WATER QUALITY MONITORING AND APPLICATION OF HYDROLOGICAL MODELING TOOLS AT A WASTEWATER IRRIGATION SITE IN NAM DINH, VIETNAM

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INTRODUCTION

The current paper is the result of a study dealing with the establishment of a water balance and an evaluation of the processes in the irrigation and drainage systems, at a field site in Nam Dinh, Vietnam that is irrigated with wastewater. The main focus has been on establishing a field monitoring program and evaluating the results using hydrological modeling tools. The hydrological modeling tools have been used to establish a water balance and a nutrient balance for the Nam Dinh project area. The objective of the project was to evaluate the impact of using wastewater on a small irrigated area.

METHODS

The study area is located outside of the town Nam Dinh, Vietnam, and comprises 19.8 hectare of agricultural land irrigated using wastewater from the town. The wastewater site was selected on the criteria that it should receive mainly domestic wastewater, and it should be possible to control input and output to the site. In a real system this is not so easy, but the selected site fills both requirements to a reasonable extent. There may be minor industrial production along the wastewater channel, but no big factories and at least in the dry season, water flow in the wastewater site seems fairly straightforward and easy to understand. The wastewater is pumped from the main wastewater canal into the irrigation canal by a large pump station, the Quan Chuot pumping station from where it is distributed by gravity or small pumps to the field site. The project area is dominated by paddy fields. The wastewater is pumped into the irrigation system from a main pump inlet and is then distributed onto the fields by gravity or small pumps. The irrigation and drainage system is designed so it is possible to measure the in- and outflow from the project area. The only inflow to the area is through the main pumping station, and the outflows from the area are either through the main drainage canal or through the irrigation canal flowing under the newly constructed road (Fig. 1). At the main pumping stations both discharge and water quality measurements were collected, though only for the main irrigation

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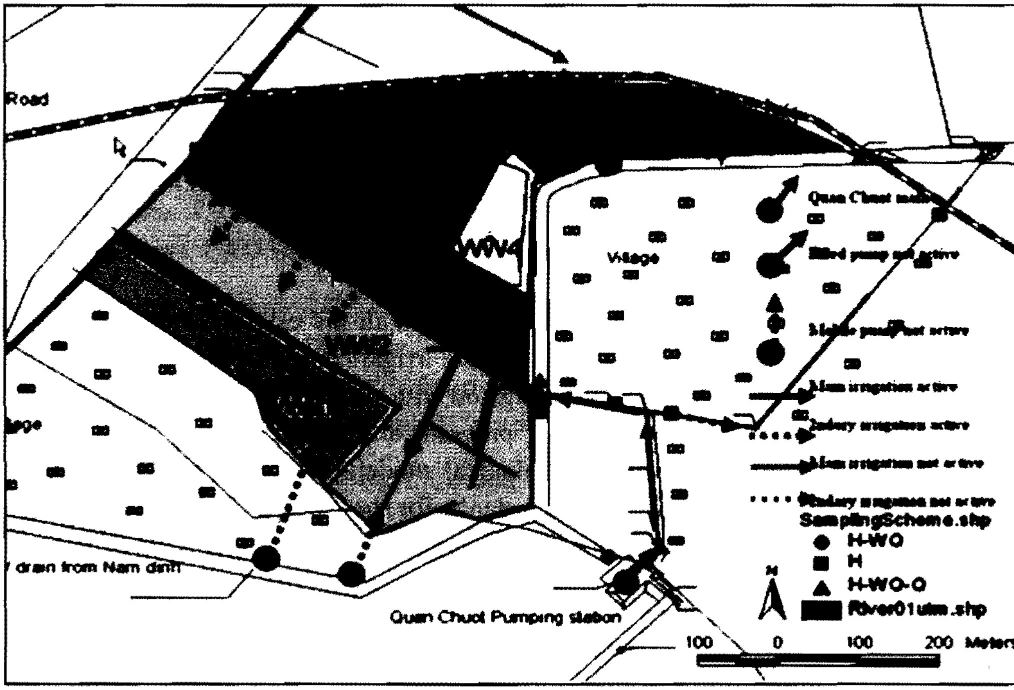
events. For the outflow locations, observation stations were established, enabling a full water balance description of the irrigation and drainage system. The study period was from January 2004 until June 2004, covering a full growth season.



