater.

Conductivity of all the agriculture return flows complied with the irrigation water quality standards (750 µS /cm). However, in Changhua, Chiayi, Tainan and Kaohsiung, where we found industrial wastewater pollution, the conductivity in the regional drainage was generally not in compliance with the irrigation water quality standards.

Colloid materials, suspended solids and turbidity in the agriculture return flow were higher than the effluent of secondary domestic wastewater treatment plans (SS:10 mg/L), especially in Yunlin, Taitung and Hualien.

Nitrogen levels in northern Taiwan, Hualien and Taitung were in compliance with the irrigation water quality standards (3 mg/L).

The total bacteria count and E. coli concentrations were not in compliance with any water quality standards.

Among the sampling sites, the concentration of heavy metals, such as As, Cd, Cr, Hg, Ni and Pb, were generally lower than the method detection limits (MDL).

## Potential users of agriculture return flows

The desire for users to use agriculture return flow is the key point of this project. It is obvious that water quality requirements are different for different users, such as domestic water, environmental water, agriculture irrigation and industry. Feasibility study results for different users are shown in Table 1. We know that the feasibility is low for domestic water and environmental water, because they are restricted by the binary water supply system and cost. It is feasible for agriculture, and it has already been widely used in irrigation zones. Feasibility for industry water mainly depends on the manufacturing process. There is high potential for reclaimed water to be used as industry cooling water because water quality requirement is relatively low, therefore the cost for water treatment could be more competitive.

**Table 1. Feasibility for different users.**

| Users | Evaluation | Feasibility |
|---|---|---|
| Domestic | Need binary water supply system | New community is feasible |
| Environment (Groundwater recharge) | Water quality requirement is high | Low |
| Agriculture | Widely used in irrigation | High |
| Industry | Water quality requirement is low. It could be used as Industry Cooling water | Depends on manufacture process |

Potential industry users were interviewed about using reclaimed agriculture return water. Their issues and concerns were as follows:

(1) Cost of reclaimed return flow.

(2) Dedicated pipelines and storage tanks are necessary for using reclaimed return flow in the factory.

(3) Stability of the water quality and quantity.

(4) Human health risk (of the employees who utilize the return flow)

(5) Subsidization for infrastructure.

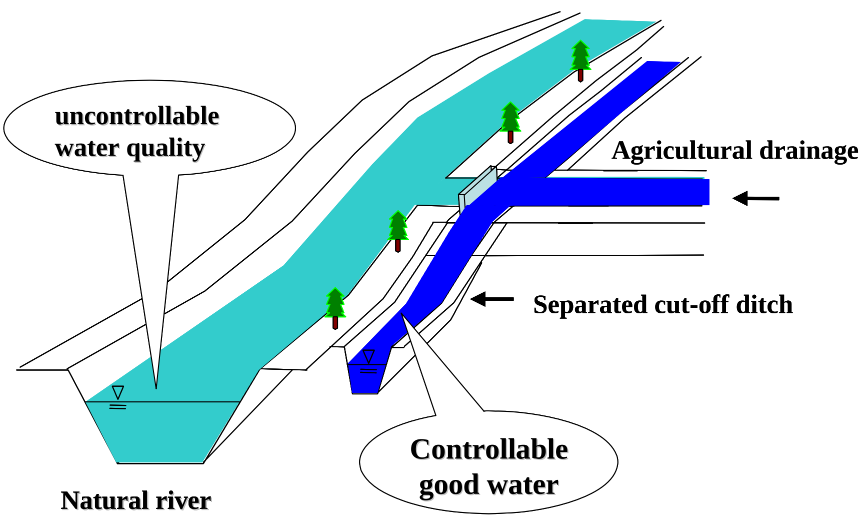
## Techniques for agriculture return flow collection

Gathering points for agriculture return flows could be located at agricultural or multiformity drainage sites. Comparisons between multiformity drainage and agriculture drainage are shown in Table 2. Facilities to gather water at multiformity drainage sites could be easier than gathering water in agriculture sites, but multiformity drainage includes waste water from industry, city and animal husbandry, thus the water quality is worse and more unstable.

**Table2. Comparison between multiformity drainage and agriculture drainage**

| Item | Multiformity drainage | Agriculture drainage |
|---|---|---|
| Quantity | Concentrated | Dispersed |
| Quality | Worse | Better |

To reduce the complexity and uncertainty of water quality treatment and gather water before it drains into multiformity drainages would be better. A scenario for return water gathering is shown in Fig. 3. Water gathers at the end of agriculture drainages before it drains into multiformity drainage. This could control return water quality.



