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*Full length Research paper*

# Numerical Modeling of Phosphate Movement through the Sandy Loamy Clayey Soil by CTRAN/W Simulations

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**In the present research work water flow and fertilizer (phosphate) movement analysis through sandy loamy clayey soil has been computed by using the slave program of Geo-Slope software i.e. SEEP/W and CTRAN/W respectively. The simulation results obtained from the SEEP/W program revealed that the overall average water flow occurs in the subsurface region throughout the one year study is of the order 8.475 x $10^{-5}$ $ft^3$/sec/ft (0.00239 LPS) respectively. Likewise, by using CTRAN/W program Phosphate concentration at the toe point of the drain's slope after 365 days was (1.05 gm/$ft^3$) which conforms that the hydraulic conductivity of the soil is low, due to which the phosphate particles take a long time to reach the toe of slope. Statistical analysis of all the research data i.e. RMSE, ME, R.E, and EF to evaluate the performance of the model are found to be 21.20 gm/$ft^3$, 16.45 gm/$ft^3$, 1.32% and 98.12% respectively. Consequently, it is concluded that simulated values of phosphate concentration are not much different than the observed.**

**Keywords:** Finite element modeling, Water flow, phosphate movement, advection-dispersion analysis, particle tracking analysis (PTA), SEEP/W, CTRAN/W.

## INTRODUCTION

Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphorus in elemental form is very toxic and is subject to bioaccumulation. Phosphorous exists in three forms: Orthophosphate, met-pho sulfate, and organically bound phosphate. Phosphates are not toxic to people or animals unless they are present in very high levels. Since phosphate is an anion, particles that generate an anion exchange capacity will form strong bonds with phosphate. As the amount of clay increases in the soil, the P-sorption capacity increases as well.

This is because clay particles have a tremendous amount of surface area for which phosphate sorption can take place Balemi et al., (2012). At low pH, soils have greater amounts of aluminum in the soil solution, which forms very strong bonds with phosphate. In fact, a soil binds twice the amount of phosphorus under acidic conditions, and these bonds are five times stronger. In addition to this phosphorus movement in saturated / unsaturated soil is very little, even with large amounts of precipitation or irrigation. This is the basic phosphorus problem due to which the pH of soil becomes alkaline and in some cases a hardpan observed at the subsurface of an agricultural land.

Different studies showed that the distance of phosphate transport significantly depends on the hydraulic conductivity of the soil and the diffusion coefficient ($D_0$) of contaminant Anion or Cation. The movement of contaminants in course soils (gravel and sand) is greater than its movement in fine soil (silt and clay) Eltarabily et al., (2015).

The movement of these fertilizers through different soil regimes can be analysis by using two techniques i.e. (i) advection-dispersion analysis (ii) particle tracking analysis.

The dispersion–advection equation is the most effective method for representation of contaminant transport through unsaturated soil.

Advection refers to the process by which solutes are transported by the bulk motion of flowing groundwater.

Dispersion refers to the phenomenon of contaminant spreading from the path that it would be expected to follow according to the advective hydraulics of the flow system. Virtually all contaminant transport analyses require computation of advection and dispersion. On the other hand the particle tracking analysis gives an idea of the contaminant travel distances and travel times. Whereas particle tracking is a quick way of presenting the contaminated region, a complete advection dispersion analysis is required to know the concentration within the contaminated region Eltarabily et al., (2015).

Nowadays, many computer software's has come in general use, and any hard computations and simulation can be carried out through them by giving them appropriate inputs and data.

This results in less error frequency and more detailed analysis when compared with field observations. In order to simulate the migration process of fertilizers through different soils regimes there are many numerical solution methods i.e. Finite Differences (FDM), Finite Elements (FEM) and Boundary Elements (BEM).

But the FEM is an effective numerical technique because of its numerous applied fields such as groundwater flow, multiphase flow, and mass flow through pours medium.

By keeping the above facts in view the present research study was conducted to check the behavior of the phosphatic fertilizer (DAP) through the sandy loamy clayey soil by using two slave programs of Geo-Slope software i.e. SEEP/W and CTRAN/W for the development of numerical model and its analysis.

## OBJECTIVES

The objectives of this research work was to study the movement of phosphate through the sandy loamy clayey soil by using finite element method through Geo-Slope computer software, to compute the flow velocities to analyze the movement of dissolved constituents in the pore-water, to simulate the phreatic surface for saturated soil conditions, to conduct the advection – dispersion analysis and particle tracking analysis for 0-365 days, and finally to compare the simulated results with field data.

