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IMPACT OF ARTIFICIAL GROUND WATER RECHARGE AT TWO NEBRASKA SITES

by

Li Ma

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GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

IMPACT OF ARTIFICIAL GROUND WATER RECHARGE

AT TWO NEBRASKA SITES

Li Ma, Ph.D.

University of Nebraska, 1996

Advisor: Roy F. Spalding

The dissertation research focuses on two ground water recharge projects. Herbicide behavior is interpreted in a watershed system with data collected from runoff, Recharge Lake and ground water at the York Ground Water Recharge Project. Maximum atrazine inputs to Recharge Lake occurred in spring runoff events and resulted in atrazine concentrations of 36 and 17 $\mu g\ L^{-1}$ in 1993 and 1994, respectively. Only about 0.28% and 0.19% of total applied atrazine was lost to runoff in 1993 and 1994. Atrazine concentrations in Recharge Lake decreased exponentially with degradation half-lives of 237 d in 1993 and 209 d in 1994. Adjusted DEA concentrations in Recharge Lake remained relatively constant, indicating little evidence for biotic degradation, and suggesting that abiotic degradation of atrazine to hydroxyatrazine was the most likely major degradative pathway in Recharge Lake. Maximum bromide concentrations obtained in the nearby aquifer represented only 27% of the initial concentration in Recharge Lake. The low detected concentrations might be due to the low infiltration rates and dilutions.

Effects of artificial recharge on ground water quality and quantity was studied at the Wood River Ground Water Recharge Project. A total of 1.10 million m^3 of Platte River water recharged the aquifer near Wood River through 5016 m^2 of the recharge basins during 1992, 1993 and 1994. This is equivalent to the quantity needed to

completely displace the ground water beneath 33.75 ha of the local primary aquifer. The water table rose rapidly in response to recharge during the early stage then leveled off as infiltration rates declined. The NO_3-N contamination improved from concentrations exceeding the maximum contaminant levels to those of drinking water quality. Infiltration rates decreased with time presumably because of clogging. Management practices such as scraping the basin floor, using a pulsed recharge strategy and maintaining low standing water heads in the basins appeared to reduce clogging, therefore enhanced infiltration.

Stable isotopes, anion concentrations and hydraulic gradients were used to delineate streamlines and mixing in ground water impacted by artificial recharge. The surface water fraction estimated from D/H ratios indicated that the recharged surface water completely displaced the ground water beneath the recharge basins from the regional water table at 7.60 m to 12.16 m below the land surface. Mixing occurred beneath the recharge structures in the lower portions of the aquifer (>12.16 m). At the end of the third recharge season, recharged surface water represented ~50% of the water in the deeper zone of the primary aquifer ~1000 m downgradient from the recharge basin.

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Chapter 1

INTRODUCTION

The research forming the basis of this dissertation focuses on two ground water recharge projects, namely the Wood River Ground Water Recharge Project (WRGWRP) and the York Ground Water Recharge Project (YGWRP). Both of these demonstration projects were implemented as part of the U.S. Bureau of Reclamation's (USBR) High Plains Ground Water Recharge Demonstration Program. The Central Platte Natural Resources District (NRD) and the Upper Big Blue NRD are the local sponsors for the projects. For the project duration funding was received from the USBR and Ciba-Geigy Corporation through the local NRDs.

This dissertation is presented as a series of four manuscripts based on the two projects (Fig. 1). The manuscripts' status and authorship, field measurements and laboratory determinations are documented in the appendices.

In chapter two, herbicide behavior is interpreted in a watershed system with data collected from runoff, Recharge Lake, and ground water which was influenced by agriculture and lake seepage. The objectives of this research were: 1) to document the occurrence of herbicides in agricultural runoff impacting a recharge basin; 2) to estimate the persistence of herbicides in Recharge Lake; and 3) to relate the distribution of herbicides in ground water to input sources. Maximum atrazine inputs to Recharge Lake occurred in May and June runoff events and resulted in atrazine concentrations of 36 and 17 $\mu g\ L^{-1}$ in 1993 and 1994 respectively. About 0.28% and 0.19% of total applied

