Bromide and Nitrate Transport in Agricultural Sandy Soils

A. K. Alva¹, S. Paramasivam², H. P. Collins¹

K. S. Sajwan², A. Fares³

¹USDA-ARS Pacific West Area, Vegetable and Forage Crops Research Unit, 24106 N Bunn Rd, Prosser, WA 99350.

²Savannah State University, P O Box 20600, Savannah, GA 31404.

³University of Hawaii,
INTEGRATED CROPPING SYSTEMS FOR IRRIGATED FARMING

Variable rate irrigation, nutrients and chemicals

Spatial variability yield monitoring

N uptake, fate and budget

Management of potatoes and rotational crops

Optimize farm profitability and environmental sustainability

Develop decision support system
Sandy soils in some parts of the Pacific Northwest (PNW) and southeastern agricultural regions in the United States contain 95 to 98% sand in the soil profile to a depth of up to 2.5 m with no confining soil horizons.

The saturated hydraulic conductivities of these soils range from 5.2 to 9.5 m d\(^{-1}\). In some areas, these soils may have shallow groundwater, thus providing favorable conditions for leaching of surface applied chemicals and soluble nutrients that could contaminate the surface waters as well as subsurface aquifers.
## Quincy Fine Sand

<table>
<thead>
<tr>
<th>Soil Depth (cm)</th>
<th>Bulk Density (kg m(^{-3}))</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>1.33</td>
<td>917</td>
<td>56</td>
<td>27</td>
</tr>
<tr>
<td>20-30</td>
<td>1.54</td>
<td>927</td>
<td>52</td>
<td>21</td>
</tr>
<tr>
<td>30-60</td>
<td>1.61</td>
<td>936</td>
<td>48</td>
<td>16</td>
</tr>
<tr>
<td>60-90</td>
<td>1.60</td>
<td>928</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td>90-120</td>
<td>1.58</td>
<td>948</td>
<td>38</td>
<td>14</td>
</tr>
</tbody>
</table>

--Particle size distribution (g kg\(^{-1}\))--
# Candler Fine Sand

<table>
<thead>
<tr>
<th>Soil Depth (cm)</th>
<th>Bulk Density (kg m⁻³)</th>
<th>Sand (g kg⁻¹)</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>1.59</td>
<td>973</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>20-50</td>
<td>1.52</td>
<td>974</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>50-90</td>
<td>1.51</td>
<td>978</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>90-130</td>
<td>1.61</td>
<td>976</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>130-245</td>
<td>1.55</td>
<td>977</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>245-275</td>
<td>1.55</td>
<td>544</td>
<td>49</td>
<td>407</td>
</tr>
</tbody>
</table>
In some parts of the intensely irrigated agricultural production region in eastern Washington state, there has been an increase in groundwater NO$_3$-N concentration in the shallow aquifer in excess of 10 mg per liter, which is the maximum contaminant level (MCL) for drinking water quality standards, per U.S. Environmental Protection Agency regulations.

The Columbia Basin region in the PNW represents the premier potato production region of the U.S. with maximum production (~ 78 Mg/ha) of high quality processed potatoes. Studies are in progress to improve nutrient and irrigation management aimed to minimize NO$_3^-$ transport below the root zone.
The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is designed to assess the status of and trends in the quality of the Nation's water resources, and to gain a better understanding of the natural and human factors that affect water quality. The Central Columbia Plateau is one of 60 NAWQA study units (major river basins and parts of aquifer systems) located throughout the Nation. In the Central Columbia Plateau, nitrate concentrations for 19% of the 573 wells shown below exceed the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for drinking water. These concentrations include USGS samples from 1942-94, although 93% of the data are from 1980-94. Where more than one analysis was available for a well, this document refers to the mean concentration as the nitrate concentration for the well.

Land use is the greatest influence over nitrate concentration.

Nitrate concentration is related in general to fertilizer and water usage.

Nitrate concentrations in shallow ground water vary greatly, but have generally increased since the 1950's.

Nitrate in drinking water is a health issue in parts of the Central Columbia Plateau.
Sandy soils provide a well aerated, deep rooting zone which is ideal for improved crop growth and production under optimal management of irrigation, nutrients and other soil applied agrichemicals.

Increased levels of nitrate-nitrogen (NO₃-N) in shallow groundwater are reported in sandy soil regions in the Columbia Basin irrigated regions in Washington and Oregon, and also in the citrus production regions of central Florida.
An improved understanding of soil characteristics that influence water and nutrient transport is important to the development of best management practices that minimize leaching losses and improve the uptake efficiency of nutrients by the crop plants.

Bromide has been used as a tracer to predict the transport of nitrate in soil.

Bromide tracer can also be used to study the lateral flow of groundwater.
Field experiments were conducted in a sandy soil in Florida (Tavares fine sand - hyperthermic, uncoated, Typic Quartzipsamments) in a commercial grove with 25+ year old Hamlin orange trees on Cleopatra mandarin rootstock.