## MATERIALS AND METHODS

### Location

The study was undertaken in the month of April, 2014 at a private agricultural farm i.e. Marri Farms located at south-east of Dhabeji, Sindh – Pakistan. This farm is located 57 KM away from Karachi on National Highway (Karachi - Hyderabad). The soil of this farm was mostly sandy loamy clayey up to 5ft depth and watertable was around 13ft deep from the ground surface.

### Field Experiment

A field experiment was designed to evaluate phosphate transport through the sandy loamy clayey soil and to produce a data set for modeling applications. In order to achieve the objectives of the research work a fallow land nearest to the free drain was selected and was divided into 3 square sub-plots i.e. 20ft x 20ft respectively. The research was conducted on 1 sub-plot with 2 replications. The dimensions of the agricultural land site are 20ft long; ground elevation was 24ft in depth and the difference between elevation of plot and ground surface was 1ft respectively.

The cross section of trapezoidal canal with bottom width 3ft and 1:1 side slopes. Each sub-plot was further divided in to 3 parts i.e. head, middle and tail in order to draw soil sample during the research period at different interval of time respectively.

In order to measure the phosphate movement; after necessary tillage operation an excessive dose of DAP fertilizer i.e. 220 gm/ft$^3$ (200 kg/acre) applied to each sub-plots accordingly.

The soil samples were drawn to monitor the evolution of soil water content and phosphate concentration during the different irrigation events. The soil samples were drawn from three different sections at a distance of 2ft (head), 10ft (middle), and 18ft (tail); and the depth of soil samples was 0-6 inches, 6-12 inches, 12-18 inches, 18-24 inches, 24-30 inches and 30-36 inches respectively.

The samples were packed and send to soil testing laboratory to find out the phosphate ($PO_4^{-3}$) concentration in the soil extract.

All auger holes were refilled to avoid disturbances in the soil water profile.

The irrigation interval was 7 days and altogether 14 irrigations of 1 inch depth were provided to each sub-plot. This interval was maintained throughout the research period.

Finally on the basis of results obtained by experiment was utilized in developing numerical modeling and computations for different parameters were took place accordingly.

### Steps for Modeling

In order to develop a numerical model two slave programs of Geo-Slope Software i.e. (SEEP/W) for the flow analysis and (CTRAN/W) for fertilizer movement analysis through the soil was used.

In first attempt by using SEEP/W finite element mesh was generated. The dimensions of the mesh were used for both SEEP/W and CTRAN/W programs to simulate the studied cases. The mesh is 90ft long and 24ft depth.

The dimensions of the agricultural land site are 20ft long; ground elevation was 24ft in depth and the difference between elevation of plot and ground surface was 1ft respectively. The cross section of trapezoidal canal with bottom width 3ft and 1:1 side slopes.

After the development of numerical model, the material properties for the materials used in subject mesh were calibrated.

Finally it is then verified by the SEEP/W software and computation for water flow through the soil profile is carried out accordingly.

Likewise, CTRAN/W program is used under different conditions to analyze the movement of phosphate through the soil profile.

The flow system established with SEEP/W was used in CTRAN/W to analyze phosphate movement.

According to the given conditions the entry of phosphate and free drain exit location are assigned boundary conditions for the mesh.

Then geological parameters and material properties are then calibrated accordingly.

After the development of complete model, it is then verified by the CTRAN/W software.

The initial concentration at the source of fertilizer is 220 gm/ft$^3$ (200 kg / acre) of phosphate.

The time step sequence consists of 20 steps.

Time starts by Zero day ends by 365 days, the longitudinal dispersivity and transverse dispersivity was set 6.1ft and 1ft respectively.

Then on the basis of specific analysis methods i.e. Advection-dispersion analysis and Particle Tracking analysis (PTA); the phosphate movement through the soil was carried out accordingly. Finally simulated results obtained from the SEEP/W and CTRAN/W program are compared with the field observations obtained from the experiment respectively.

## RESULTS AND DISCUSSION

### FEM Mesh Formation and Its Verification

The FEM mesh for the selected agricultural land is composed of four types of elements, i.e. triangular, square, rectangular and trapezoidal type of elements of 3 ft size (Figure:1). The domain is discretised into a mesh by 287 elements through placement of nodal points 319. The material properties for subject mesh with proper dimensions are made as input to the software respectively and verification has been made accordingly. As the soil of the farm was mostly sandy loamy clay upto 5ft depth from the ground surface therefore, it is assumed that the complete soil region of the subject is to be considered as sandy loamy clay.

For the calibration of material properties for subject mesh, relevant values from the soil samples i.e. saturated hydraulic conductivity (Ks) (1.913 x $10^{-5}$ ft/s) were provided to the specified section accordingly. After all the necessary inputs, the computer program SEEP/W verified the mesh development and delivered report that the vertical and horizontal meshing is strong enough and there is no error in formation of mesh model. Thus the model is ready for computation and analysis of the results.

