Atrazine transport and distribution in field soils and comparison of the predictions made by leaching estimation and chemistry model-pesticide (LEACHP) model

Javanshir Azizi Mobaser1, Hadi Moazed1, Abdolazim Behfar2*, Saeed Boroomand Nasab1 and Zahra Nazari Khorasgani2

1Department of Water Sciences Engineering, Shahid Chamran University, Iran.
2Faculty of Pharmacy, Ahvaz Jondishapur University of Medical Sciences, Iran.

INTRODUCTION

Although pesticides increase crop production (Kalkhoff et al., 1992; Singh and Kanwar, 1991), they could contaminate groundwater resources under poorly managed conditions. Use of agrochemicals improves farming productivity in the world, and their fate in soils is of main concern when applied improperly, as they pose a major threat to water resources (Boivin et al., 2005). Concerns regarding the impacts of pesticide and herbicide on aquatic species and drinking water sources have increased demands on water quality monitoring programs (Byer et al., 2011). According to reports and estimations in 1993, approximately $5 \times 10^6$ kg of toxicants (herbicides and pesticides) are consumed in United State of America and that 75% of it was used in agriculture and $3.4 \times 10^7$ kg of these toxicants was atrazine (Aspin, 1994). Atrazine is the most important pollutant of groundwater in many countries (Kovalos et al., 2006). In another study, looking at combined data from 236 Universities corn field trials from 1986 to 2005, atrazine treatments showed an average of 5.7 bushels more per acre than alternative herbicide treatments (Fawcett,
Atrazine is increasingly used in corn, sorghum and sugar cane farms for weed control (Moreland et al., 1959). However, the use of herbicides makes farms to be more productive, but when farm management is weak, herbicides will pollute underground water resources (Aspin, 1994). For decreasing ground water pollution potentiality, factors which directly influence degradation and motion dynamic of pesticides must be recognized and processed and management factors must be investigated.

Subsequently, having a full information about motion and dynamic of herbicides in soil is necessary (Weed et al., 1995). This information requires cases like determination of motion size and herbicides concentration in relation to different soils and water. These are applied factors in farm management. As for the decomposition of herbicide in the neighborhood of air and soil after a particular time period, a suitable management method can be used to delay degradation of herbicide to ground water, in other words it can be used to prevent propulsion from the root zone.

The application of a mixture of bentazon and atrazine is a practical approach to enhance the herbicidal effect. These results indicated that biological degradation accounted for the degradation of both herbicides in the soil. When compared with the degradation of the herbicide applied alone, the degradation rates of the herbicides applied in combination in the soils were lower and the lag phase increased (Li et al., 2008). Because of atrazine widespread use, relatively high chemical and biological stability in soils and aquifers, and high leaching potential, atrazine has been detected in surface ground water at high concentration levels (Correia et al., 2007; Guzzella et al., 2006).

Researchers showed that atrazine, notwithstanding its relatively low solubility (about 33 mg l⁻¹), is the cause of most pollution in ground water (Poinike et al., 1989; Wilson et al., 1987). Measure of degradation and seepage of atrazine is a function of soil structure and irrigation or raining intensity in field (Isensee et al., 1990). Siczek et al. (2008) were to examine leaching of atrazine in tilled and orchard silt loam soils. The experimental objects included: conventionally tilled field (CT) and a 35 year-old apple orchard (OR) with a permanent sward. Atrazine concentration in the leachiest soil was determined by means of HPLC waters. The results indicated potential of management practices for minimizing atrazine leaching.

The decreased dissipation of atrazine with increasing depth in the profile is the result of decreased microbial activity toward atrazine, measured either as total biomass or as populations of atrazine-degrading micro-organisms. The combination of reduced dissipation and low sorption indicates that there is potential for atrazine movement in the subsurface soils (Blume et al., 2004). One of the best and suitable management in field is collection of activities that decrease percolation of atrazine in irrigated farms, such as using little water when water requirement is low thus, atrazine movement potential and pollution will be decreased (Aspin, 1994). The maximum loss of atrazine in the percolate took place in the soils with the highest organic carbon (OC) level with no effects of tillage practices. These soils had fine texture, and were well structured and aggregated. Intraparticulate and intraorganic matter diffusion appear to be responsible for no equilibrium sorption. Delayed sorption in aggregated soils leads to high concentration of atrazine available for leaching (Montoya et al., 2006).