Note: WW1-5 is the wastewater irrigated sites in the study area.

Fig. 1. Irrigation flow in the area

For the climatic data, a meteorological station was established inside the model area, but due to problems with the equipment, it has not been possible to establish a full data series for the study period (Jensen, 2005). Instead it was necessary to use data from a nearby national weather station. For the potential evaporation the local station is used, when data is available. For the remaining time, data from the National Weather Station is used (with the monthly correction factors). For rainfall the local climate station and the National Weather Station has similar data so no correction was needed.

One of the objectives was to determine the cycling of nitrogen and phosphorus in the channels and in the rice field. In addition wastewater was analyzed for any toxic or high concentration elements. A water quality sampling strategy and methodology was established and during the project period, 41 water samples were collected. 7 of the samples were screened for the main parameters DO, Conductivity, Temperature and pH, while the remaining 34 sample was analyzed for approximately 30 parameters.

The hydrological processes in the project area are simulated using the integrated hydrological modeling tool MIKE SHE - MIKE 11. MIKE SHE is a comprehensive mathematical modeling system that covers the entire land-based hydrological cycle. It is a finite difference model, which solves a system of equations describing the major flow and related processes in the hydrological system. A number of model components simulating surface flow, infiltration, flow through the unsaturated zone, evapotranspiration and groundwater flow are combined, and the dynamic exchange of the water between the components is described. Model input data and parameters vary across the model area through specification of maps and time series. MIKE SHE has several modules among which Water Movement (WM) is the basic flow module. Detail about WM module is described in the reference manual of MIKE SHE (DHI, 2003). MIKE 11 is a 1-D hydrodynamic model for calculating flow and water level in rivers and channels. Some of the MIKE 11 modules include description of flow over hydraulic structures and structure operation. The formulation can be applied to looped networks and quasi-two dimensional flow simulation on flood plains. For detail information, see Reference Manual of MIKE11 (DHI, 2003). The MIKE SHE and MIKE 11 models are dynamically coupled; hence the models are running simultaneously during a simulation. Water are exchanged through base flow (seepage from rivers or infiltration from the groundwater to the rivers), overland flow (from the surface to the rivers), flooding (water flowing from the rivers onto the flood areas) and drainage flow (flow from drained areas are routed to the river system).

RESULTS AND DISCUSSION

Water Balance

The irrigation demand for the area is estimated by using a simple spreadsheet method (developed and used by one of the project partners KVL; Jensen, 2005, Jensen and Tuan 2006, this volume), and using the integrated hydrological model MIKE SHE - MIKE 11. For the spread sheet method the irrigation demand is calculated for the period February to June 2003, and is based on a simple water balance approach where the irrigation demand is calculated based on a specified field depth (depth of water on the surface), and the water input/loss (rainfall, infiltration, evapotranspiration and overland run-off). During the calculation it is assumed that the root zone depth and the infiltration rate are constant. Using the spread sheet method the irrigation demand, for the period is 360 mm, excluding 200 mm for the land preparation phase. Consequently the total irrigation demand is around 560 mm for the period.

The approach has been to calibrate the hydrological model so simulated water levels and discharge values matches with the observed values. For the Nam Dinh model the focus during the calibration has primarily been on simulating the correct water level and discharge in the irrigation channels. The results show a reasonable correlation between observed and simulated values (DHI 2005). It is noticeable that the effect of the inflow through the main pump is so significant that even a small uncertainty in the observed data will cause a large discrepancy in the simulated values. Based on the calibrated hydrological model it was possible to calculate a water balance for the irrigated area, shown in the below figure.