Likewise, CTRAN/W program is used for numerical modeling for the selected agricultural land. According to the given conditions the entry of phosphate and free drain exit location are assigned boundary conditions for the mesh.

Then geological parameters and material properties are

then calibrated accordingly.

After all the necessary inputs, the computer program CTARN/W verified the mesh development and delivered report there is no error in formation of numerical model.

Thus the model is ready for computation and analysis of the results.

### Analysis of Subsurface Flow through Soil Profile by SEEP/W

In order to study the behavior of phosphate movement initially the SEEP/W program was used to acquire the subsurface flow of water through the developed mesh. The flow net comprises of streamlines, equipotential lines, velocity vectors showing water flow field and phreatic surface in the subsurface region. From (Figure:2), it is revealed that the streamlines and equipotential lines are normal to each other, and vectors displaying the velocity of the flow direction.

The result showed that average water flow occurs in the subsurface region is of the order 8.475 x $10^{-5}$ ft$^3$/sec/ft (0.00239 LPS) respectively.

The water flow velocities computed from SEEP/W are then used by CTRAN/W for the phosphate movement analysis.

### Analysis of Phosphate Movement through Soil Profile by CTRAN/W

The CTRAN/W program is used to analyze the phosphate movement through the sandy loamy clayey soil by two specific analysis methods i.e. Advection-

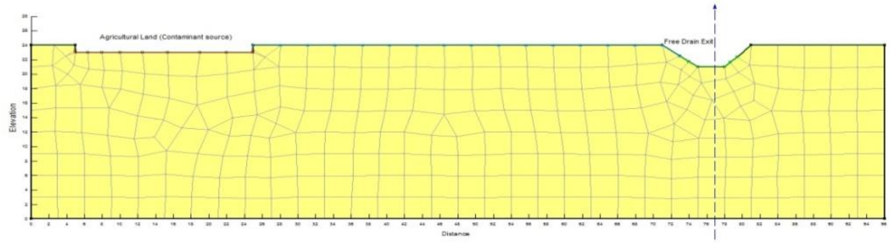


**Figure 1:** The mesh of the domain showing the boundary conditions for SEEP/W analysis

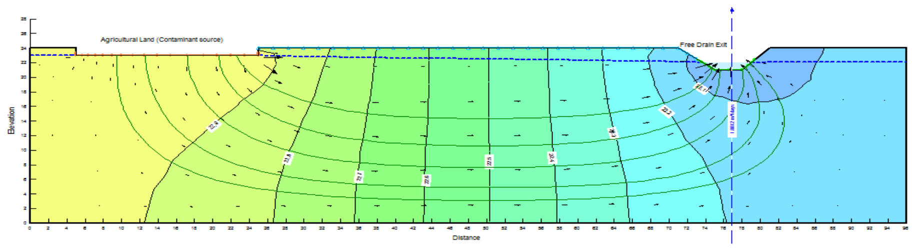


**Figure 2:** Total head distribution and flux section at the drain side.

dispersion analysis and Particle Tracking analysis (PTA) respectively.

## Advection- Dispersion Analysis

The results showed that adsorption of phosphate on the soil particles are linearly related to concentration of phosphate fertilizer for the case of in the advection-dispersion. The movement is reported as temporal variation of the phosphate concentration due to water percolation through the soil. This is the concept of chemical partitioning between the fluid and solid phases, quantified by a chemical partitioning coefficient. This means that the chemical partitioning coefficient, (which is the slope of the adsorption/concentration function), can be specified as a function of concentration. (Figures:3a-3g) are graphical representations of advection-dispersion analysis of a solution of Phosphate; for 50, 100, 150, 200, 250, 300 and 365 days at starting concentration (220 gm/ft$^3$) = (200 kg / acre) respectively. The contours represent the different concentration of phosphate for different interval of time throughout the research period; from which the light blue color indicates the maximum concentration while the sea green colour indicates the minimum concentration.

Results of phosphate concentration through soil profile at the toe point of the drain's slope for numerical simulation showed that phosphate concentration after 365 days was (1.05 gm/ft$^3$) which conforms that the hydraulic conductivity of the soil is low, due to which the phosphate particles take a long time to reach the toe of slope.

The shape and spread of contours for phosphate concentration showed that the movement of the particles highly depends on their diffusion and adsorption function and the total head of irrigation water applied on the agricultural land. (Figures:4a - 4c) describes the concentration of phosphate in an agricultural land at different soil depths at a distance of 2ft (head), 10ft (middle), and 18ft (tail) and at different interval of time obtained by CTRAN/W simulations and the complete summary results are elaborated in Table: 1 – Table: 3 respectively.