Cost and time limitation restricted farm experiments from the view of the extent and collectivism of its goals. Therefore, it is impossible that field experiments can provide all needed information for performance and development of environment management in each region. So, simulation models are developed with using experiences and field experiments to access more parameters for more suitable management of the farm. Models simulations have different management and hydrological factors on percolation and dynamics of herbicide in various condition of saturated soil. Simulation models with field experiences could be used as a suitable device for management decision (Loague et al., 1995). Simulation models are increasingly used to predict pesticide leaching (Cohen et al., 1995). Computer model and field measurement are used for evaluation of atrazine degradation with different levels of irrigation and atrazine. A lot of pollution transmissions are now available such as PESTAN (Enfield et al., 1982), PRZM (Carsel et al., 1985), GLAMS (Knisel et al., 1989), LEACHP (Hutson and Wagenet, 1992) and SWMS-2D (Simunek et al., 1992).

High-performance liquid chromatography (HPLC) model description

LEACHM (leaching estimation and chemistry model) is a modular package for calculating the one-dimensional water flux and solute movement in vertically layered soils under transient conditions. The latest version is described in detail by Hutson and Wagenet (1992). LEACHM has several component models, each of which describes a different class of chemical. The water flow module is common to all components. In this work, we used LEACHP which simulates pesticide fate and transport. Water flow is modeled with the one-dimensional Richards’ equation. The θ ± h relationship is described with a two-part function (Hutson and Cass, 1987):

\[ K(S_c) = K_s S_c^2 \left(1 - \left(\frac{1}{S_w}ight)^m\right)^2 \]  

(1a)

\[ h = a \left(\frac{\theta_s}{\theta_s^*}\right)^b \quad , \quad h_s > h > -x \]  

(1b)

Where \( h \) is the pressure potential, \( \theta_s \) the saturated water...
content \( (m^3 m^{-3}) \) and \( a, b \) are constants. \( hc, \theta_c \) defines the point of intersection of the two curves \( h_c = a \left( \frac{2b}{1+2b} \right) b \) and
\[
\theta_c = \frac{2b}{1+2b}.
\]
For the hydraulic conductivity the following equation is available:
\[
K(\theta) = K_s \left( \frac{\theta}{\theta_c} \right)^{2b+2+p}
\]
(2)

Where \( K(\theta) \) is the hydraulic conductivity (mm per day), \( K_s \) are the hydraulic conductivity at saturation \( \theta_s \) and \( p \) is a pore interaction parameter, alternatively, for the \( K-\theta-h \) relationship the following equations are available (Mualem, 1976; Van Genuchten, 1980):
\[
\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha h)]^m}
\]
(3)

Where \( \theta \) is the volumetric water content \( (m^3 m^{-3}) \), \( h \) the pressure head (mm), \( \theta_r \), the residual water content \( (m^3 m^{-3}) \), and \( \alpha \) \((mm^{-1})\), \( n \) \((-\)), and \( m \) \((-\)) are empirical parameters.

\[
K(S_e) = K_s S_e^\lambda (1 - (1 - S_e^m)^n)^2
\]
(4)

Where \( S_e \) is the effective saturation \( \lambda, ((\theta - \theta_r)/(\theta_s - \theta_r)) \), \( \lambda \) the pore connectivity parameter \((-\)), and \( m \) the empirical parameter from Equation (3), the water flow equation is combined with the convection-dispersion equation in LEACHP. Solute sorption to soil can either be described with a linear Equations 5 and 6 or non-linear (Equation 7) isotherm or by two site sorption (Equation 8). For a linear isotherm we have:
\[
C_s = K_d \times C_f
\]
(5)

Where \( K_d \) is the linear distribution coefficient \((dm^3 kg^{-1})\), \( K_d \) can vary with depth. For pesticides, \( K_d \) values are calculated from the organic carbon partition coefficient \( K_{oc} \) and the organic carbon fraction \( f_{oc} \) as:
\[
K_d = K_{oc} \times f_{oc}
\]
(6)

Non-linear sorption is described with the Freundlich isotherm. Atrazine (6-chloro-N2-ethyl-N4-isopropyl-1, 3, 5-triazine-2, 4-diamine) has relatively low adsorption coefficient with \( K_{oc} \) values ranging from 40 to 394 mill/g for atrazine (Giddings et al., 2005):
\[
C_s = K_f \times C_f^{n_f}
\]
(7)

Where \( k_f \) and \( n_f \) are constants.