Bromide was applied at a 112 kg ha\(^{-1}\) rate (as KBr) under the tree canopy area which represented wetting zone by under the tree sprinklers. Various rates of N was also applied in dry granular form using ammonium nitrate.

Irrigation was scheduled when the soil moisture content was depleted to 66% of available soil moisture in the top 1.2 m depth soil which represents the rooting depth for mature citrus trees.
The quantity of each irrigation was adjusted to replenish the soil moisture content to field capacity within the rooting depth in order to minimize leaching of water, and soluble nutrients and chemicals below the rooting depth.

The transport of Br⁻ and nitrate in the soil profile was monitored by soil sampling to 2.4 m depth at various time intervals after the application of Br⁻.
Concentration of bromide (mg kg⁻¹)

Day 7
Day 14
Day 21
Day 28
Day 35
Day 42

Depth of soil profile (m)

Simulated
Measured
Nitrogen mass balance for different fertilization rates as simulated by LEACHM.
(All values are in kg/ha)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Input</th>
<th>Output Removal or Losses</th>
<th>Soil Storage (Input-Removal or Losses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mineral form</td>
<td>Organic form</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>56</td>
<td>14</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>84</td>
<td>14</td>
<td>39</td>
<td>28</td>
</tr>
<tr>
<td>112</td>
<td>14</td>
<td>51</td>
<td>30</td>
</tr>
<tr>
<td>Br</td>
<td></td>
<td>80</td>
<td>0</td>
</tr>
</tbody>
</table>
Water mass balance as simulated by LEACHM (in mm)

<table>
<thead>
<tr>
<th>Input</th>
<th>Removal or Loss</th>
<th>Soil Storage (Input-Removal or Loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain 1612</td>
<td>335</td>
<td>920</td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td>985</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-39</td>
</tr>
</tbody>
</table>
In a parallel experiment using the similar soil series, transport of nitrate was evaluated in an area impacted by an accidental spill of heavy dose of N as liquid N (as ammonium nitrate), P, K blend intended to be used for fertigation.
NO$_3$-N concentration in soil solution (mg L$^{-1}$) (x 10$^4$)

Depth below ground surface (m)

- 3 DAS (0 mm)
- 10 DAS (42 mm)
- 181 DAS (867 mm)
- Control Plot
Evaluation of the direction and rate of lateral flow of groundwater is important to understand the potential impact of pollutants from an area of its source of origin into adjacent areas in the direction of groundwater flow.

Br can be used to determine the lateral flow rate of groundwater.
A study conducted in an Entisol showed that the lateral flow rate of surficial groundwater was 0.08 m d$^{-1}$. 
A leaching column experiment was conducted using a Quincy fine sand to evaluate the leaching of N from Urea or manure, and Br applied as KBr.

The columns were leached with one pore volume of water followed by a dry period to mimic the intermittent wet and dry conditions (five wet and dry cycles) and the effects on N transformation leaching.
Leachate Volume (ml)

Quantity of Br in the leachate (mg)

- Unamended
- Urea (112 kg N ha$^{-1}$)
- Urea (112 kg N ha$^{-1}$) + KH$_2$PO$_4$ (112 kg P ha$^{-1}$)
- Manure (224 kg N/ac)
Leachate Volume (mL)

Quantity of NH₄-N in the leachate (mg)

- Unamended
- Urea (112 kg N ha⁻¹)
- Urea (112 kg N ha⁻¹) + KH₂PO₄ (112 kg P ha⁻¹)
- Manure (224 kg N ha⁻¹)
Leachate Volume (mL)

Quantity of NO₃-N in the leachate (mg)

- Unamended
- Urea (112 kg N ha⁻¹)
- Urea (112 kg N ha⁻¹) + KH₂PO₄ (112 kg P ha⁻¹)
- Manure (224 kg N ha⁻¹)
Br was leached completely in the second pore volume regardless of amendments. The cumulative amount of Br leached across different treatments varied from 211 to 269 mg.

Leaching of nitrate and ammonium followed a cyclic pattern. It appears that intermittent mineralization of organic N which was subject to leaching in the subsequent leaching event.

Cumulative leaching of N was 704 to 733 mg from urea and was 572 mg from manure, despite total N application from the latter was twice than that from the former N source.
CONCLUSIONS

- Transport of Br in a field experiment with Candler fine sand was quite rapid. All of applied Br (112 kg/ha) was leached from the top 2.4 m soil within 28 to 35 DAA.

- In the same soil, Nitrate_N in the top 2.4 m attained the background levels within 28 and 42 DAA of 28 and 112 kg/ha N, respectively.
CONCLUSIONS

- LEACHMN predictions of Nitrate concentration distribution in the soil profile compared favorably with those measured in the soil.

- The lateral flow rate of surfacial groundwater in an Entisol was 0.08 m/day.