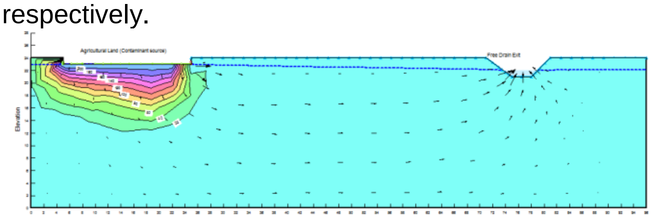

**Figure 3a:** Advection-dispersion analysis after 50 days.

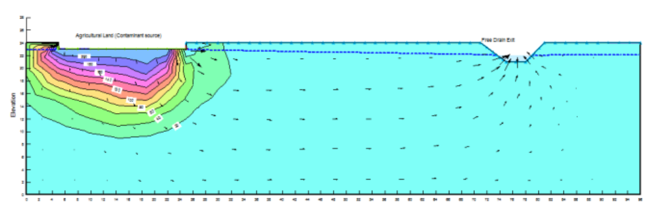

**Figure 3b**: Advection-dispersion analysis after 100 days.

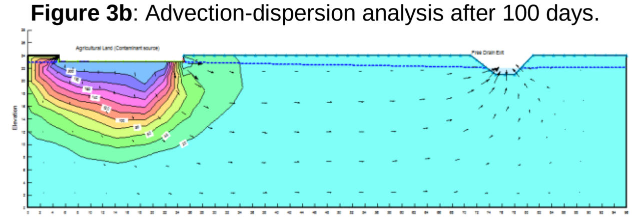

**Figure 3c**: Advection-dispersion analysis after 150 days.

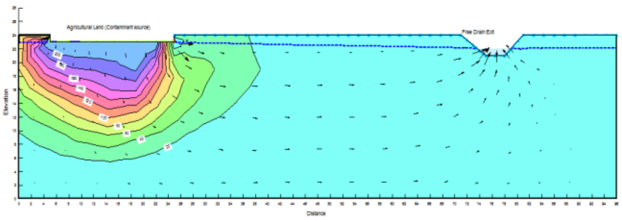

**Figure 3d**: Advection-dispersion analysis after 200 days.

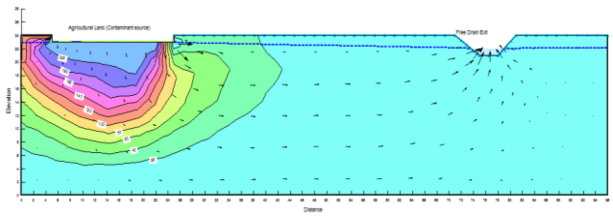

**Figure 3e:** Advection-dispersion analysis after 250 days.

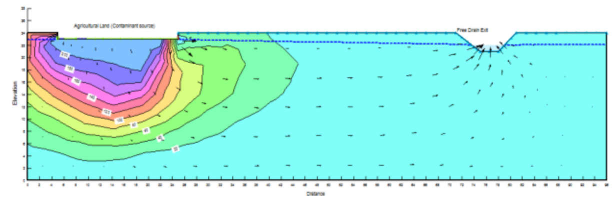

**Figure 3f:** Advection-dispersion analysis after 300 days.

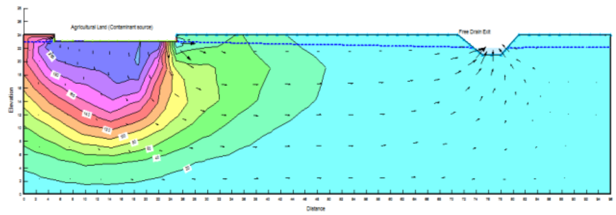

**Figure 3g:** Advection-dispersion analysis after 365 days.

**Table: 01.** Phosphate Concentration in an agricultural land at a distance of 2ft (head) for different soil depths at different interval of time

| S. No | Soil Depth (ft) | Phosphate Concentration (g/ft$^3$) at different interval of time (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 50 days | 100 days | 150 days | 200 days | 250 days | 300 days | 365 days | Average |
| 1 | 22.5 | 202.29 | 210.38 | 212.79 | 214.9 | 216.14 | 216.71 | 217.51 | 212.96 |
| 2 | 22.0 | 184.55 | 200.72 | 205.55 | 209.78 | 212.26 | 213.4 | 215 | 205.9 |
| 3 | 21.5 | 166.77 | 191.04 | 198.28 | 204.63 | 208.36 | 210.08 | 212.48 | 198.81 |
| 4 | 21.0 | 149.39 | 180.7 | 190.37 | 198.94 | 204.01 | 206.35 | 209.65 | 191.34 |
| 5 | 20.5 | 133.37 | 169.16 | 181.22 | 192.18 | 198.76 | 201.83 | 206.18 | 183.24 |
| 6 | 20.0 | 117.85 | 157.99 | 172.36 | 185.61 | 193.65 | 197.42 | 202.78 | 175.38 |