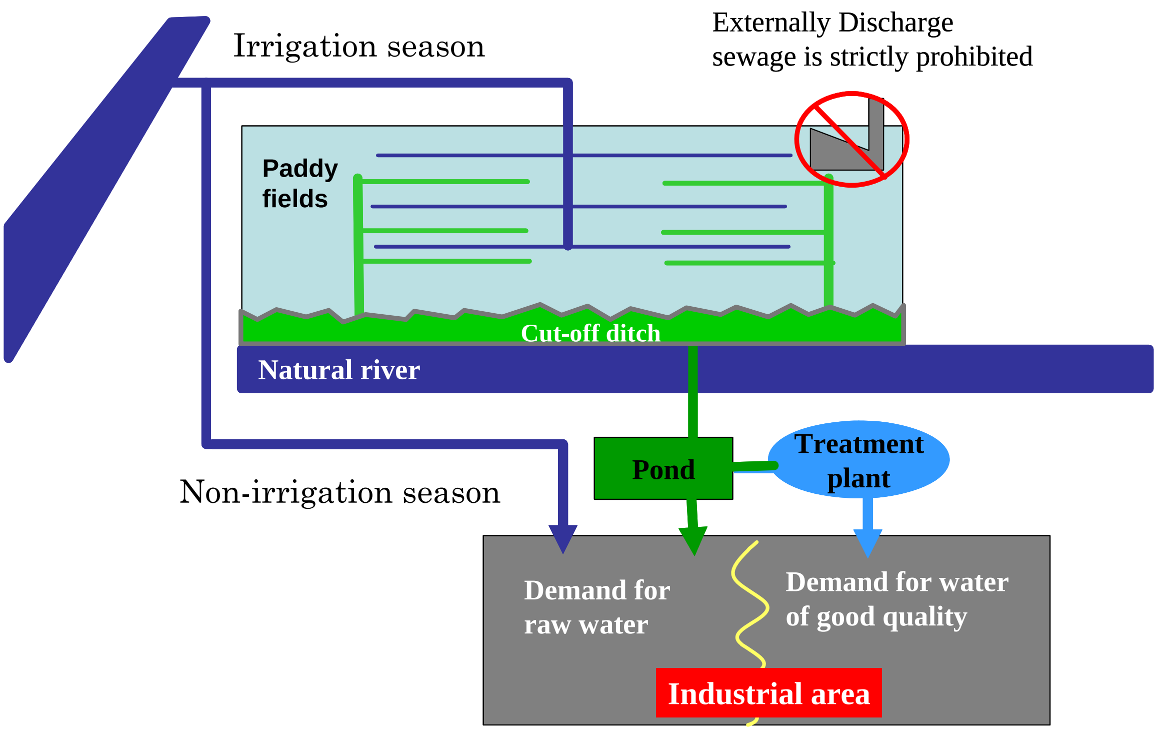

(Reference : Kan CE, Chang YC, 2007)

**FIG 3.** Concept of water gathering techniques

Figure 4 shows the whole water supply scenario for reclaimed return flow. In irrigation users could get water from the return water gathering channels, and get water directly from rivers in non-irrigation seasons. This could enhance the stability of return water supply.

### Technique for agriculture return flow treatment

Current cooling water systems always loop water 3 to 6 times in modern factories for water conservation, so that assuring the stability of water quality, including dissolved solids (to avoid fouling or corrosion), hardness, conductivity, organic compounds, nitrogen and phosphorus (to avoid bacteria fouling), are very important. General speaking of numerous the agriculture return flow, due to contaminated by domestic sewage and animal husbandry water, the concentration of NH3, total bacteria count and E. coli are slightly higher than water quality standards. In addition, the suspended solids and turbidity in the majority of the agriculture return flows are higher than the effluent of secondary domestic wastewater treatment plants (SS:10mg/L). Therefore, in order to make the quality of water more stable, we suggest that a coagulation – sedimentation – aeration – sand filter – disinfection process can be applied.  This is an aeration process that degrades NH3 through "air stripping" in the alkaline state. Noticeably, if the conductivity, TDS or




(Reference: Kan CE , Chang YC,2007)

**Figure 4.** Return water supply system

hardness cannot achieve regulatory compliance, then reverse osmosis will be required for desalination.

In setting up water softening or purified water systems for most manufacturers in Taiwan, the influence of water quality is always set to achieve at least “tap water quality standards” or local tap water standards. Therefore, to investigate agriculture return flow reuse for industrial use, “tap water quality standards” was used as a benchmark in this research. The criteria for settling the treatment unit based on water quality standards is shown as Table 4. For evaluating the cost, herein, we only consider the treatment cost (land construction, equipment, and operation/maintenance), which is about NT$7.5~15/ton.

**Table 4. Process unit requirement analysis**

| Process Unit | Water quality standards (tap water quality standards ) |
|---|---|
| Equalization tank | Equalization tank is required for all cases. |
| Coagulation - Sedimentation | Turbidity > 2 NTU, “Coagulation–Sedimentation” Process is required. |
| Aeration | $NH_3$ > 0.5 mg/L, the aeration is required. |
| Sand filter | Turbidity > 2 NTU, the “sand filter” is required. |
| Disinfection | E. coli > 6 CFU/100mL, “disinfection” is required. |
| Reverse Osmosis ( RO ) | When TDS > 800 mg/L or hardness > 400 mg/L, the “RO”is required. |
| Sludge Treatment | Sludge treatment is required for all cases. |

## Conclusion

Irrigation water reuse planning needs to consider more factors, including total irrigation return amount, distribution of irrigation drainages, land use, the stability of quantity and quality of return water, and the demand for water users . Our study,shows that irrigation water reuse is feasible through engineering techniques and it is also feasible economically in some irrigation areas as long as is an efficient water management plan for irrigation water usage.

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