Non-equilibrium linear sorption assumes that a fraction of sites \( f \) display local chemical equilibrium and a fraction \( (1 - f) \) is subject to kinetically controlled sorption and desorption. The sorbent concentration is the sum of sorption to the kinetic \( S_k \) and equilibrium \( S_e \) sites. Flux density of solute \( J_a \) \((mg kg^{-1})\) between the kinetic sites and solution phase \( C \) \((mg dm^{-3})\) is assumed to depend upon the current degree of non-equilibrium:
\[
J_a = \alpha P_b ((1 - f) K_d c - S_f)
\]
(8)

Where \( \alpha \) is a phase transfer rate coefficient and \( \rho_b \) the soil bulk density \((kg dm^{-3})\). The liquid-vapor partition is represented by a modified Henry’s law as proposed by Jury et al. (1983). Degradation of pesticides is assumed to follow first-order kinetics. The rate constant may be adjusted for temperature and/or water effects. The temperature correction factor \( (T_{cf}) \) at a temperature \( t \) \((°C)\) is calculated as:
\[
T_{cf} = Q_{10}^{1.1(log_{10} t_{base})}
\]
(9)

Where \( Q_{10} \) is a constant and \( t_{base} \) is the base temperature for which the rate constants are specified in the data file. The water correction factor \( (W_{cf}) \) is set to one in the optimum water content range, which is between \( \theta_{min} \) and \( \theta_{max} \). If \( \theta \) is higher than the optimum, \( W_{cf} \) becomes:
\[
W_{cf} = W_{cfat} + \frac{(1 - W_{cfat})(\theta_s - \theta)}{\theta_s - \theta_{max}}
\]
(10)

Where \( W_{cfat} \) is the relative rate constant at saturation and \( \theta_s \) the saturated water content. If the soil moisture is lower than the optimum water content range, the correction factor is:
\[
W_{cf} = \frac{MAX(\theta, \theta_{wp}) - \theta_{wp}}{\theta_{min} - \theta_{wp}}
\]
(11)

The correction factor is zero at wilting point \( \theta_{wp} \). Furthermore, uptake of pesticides in the transpiration stream can be included if desired.

**MATERIALS AND METHODS**

Field information are investigated on the basis of evaluating the study’s model and the simulation results obtained. In this research, LEACHP model which is a transport module from LEACHM model, version3, was used (Hutson and Wagenet, 1992). Elaborate input parameters describing hydraulic and solute properties are often lacking, which prevents the proper use of research models like LEACHP (Walker et al., 1995). In order to gain confidence in the
Table 1. Soil properties used for the simulation.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Air entry potential (J kg⁻¹)</th>
<th>Saturation (sp)%</th>
<th>EC (dS m⁻¹)</th>
<th>Organic carbon (10⁻², g g⁻¹)</th>
<th>Field capacity (m³ m⁻³)</th>
<th>PWP (m³ m⁻³)</th>
<th>Kₓ(10⁻⁵, s⁻¹)</th>
<th>Bulk density (g cm⁻³)</th>
<th>B-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>-3.66</td>
<td>38</td>
<td>7.5</td>
<td>0.35</td>
<td>0.17</td>
<td>0.08</td>
<td>1.86</td>
<td>1.6</td>
<td>3.33</td>
</tr>
<tr>
<td>25-50</td>
<td>-2.98</td>
<td>39</td>
<td>4.2</td>
<td>0.31</td>
<td>0.17</td>
<td>0.09</td>
<td>1.68</td>
<td>1.61</td>
<td>3.28</td>
</tr>
<tr>
<td>50-75</td>
<td>-3.5</td>
<td>38.1</td>
<td>3.6</td>
<td>0.28</td>
<td>0.18</td>
<td>0.09</td>
<td>1.55</td>
<td>1.55</td>
<td>3.01</td>
</tr>
<tr>
<td>75-100</td>
<td>-2.08</td>
<td>38.2</td>
<td>4.5</td>
<td>0.24</td>
<td>0.18</td>
<td>0.07</td>
<td>1.46</td>
<td>1.51</td>
<td>2.85</td>
</tr>
<tr>
<td>100-125</td>
<td>-2.66</td>
<td>43.1</td>
<td>7.5</td>
<td>0.22</td>
<td>0.17</td>
<td>0.08</td>
<td>1.73</td>
<td>1.35</td>
<td>3.14</td>
</tr>
<tr>
<td>125-150</td>
<td>-3.43</td>
<td>43.5</td>
<td>7.4</td>
<td>0.18</td>
<td>0.17</td>
<td>0.09</td>
<td>1.38</td>
<td>1.4</td>
<td>3.44</td>
</tr>
</tbody>
</table>

model performance, repeated testing of predictions against field data is necessary.