**Table: 02.** Phosphate Concentration in an agricultural land at a distance of 10ft (middle) for different soil depths at different interval of time

| S. No | Soil Depth (ft) | Phosphate Concentration (g/ft$^3$) at different interval of time (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 50 days | 100 days | 150 days | 200 days | 250 days | 300 days | 365 days | Average |
| 1 | 22.5 | 205.85 | 212.32 | 214.36 | 216.15 | 217.20 | 217.68 | 218.34 | 214.56 |
| 2 | 22.0 | 191.69 | 204.63 | 208.71 | 212.29 | 214.40 | 215.36 | 216.68 | 209.11 |
| 3 | 21.5 | 177.52 | 196.93 | 203.06 | 208.43 | 211.59 | 213.03 | 215.01 | 203.65 |
| 4 | 21.0 | 163.33 | 189.22 | 197.39 | 204.56 | 208.77 | 210.70 | 213.35 | 198.19 |
| 5 | 20.5 | 149.12 | 181.50 | 191.72 | 200.68 | 205.95 | 208.36 | 211.67 | 192.71 |
| 6 | 20.0 | 134.90 | 173.77 | 186.04 | 196.80 | 203.13 | 206.02 | 209.99 | 187.23 |

**Table: 03.** Phosphate Concentration in an agricultural land at a distance of 18ft (tail) for different soil depths at different interval of time

| S. No | Soil Depth (ft) | Phosphate Concentration (g/ft$^3$) at different interval of time (days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 50 days | 100 days | 150 days | 200 days | 250 days | 300 days | 365 days | Average |
| 1 | 22.5 | 136.91 | 140.04 | 140.84 | 141.48 | 141.84 | 141.99 | 142.20 | 140.76 |
| 2 | 22.0 | 127.30 | 133.53 | 135.13 | 136.41 | 137.12 | 137.43 | 137.84 | 134.97 |
| 3 | 21.5 | 118.19 | 127.46 | 129.85 | 131.78 | 132.84 | 133.30 | 133.92 | 129.62 |
| 4 | 21.0 | 109.55 | 121.83 | 125.01 | 127.58 | 128.99 | 129.62 | 130.44 | 124.72 |
| 5 | 20.5 | 101.38 | 116.64 | 120.59 | 123.80 | 125.58 | 126.36 | 127.38 | 120.25 |
| 6 | 20.0 | 94.12 | 112.14 | 116.95 | 120.93 | 123.16 | 124.15 | 125.45 | 116.70 |

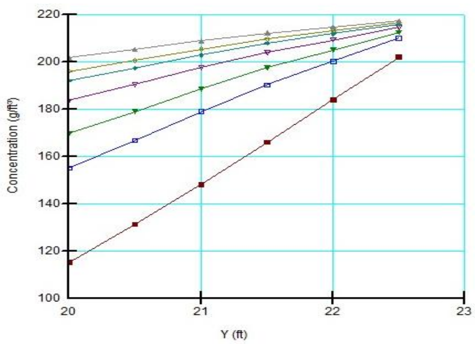


**Figure 4a:** Phosphate Concentration vs Soil Depth at a distance of 2ft (head) at different interval of time

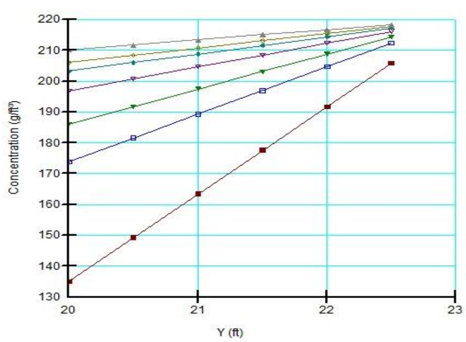


**Figure 4b:** Phosphate Concentration vs Soil Depth at a distance of 10ft (middle) at different interval of time

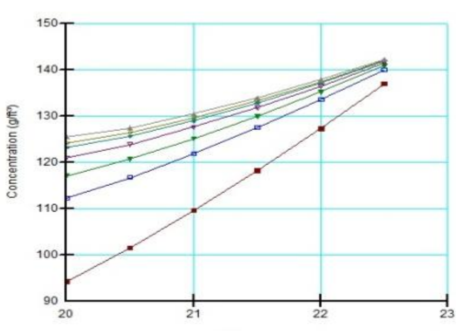


**Figure 4c:** Phosphate Concentration vs Soil Depth at a distance of 18ft (tail) at different interval of time.

## Particle Tracking Analysis

In particle tracking analysis, the dissolved solutes are represented by particles.