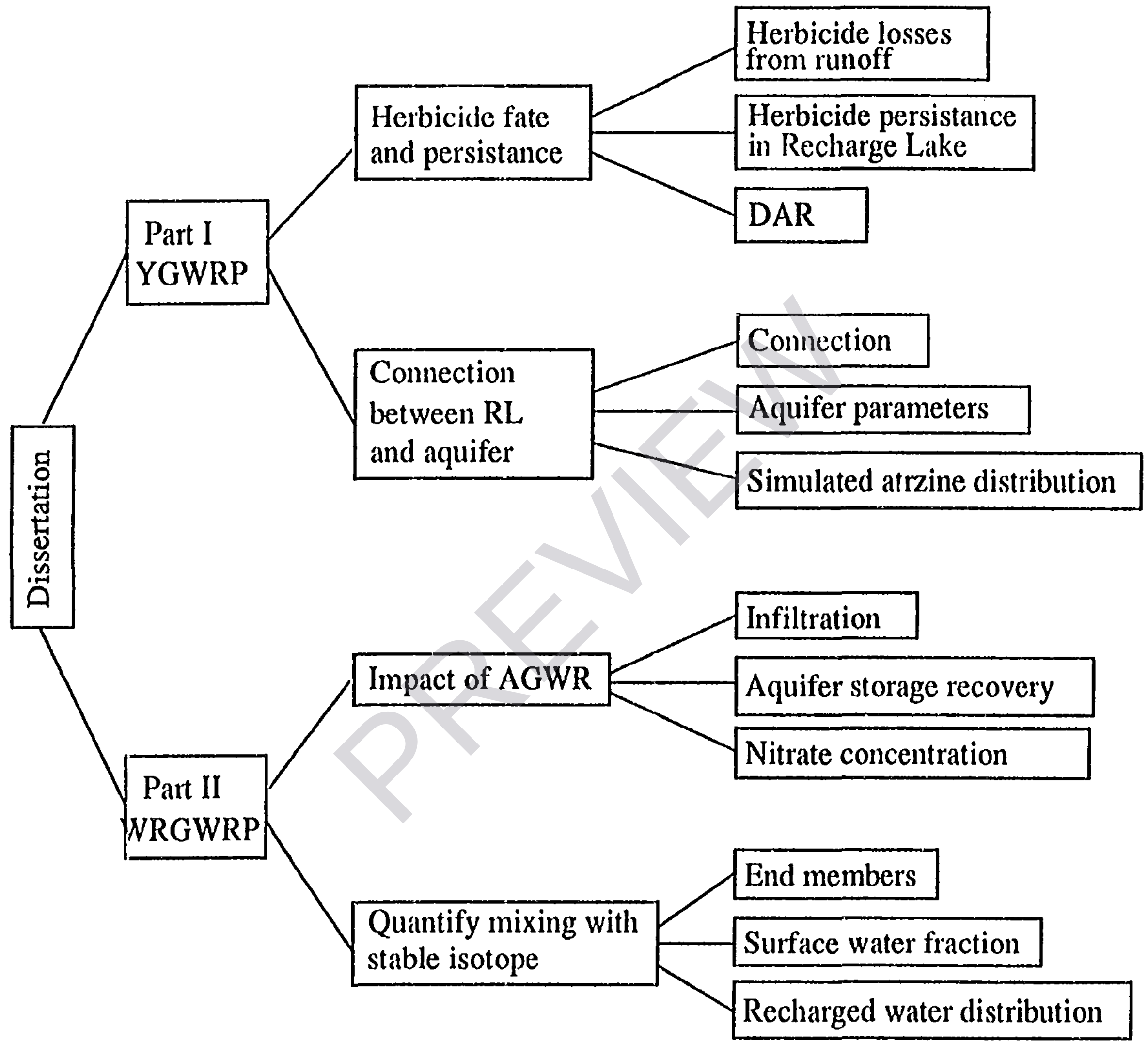

Figure 1. Outline of the dissertation.

atrazine was lost to runoff in 1993 and 1994, respectively. The deethylatrazine (DEA) to atrazine molar ratio (DAR) decreased rapidly over a period of several hours in runoff samples, which is consistent with inputs from recently atrazine treated soil. Atrazine concentrations in Recharge Lake decreased exponentially with time. Degradation half-lives were 237 d (r=0.93) in 1993 and 209 d (r=0.91) in 1994. Adjusted DEA concentrations in Recharge Lake remained relatively constant, providing no direct evidence for biotic degradation, and suggesting that abiotic degradation of atrazine to hydroxyatrazine was the most likely major degradative pathway in Recharge Lake.

Chapter three examines the interaction between Recharge Lake and adjacent aquifer with bromide and the simulated atrazine distribution. Maximum bromide concentrations obtained in the nearby aquifer represented only 27% of the initial concentration in Recharge Lake. The low detected concentrations might be due to the low infiltration rates and followed by dilution with the ground water. Breakthrough times varied considerably at different depths of the same horizontal distance from Recharge Lake, indicating a highly heterogenous aquifer beneath Recharge Lake and adjacent area. The lake infiltration rates declined with time due to biofouling accumulation of organic material on the bottom of Recharge Lake. Hydraulic conductivities (K) of the adjacent aquifer were estimated with the Kozeny-Carmen equation based on grain size distribution and ranged from 1 to 390 ft/day. The aquifer was divided into three layers with an averaged K of 128 ft/day for top layer (25 ft thickness), 162 ft/day for layer 2 (26 ft), and 29 ft/day for layer 3 (18 ft). A pumping test at 1000 ft downgradient from Recharge Lake with a pumping well screened from 44 ft to 70 ft resulted in a K of 136 ft/day.