This model has conceptual principles for soil humidity and contaminant transport dynamic simulation. However, LEACHP needs entry parameters such as distribution coefficient, first order degradation rate constant of pesticide, bulk density, organic matter and dispersion length. The overall objective was to collect data for use in formulating best water management practices to minimize atrazine leaching potential in irrigated soil. The soil specific objectives were to use the measured atrazine data to test and evaluate conceptually contaminant transport model. The model involved is LEACHP which use Richard/Convection-Dispersion equations to approximate water and solute dynamics in soils.

**Irrigation treatment**

Corn is cultivated as furrow and irrigated as surface irrigation. Water requirement is estimated by using evaporation from class (A) pan and irrigation was at constant volume with various intervals on the basis of 7 mm evaporation from pan to end of growth period. Three irrigation treatments were respectively used for irrigation levels I₁, I₂ and I₃, and it was observed that I₁ showed low level of irrigation which was equal to 25% but less than that of normal irrigation (deficit irrigation), level I₂ showed normal irrigation percentage (full irrigation) and level I₃ showed 25% more than that of normal irrigation (excess irrigation).

**Used atrazine and soil sampling**

Atrazine added to soil five days after the first irrigation and before germination of weeds as three treatments of P₁, P₂ and P₃ are respectively equal to 3.75, 5 and 6.25 kg/ha. Primarily samples of soil are taken from depths of 0 to 120 cm with 20 cm distance (August 11th); second sampling was on the September 11 and January 15th 2010. Complex soil samples were taken from each layer of soil for atrazine analysis. The position of the center of mass of atrazine profiles at different sampling dates was estimated following the procedure used by Zacharias and Heatwole (1994):

\[
Z_c = \frac{\sum_{i=1}^{n} c_id_iZ_i}{\sum_{i=1}^{m} c_id_i}
\]

Where \(Z_c\) is the position of the center of mass of atrazine profile (cm) in which the base point is the soil surface, \(C\) is atrazine concentration in the \(i^{th}\) layer, \(d_i\) is the thickness of the layer (cm), and \(Z_i\) is the \(i^{th}\) depth to the center of the \(i^{th}\) layer from the soil surface (cm). The position of the center of mass were used to assess the extent and time course of atrazine leaching in relation to the different amounts of early season and seasonal irrigation used in this study. The position of the center of mass solute profile is the result of the net balance among infiltration, percolation, solute movement, water and solute redistribution, solute degradation and transformation (if applicable), and plant uptake processes that had occurred in the soil profile at the time of sampling.

**Determination of atrazine concentration**

Concentration of atrazine in samples were determined the by HPLC method. Atrazine was extracted using a solid phase extraction cartridge SCX-Vertical (Phewnil et al., 2010). Briefly, an approximately 100 g of soil was suspended in 99 ml of acetronitrile/water (9:1, v/v), then the standard solution at the amount of 1 ml (0.2 mg ml⁻¹ atrazine) was added and the sample was shaken vigorously for 5 min. The samples were then filtered through a paper filter (Whatman GF/C), with the first 5 ml of filtrate being discarded and the following 10 ml being used for analysis. The cartridges were then flushed with 1 column volume of acetic acid (1%), after which 2 ml of acetic acid (1%) were added. A reservoir was placed onto the cartridge with the adaptor prior to use. Subsequently, 5 ml of each sample were then mixed with 25 ml of acetic acid (1%) and poured into the reservoir, stirred and slowly

---

**Site description**

Field experiment was located at Chamran University in pilot farm of Water Science Engineering Faculty, Farming in Ahvaz. The climate at this site is semi-arid with annual mean precipitation of about 250 mm. The soil at the site is silt loam. An automated climate station located close to the study’s site recorded the daily weather data. Discretisation of the soil profile and hydraulic parameters are given in Table 1. The study was conducted in pilot farm of Chamran University, Faculty of Water Science Engineering, Ahvaz, Iran (UTM: X=3564212 and Y=5431236). The climate at the site is semi-arid with annual mean precipitation of about 240 mm. The mean pH is 8.10 in the 0 to 25 cm soil layer. The soil profile is deep and well drained. An automated station climate station located Chamran University recorded daily weather data.
aspirated through the cartridge. The reservoir was then washed with 2 ml of acetic acid (1%), after which the cartridge was washed with 1 ml of acetonitrile, then 1 column volume of water and finally 1 ml of 0.1 M dipotassium hydrogen phosphate. Between the washing steps, the cartridge was dried briefly for about 15 s under vacuum.