Initially total six nodal points was selected from each section i.e. 2 nodal points at head section, 2 nodal points at middle section, and 2 nodal points at section respectively.

From the tail simulated results it is observed that the average velocity for the two points at head approximately equal (0.276 ft/day) until 50 days, (0.253 ft/day) until 100 days, (0.243 ft/day) until 150 days, (0.233 ft/day) until 200 days, (0.229 ft/day) until 250 days, (0.234 ft/day) until 300 days, and (0.246 ft/day) until 365 days respectively. (Figures: 5a–5g) describes that the average particles tracking velocity in the soil significantly depends on the water velocity and their total distance depends on the time.

Likewise same trend for the nodal points at other two sections i.e. middle and tail is observed.

The overall average velocity for the selected nodal points at head, middle and tail section was 0.2512 ft/day, 0.4246 ft/day and 0.7945 ft/day respectively.

However the nodal points at the tail section reaches the free exit drain in between 250 to 365 days with the average velocity of 0.7929 ft/day respectively.

Hence, from the results it is clear that the particles present at the head and middle section of the land will move slowly as compared to the particles present at tail section.

This may be due to less P-sorption capacity in the tail region due to which the bonding was not strong as compared to the head and middle section and the particles reaches the free exit drain within a year.

## Model Validation

Validation of any model is made by comparing predicted

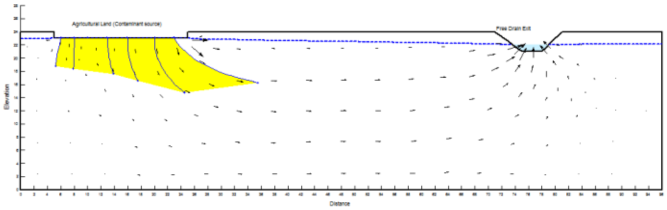

**Figure 5a:** Particle tracking analysis after 50 days

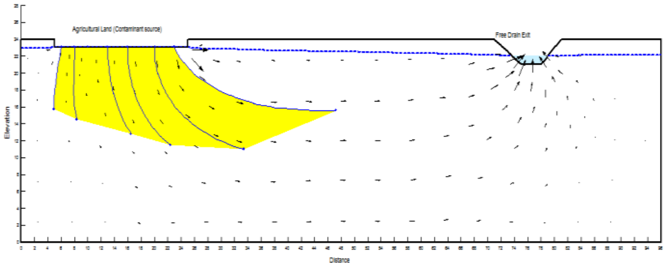

**Figure 5b:** Particle tracking analysis after 100 days.

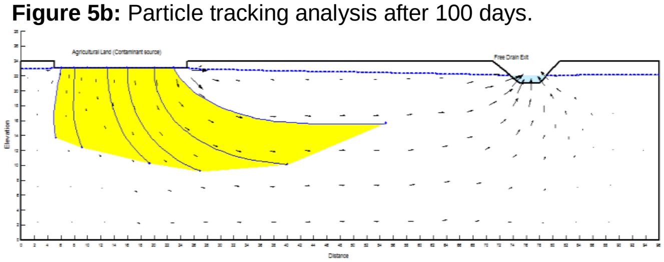

**Figure 5c:** Particle tracking analysis after 150 days.

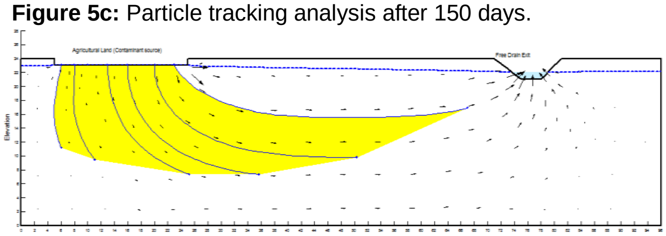

**Figure 5d:** Particle tracking analysis after 200 days.

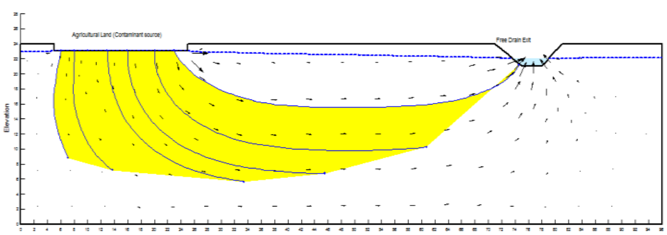

**Figure 5e:** Particle tracking analysis after 250 days.

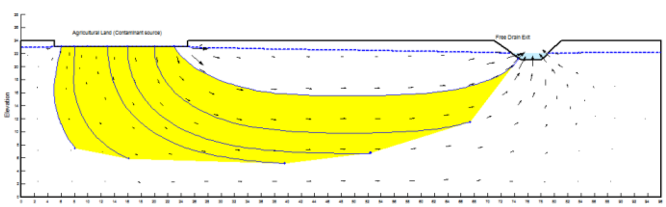

**Figure 5f:** Particle tracking analysis after 300 days.

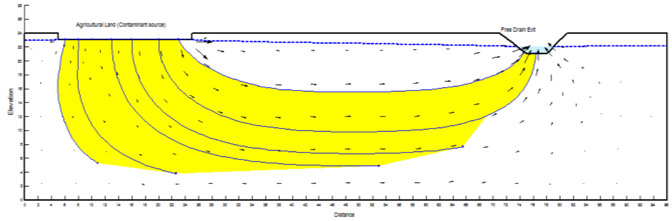

**Figure 5g:** Particle tracking analysis after 365 days

results against the field observations for the acceptability of the model. If the comparison shows a good coincidence, then the model developed can be recommended for practice. (Table: 4) contain the overall average data pertaining to observed and simulated concentration of phosphate at different soil depths and at different sections i.e. head, middle and tail with the relative error.