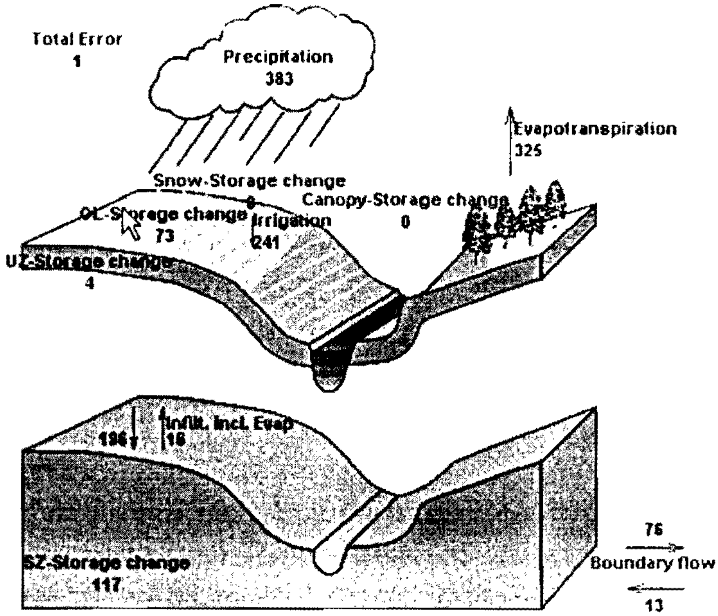


Fig. 2. Water balance for the period 31st of December 2003 until 29th of May 2004 (Note that irrigation demand is excluding land preparation phase, approximately 200 mm of water)

Water quality results

Based on the relatively short transport time in the irrigation system it was not expected that the change in concentrations would be significant. This is also evident when analyzing the observed data as the concentrations for Phosphate, Potassium, Calcium, Nitrogen or Ammonia are relatively constant during the transport through the system. This indicates that the water quality processes for the main parameters are not significant for the irrigation system, and that the concentrations in the irrigation water are equal to the measured concentration at the main pumping station. For the dissolved oxygen a change throughout the irrigation system is observed. It is believed, though observed data are lacking, that the water is almost fully saturated when leaving the pumping station, mainly caused by the turbulence through the pump, but the level of dissolved oxygen drops very fast throughout the system. The reason is that that the organic material in the wastewater is decaying. In general the observation data indicates that the main processes to evaluate and observe is the plant uptake and the evaporation while the processes in the irrigation canal are not significant. For the evaluation of the nutrient balance on the irrigated fields the concentrations at the pump intake could be used, as the change in concentration over the length of the irrigation system is very small, for the main water quality parameters.

Based on the collection of water quality data it could be concluded that:

1. Nitrogen, Ammonia, Phosphate, Potassium and Calcium remain relatively constant during the transport through the irrigation system, but Sulphate, BOD(1) and COD(2) showed some variations. The dissolved oxygen level is at saturation in the wastewater leaving the station, due to aeration from pump turbulence.
2. The total nitrogen varied from 47.8 and 57.2 mg/L depending on the measurement period. Total Phosphorus concentration varied between 3.6 and 4.6 mg/L and Potassium between 14 and 21 mg/L
3. Cadmium concentrations in the wastewater were low but Nickel and Arsenic concentrations were higher with an average application of 1.5 kg/ha and 1.1 kg/ha respectively

To evaluate the water quality processes in the irrigation and drainage system the MIKE 11 water quality module coupled with the ECO lab module is used. The objective with the water quality modeling is to simulate the processes that occur in the irrigation and drainage system and to evaluate if these processes are important for the nutrient balance in the Nam Dinh system. The water quality modeling focuses on the processes occurring between the main pump inlet and the field intake structures evaluating the following constituents: Dissolved oxygen, Temperature, Ammonia, Nitrate, BOD, Fecal Coliform Bacteria and Total Coliform Bacteria. The water model showed a very good correlation between the observed and simulated water quality parameters. For all of the parameters the model is able to simulate the observed values well within the range of the uncertainty. For the oxygen levels the model underestimates the observed concentrations, but as this observation parameter has a large uncertainty the simulated values are accepted. In general the water quality model showed a large potential for simulating the processes in the irrigation system.