The cartridges were then eluted with 2 ml acetonitrile/0.1 M dipotassium hydrogen phosphate (1:1). Finally, the samples were filtered with nylon filter and 2 \( \mu \)L of each sample was injected into the HPLC.

**Calibration of LEACHP Model**

Module of water flow in the LEACHP model called LEACHW is related to soil physical parameters such as saturated hydraulic conductivity, air entry value, b-value of Campbell’s equation and sorption coefficient of atrazine which is recommended by Wauchap et al., (1992) for field studies is equal to 1001 kg\(^{-1}\). Moreover, atrazine half life is selected 40 days after sensitivity analysis during model calibration (Figure 1). Prediction of the atrazine profile was estimated using the Root Mean Square Error (RMSE) objective function as follows:

\[
RMSE = \left( \frac{\sum (P_i - O_i)^2}{n} \right)^{0.5}
\]

Where \( n \) is the sample size, \( P \) is the predicted data using LEACHP model, \( O \) is the measured data, \( \bar{x} \) is the mean of the measured data, and \( i \) is soil layer index. The closer the RMSE value is to zero the better the model prediction. The other indexes for evaluation of model are:

- **Maximum error**
  \[
  ME = \max |P_i - O_i|
  \]

- **Modelling Efficiency**
  \[
  MEF = \frac{\sum (O_i - \bar{O})^2 - \sum (P_i - O_i)^2}{\sum (O_i - \bar{O})^2}
  \]

- **Coefficient of residud mass**
  \[
  CRM = \frac{\sum O_i - \sum P}{\sum O_i}
  \]

**RESULTS AND DISCUSSION**

Estimated maximum density of atrazine from domain and location view is different from measured density estimated and measured. Maximum density of atrazine estimated is generally the same with other estimated densities. Deviations of anticipated quantities are shown by LEACHP model, regardless of the irrigation treatments used with RMSE quantity. The maximum value of difference accrues for 175 days after atrazine was added. It has been shown that standard deviation decreased with lapsing time. Maximum quantity of deviation resulted in first lager (0 to 25) for RMSE. Location of mass center for atrazine in profile for LEACHP model statically increased with lapsing time (Figures 2 to 4).

The model predicted a comparatively higher total amount of atrazine remaining in the soil profile on the first two sampling dates than were measured. The measured amounts of atrazine, however, were under-estimated on the last sampling (Tables 2 and 3). Generally, the measured and predicted atrazine amounts in the soil profile were within one of magnitude.

However, measured Zc is greater than estimated Zc in conditions of soil profile because used models atrazine quantity in soil profile was underestimated. For example, this quantity is estimated to be about 42% in LEACHP model in the highest level of irrigation, Zc of model is about 24%. Generally, it could be said that this model is simulating drained atrazine better in more irrigated conditions.

Model anticipation for Zc in farm condition is attained in 13.4 to 72.8 cm range. Also, aterazine density in deepest layer of soil (140 to 160 cm) was about zero. Simulation results showed that there is a relationship between quantity of irrigation water and leached atrazine and as such, it can be deduced that this model can show the
Figure 2. Measured and predicted atrazine profiles at different times of sampling under irrigation level 1, Means days after atrazine application (DAA).

Figure 3. Measured and predicted atrazine profiles at different times of sampling under irrigation level 2, Means days after atrazine application (DAA).
Figure 4. Measured and predicted atrazine profiles at different times of sampling under irrigation level 2, Means days after atrazine application (DAA).

Table 2. Objective function values showing the performance of LEACHP in predicting the measured atrazine profiles RMSE, ME, MEF and CRM values for sampling dates.