These parameters were used to calibrate ground water flow and solute transport models used to simulate atrazine distribution in the adjacent aquifer. A simulated atrazine plume dispersed radially from Recharge Lake with a strong southeast movement and simulated concentrations agreed favorably with the measured concentrations.

Chapter four, Effects of Artificial Recharge on Ground Water Quality and Aquifer Storage Recovery, discusses the impacts of the WRGWRP during 1992, 1993 and 1994. The objectives of this research were to document improved ground water quality and increased quantity from artificial ground water recharge (AGWR) and to determine beneficial operation and management strategies. A total of 1.10 million m^3 of Platte River water recharged the aquifer through 5016 m^2 of the recharge basins near Wood River, Nebraska during 1992, 1993 and 1994. This is equivalent to the quantity needed to completely displace the ground water beneath 33.75 ha of the local primary aquifer. The water table at the site rose rapidly in response to recharge during the early stage then leveled off as infiltration rates declined. Both NO_3-N and atrazine contamination dramatically improved from concentrations exceeding the maximum contaminant levels to those of drinking water quality. Resultant ground water quality improvement and aquifer storage increase from the artificial recharge were measured at ~1000 m downgradient and ~600 m upgradient from the recharge basins. Constant infiltration rates were not sustained in any of the three years, and the rate always decreased with time presumably because of clogging. Scraping the basin floor increased infiltration rates. Other management practices, such as using a pulsed recharge strategy to create dry and wet cycles and maintaining low standing water heads in the basins appeared to reduce microbial growth resulted in more sustainable infiltration rates.

In chapter five, stable isotopes of deuterium and oxygen-18 of surface and ground water, together with anion concentrations and hydraulic gradients, were used to interpret mixing and flow in the ground water impacted by artificial recharge. The surface water fraction (SWF), the percentage of surface water in the aquifer impacted via recharge, was estimated at different locations and depths from measured D/H ratios during the 1992, 1993 and 1994 recharge seasons. Recharged surface water completely displaced the ground water beneath the recharge basins from the regional water table at 7.60 m to 12.16 m below the land surface. Mixing occurred beneath the recharge structures in the lower portions of the aquifer (>12.16 m). Approximately 12 m downgradient from the recharge basin, the deeper zone (19.15 m depth) of the primary aquifer was displaced completely by recharged surface water within 193, 45, and 55 days in 1992, 1993 and 1994, respectively. At the end of the third recharge season, recharged surface water represented ~50% of the water in the deeper zone of the primary aquifer ~1000 m downgradient from the recharge basin. A classic asymmetrical distribution of recharged surface water resulted from the recharge induced horizontal and vertical hydraulic gradients. The distribution and breakthrough times of recharged surface water obtained with stable isotopes concurred with those of major anions.

Future Researches

This research suggests abiotic degradation of atrazine to hydroxyatrazine is the most likely major degradative pathway in Recharge Lake. Research is needed to determine the accumulation rate of hydroxyatrazine (HA) in the lake bottom and conduct experiments to increase HA degradation. HA is the only major dehalogenated degradate that is considered nontoxic. Drs. Spalding and Cai, both at the Water Sciences Laboratory, have written a proposal for method development to analyze hydroxyatrazine in the sediment, which has an excellent chance of being funded.

More research is needed to identify effective methods to control clogging in the recharge basins and to enhance efficacy of recharge. Alternating biological growth conditions, such as introducing a disinfectant chlorine into the basins, may be effective in controlling the biological growth in recharge basins. Improved design of the settling basin may be tested to reduce the solid particles entering the recharge basins.

Chapter 2

Herbicide Persistence and Mobility in Recharge Lake Watershed in York, Nebraska

ABSTRACT

Reports of the detection of elevated levels of herbicides in surface water and ground water have created increasing concern in the cornbelt in the USA. Herbicide behavior is interpreted in a watershed system with data collected from runoff, Recharge Lake and ground water influenced by agriculture and lake seepage. The York Ground Water Recharge Project was constructed on a tributary of Beaver Creek which drains a watershed of 3,327 ha of primarily row-cropped heavily irrigated farmland. The estimated average runoff is 1.48×10^6 m^3 yr^{-1} under a precipitation norm of 635 mm yr^{-1}. Maximum atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) inputs to Recharge Lake occurred in May and June runoff events and resulted in atrazine concentrations of 36 and 17 μg L^{-1} in 1993 and 1994 respectively. Deethylatrazine (2-chloro-4-amino-6-isopropylamino-*s*-triazine; DEA), deisopropylatrazine (2-chloro-4-ethylamino-6-ethylamino-*s*-triazine; DIA), alachlor (2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide), cyanazine (2-[[4-chloro-6-(ethylamino)-*s*-triazin-2-yl]amino]-2-methylpropionitrile), and metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide) were also present in runoff, Recharge Lake and the ground water samples. About 0.28% and 0.19% of total applied atrazine was lost to runoff in 1993 and 1994, respectively. The DEA to atrazine molar ratio (DAR) decreased rapidly over a period of several hours in runoff samples, which is consistent with inputs