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(1) Biochemical Oxygen Demand
(2) Chemical Oxygen Demand

The model was used to evaluate the transport time from the pumping station to the point where the water is distributed onto the fields. This is interesting as it indicates the time span for the processes in the irrigation system. The transport time is evaluated by applying a short flux at the pumping station and monitoring the break through point at different locations throughout the system. Analyzing the events during the period January to June 2004 the total transport time is around 4 to 6 hours. For an event as the discharge during the period January 15th to 16th the average transport time is 5 hours. The model simulation indicates that the time available for decay or biological processes are between 1 to 5 hours. The model was used to estimate the reduction in coliform bacteria during the transport in the irrigation system. Even though the transport time is rather small, the model estimates a reduction in the order of 50%, which could be very beneficial for the irrigated areas. It must be noted that with respect to coliform bacteria sufficient data is lacking, and there are some uncertainties in these estimates.

CONCLUSIONS AND PERSPECTIVES

At the outset of the current study the aim was to construct a fully coupled water and plant nutrient model, but due to data and time constraints this has not been possible. We were therefore unable to do a nutrient balance and close the loop. Instead the focus has been on calculating total loads and comparing these with plant uptake and nutrient availability as seen from the parallel crop and soil studies. Similarly the water balances from the model have been compared with those calculated by the spreadsheet method mentioned elsewhere.

The method applied to determine total loads may introduce some uncertainties mainly due to data limitations and poor analytical procedures, but the methodology may be a good way to determine actual loads applied to the fields. For simplicity the current study suggests that for a small area like the one studied, nutrient concentration in the main wastewater channel could be used directly for major nutrients.

For heavy metals and bacteria the WQ model of the irrigation channels provides useful data to test various scenarios even for small systems, and where the data are somewhat lacking. For larger irrigation systems where the water is retained in the channels longer than a few hours which are the case for most systems, it is believed that the approach described in the report will be very useful.

The established water balance is used for estimating the main water loss components in the irrigated areas and for evaluating the different hydrological processes. The water quality modeling and the data analysis showed that there where none or very small changes in the main water quality components in the irrigation and drainage system. The established water quality model could definitely be used for evaluating different management strategies or for evaluating the impact during periods with none or few observation data. The current water quality model has shown that it is possible to model the water quality processes with very satisfactory results.

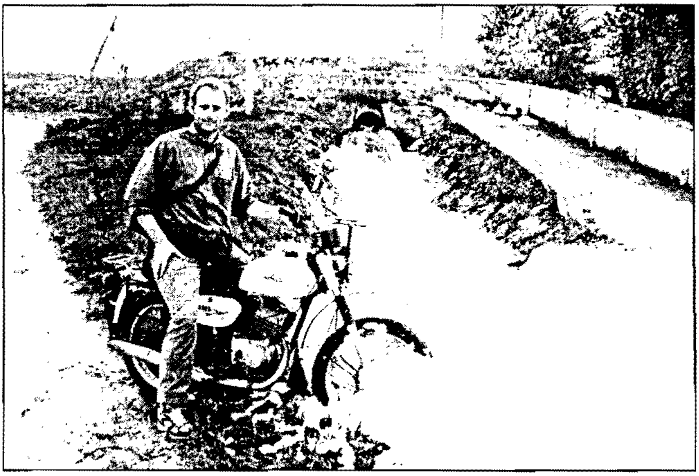

Fig. 3. Outlet from pumping station

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