Performance of any model is evaluated on the basis of statistical parameters.

Following parameters that is mean error (ME), root mean square error (RMSE) and model efficiency (EF) are assessed Arshad et al., (2014) .

Their formulation is given below:

$$ME = \frac{1}{n} \sum_{i=1}^{n} (C_{si} - C_{oi}) \quad (1)$$

$$RMSE = \left[ \frac{1}{n} \sum_{i=1}^{n} (C_{si} - C_{oi})^2 \right]^{0.5} \quad (2)$$

$$EF = 1 - \frac{\sum_{i=1}^{n} (C_{si} - C_{oi})^2}{\sum_{i=1}^{n} (C_{oi} - C_{oa})^2} \quad (3)$$

Where;

Csi: is the ith value of simulated phosphate concentration,

Coi: is the ith value of observed phosphate concentration, and

Coa: is the average or mean of observed phosphate concentration.

The EF is another parameter to evaluate the performance of the model.

For the developed simulation model, RMSE and ME values are found 21.20 gm/ft3 and 16.45 gm/ft3, respectively (Table: 5) and the absolute maximum relative error amongst all the data sets is 1.32 %. Thus it

**Table: 04.** Observed and simulated concentration of Phosphate with statistical computational steps

| Sections | Y Soil Depth (ft.) | Observed Concentration Co (gm/ft$^3$) | Simulated Concentration Cs (gm/ft$^3$) | Relative error (%) $= \frac{(C_o - C_s)}{C_o} \times 100$ | $(C_{si} - C_{oi})$ | $(C_{si} - C_{oi})^2$ | $(C_{oi} - C_{oa})^2$ |
|---|---|---|---|---|---|---|---|
| Head | 22.5 | 210.19 | 212.96 | -1.32 | 2.77 | 7.66 | 2724.32 |
| | 22 | 196.84 | 205.9 | -4.60 | 9.06 | 82.08 | 38746.14 |
| | 21.5 | 152.09 | 198.81 | -30.72 | 46.72 | 2182.79 | 23131.26 |
| | 21 | 187.13 | 191.34 | -2.25 | 4.21 | 17.72 | 35017.83 |
| | 20.5 | 175.18 | 183.24 | -4.60 | 8.06 | 65.00 | 30687.14 |
| | 20 | 163.80 | 175.38 | -7.07 | 11.58 | 133.98 | 26832.05 |
| Middle | 22.5 | 165.43 | 214.56 | -29.70 | 49.13 | 2414.17 | 27365.68 |
| | 22 | 192.59 | 209.11 | -8.58 | 16.52 | 272.90 | 37091.03 |
| | 21.5 | 185.73 | 203.65 | -9.65 | 17.92 | 321.17 | 34495.19 |
| | 21 | 195.61 | 198.19 | -1.32 | 2.58 | 6.64 | 38264.65 |
| | 20.5 | 172.86 | 192.71 | -11.48 | 19.85 | 393.99 | 29880.88 |
| | 20 | 170.75 | 187.23 | -9.65 | 16.48 | 271.47 | 29156.85 |
| Tail | 22.5 | 137.66 | 140.76 | -2.25 | 3.10 | 9.59 | 18951.18 |
| | 22 | 114.99 | 134.97 | -17.37 | 19.98 | 399.02 | 13223.72 |
| | 21.5 | 106.68 | 129.62 | -21.51 | 22.94 | 526.37 | 11380.04 |
| | 21 | 116.49 | 124.72 | -7.07 | 8.23 | 67.76 | 13569.57 |
| | 20.5 | 90.91 | 120.25 | -32.28 | 29.34 | 860.89 | 8264.45 |
| | 20 | 109.00 | 116.7 | -7.07 | 7.70 | 59.32 | 11880.52 |