<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Date</th>
<th>RMSE</th>
<th>ME</th>
<th>MEF</th>
<th>CRM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11-Aug-10</td>
<td>4.4</td>
<td>305</td>
<td>-0.95</td>
<td>-1.83</td>
</tr>
<tr>
<td></td>
<td>11-Sep-10</td>
<td>2.54</td>
<td>54</td>
<td>-11.28</td>
<td>-0.85</td>
</tr>
<tr>
<td></td>
<td>15-Jan-11</td>
<td>1.5</td>
<td>11.3</td>
<td>0.98</td>
<td>0.74</td>
</tr>
<tr>
<td>I1</td>
<td>11-Aug-10</td>
<td>7.3</td>
<td>85</td>
<td>-12</td>
<td>-2.62</td>
</tr>
<tr>
<td></td>
<td>11-Sep-10</td>
<td>1.32</td>
<td>31</td>
<td>-5.6</td>
<td>-0.38</td>
</tr>
<tr>
<td></td>
<td>15-Jan-11</td>
<td>1.4</td>
<td>2.8</td>
<td>0.96</td>
<td>0.66</td>
</tr>
<tr>
<td>I2</td>
<td>11-Aug-10</td>
<td>10.73</td>
<td>286</td>
<td>-79</td>
<td>-5.15</td>
</tr>
<tr>
<td></td>
<td>11-Sep-10</td>
<td>0.57</td>
<td>10</td>
<td>-0.7</td>
<td>-0.27</td>
</tr>
<tr>
<td></td>
<td>15-Jan-11</td>
<td>0.82</td>
<td>3</td>
<td>0.89</td>
<td>0.63</td>
</tr>
</tbody>
</table>

state of atrazine motion versus irrigation variations. Using an irrigation of about 97 cm with 85% efficiency proved 6 t/ha performance of the product. This performance efficiency was attained under a suitable programming. Decreasing irrigation in respect to level 1 is causing a reduction of production at MAX state but also reducing
Differences in the predicted atrazine profiles and leaching LEACHP model underestimated atrazine leaching. Results observed from a field experiment. However, the extent of atrazine leaching depends on the level of measured and simulated atrazine profiles suggest that resulting from targeted irrigation management strategies. Twice, used for preliminary assessment of atrazine leaching, dynamics in the soil. Uses by LEACHP for simulating moisture and solute different conceptual processes and mechanisms was between the model and field experiment due to the measured density in soil profile in respect to model measurement. Furthermore, it can be noted that measured atrazine leaching in response to addition of irrigation water to the soil which is compatible with farm results. Furthermore, it can be noted that measured atrazine density in soil profile in respect to model measurement was lower which could be because of conceptual trend type and used mechanism for simulation of humidity and solvent dynamics in the soil. With the use of the model results and farm measurements, it can be specified that the quantity of leached atrazine is equal to the quantity of irrigation water after atrazine application.

**Conclusions**

LEACHP performed well in simulating the trend in the measured atrazine distribution in the soil profile. Also, this model predicted increasing atrazine leaching in response to increasing irrigation levels, which is in line with the results observed from a field experiment. However, LEACHP model underestimated atrazine leaching. Differences in the predicted atrazine profiles and leaching between the model and field experiment due to the different conceptual processes and mechanisms was used by LEACHP for simulating moisture and solute dynamics in the soil.

The conclusion, however, is that this model could be used for preliminary assessment of atrazine leaching, resulting from targeted irrigation management strategies. Measured and simulated atrazine profiles suggest that the extent of atrazine leaching depends on the level of irrigation water applied after atrazine application.

**REFERENCES**


<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Index</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>11-Aug-10</td>
</tr>
<tr>
<td>I_1</td>
<td>Measured</td>
<td>13.4</td>
</tr>
<tr>
<td></td>
<td>LEACHP</td>
<td>8.8</td>
</tr>
<tr>
<td>I_2</td>
<td>Measured</td>
<td>22.6</td>
</tr>
<tr>
<td></td>
<td>LEACHP</td>
<td>9.1</td>
</tr>
<tr>
<td>I_3</td>
<td>Measured</td>
<td>37.6</td>
</tr>
<tr>
<td></td>
<td>LEACHP</td>
<td>19.8</td>
</tr>
</tbody>
</table>

Table 3. Atrazine center of mass positions estimated from the measured and predicted atrazine profiles center of mass (cm) for sampling dates.
and nitrate variation in alluvium underlying a corn field at a site in Iowa county. 28(6): 1001-1011.