**Table: 05.** Summary of statistical parameters showing model performance

| Statistical Parameters | Values |
|---|---|
| Mean Error (ME) | 16.45 gm/ft$^3$ |
| Root Mean Square Error (RMSE) | 21.20 gm/ft$^3$ |
| Model Efficiency (EF) | 98.12% |
| Maximum relative error | 1.32%. |

is found that the performance of the model is good enough with model efficiency of 98.12 %.

## CONCLUSIONS

In the present research work using the Geo-Slope software, water flow and fertilizer (phosphate) movement analysis through sandy loamy clayey soil was studied. SEEP/W software was used to compute subsurface flow of water through the developed mesh, while CTRAN/W was used for the analysis of phosphate movement through the developed mesh by using two specific analysis methods i.e. Advection-dispersion analysis and Particle Tracking analysis (PTA) respectively. Results of the study showed that the streamlines and equipotential lines are normal to each other, and vectors displaying the velocity of the flow direction. The phreatic surface in the subsurface region has been simulated; which conforms that the flow is proportional to the hydraulic gradient and the coefficient of permeability. The average water flow occurs in the subsurface region is of the order 8.475 x 10$^{-5}$ ft$^3$/sec/ft respectively. The overall average flow rate of $^5$ $ft^3$/sec/ft respectively. The overall average flow rate of water throughout the one year study is around 0.00239 LPS. The water flow velocities computed from SEEP/W are then used by CTRAN/W for the contaminant transport analysis.

CTRAN/W program is used to analyze the phosphate movement through the sandy loamy clayey soil. The movement of the phosphate was checked by two different analysis methods i.e. Advection-dispersion analysis and Particle Tracking analysis (PTA) accordingly. The simulation results obtained from advection-dispersion analysis revealed that the adsorption of phosphate on the soil particles is linearly related to concentration. The contours represent the different concentration of phosphate for different interval of time throughout the research period; from which the light blue color indicates the maximum concentration while the sea green colour indicates the minimum concentration. Results of phosphate concentration through soil profile at the toe point of the drain's slope for numerical simulation showed that phosphate concentration after 365 days was (1.05 gm/$ft^3$) which conforms that the hydraulic conductivity of the soil is low, due to which the phosphate particles take a long time to reach the toe of slope. The shape and spread of contours for phosphate concentration showed that the movement of the particles highly depends on their diffusion and adsorption function and the total head of irrigation water applied on the agricultural land.

The simulation results obtained from particle tracking analysis revealed that the average velocity for the two points at head approximately equal (0.276 ft/day) until 50 days, (0.253 ft/day) until 100 days, (0.243 ft/day) until 150 days, (0.233 ft/day) until 200 days, (0.229 ft/day) until 250 days, (0.234 ft/day) until 300 days, and (0.246 ft/day) until 365 days respectively. Likewise same trend for the nodal points at other two sections i.e. middle and tail is observed. The overall average velocity for the selected nodal points at head, middle and tail section was 0.2512 ft/day, 0.4246 ft/day and 0.7945 ft/day respectively. However the nodal points at the tail section reaches the free exit drain in between 250 to 365 days with the average velocity of 0.7929 ft/day respectively. Hence, from the results it can be concluded that the particles present at the head and middle section of the land will move slowly as compared to the particles present at tail section. This may be due to less P-sorption capacity in the tail region due to which the bonding was not strong as compared to the head and middle section and the particles reaches the free exit drain within a year.

In order to counter-check the simulation results and to evaluate the performance of numerical model the soil samples to find out the phosphate ($PO_4^{-3}$) concentration in the soil extract were drawn at different stages of the research period throughout the year and which was finally compared with the simulated concentration accordingly.

The soil samples were drawn from three different sections at a distance of 2ft (head), 10ft (middle), and 18ft (tail); and the depth of soil samples was 0-6 inches, 6-12 inches, 12-18 inches, 18-24 inches, 24-30 inches and 30-36 inches respectively. Statistical analysis of all the research data i.e. RMSE, ME, R.E, and EF to evaluate the performance of the model are found to be 21.20 gm/$ft^3$, 16.45 gm/$ft^3$, 1.32% and 98.12% respectively.

The compared results showed that experimental phosphate concentration readings are very close to the simulated readings; however some variation has been observed which may be due to personal errors. Consequently, it is concluded that simulated values of phosphate concentration are not much different than the observed.

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