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(Review Article)

A study of the water quality parameter and its impact using HYDRUS-1D in Deepor Beel, Guwahati, Assam

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Abstract

This study focuses on knowing the status of 12 water quality parameters with their variation and soil-solute interaction due to dumping of wastes at six different locations of Deepor Beel (a Ramsar site), finding their necessary correlations and development of a solute transport model using HYDRUS-1D software. HYDRUS-1D model used in this study will show the movement of iron through the soil profile in the area selected near the Municipal dumping yard at Boragaon. The results indicated that certain parameters are higher than their standard permissible limits with its extreme values obtained at the dumping location at Boragaon. The water near the dumping site is acidic (pH= 5.92), with high iron concentrations (3.68 mg/l), increasing hardness and turbidity as well as lower D.O level (3.67 mg/l). HYDRUS-1D solute transport model gives a distinct and clear picture of the solute movement, water flow, water content, pressure head and concentration profile variation along the soil profile with respect to time and depth. The results of this model showed that continuous influx of harmful solutes on the surface of the Deepor Beel could lead to break through of this solute through the soil column into the groundwater storage. Hence the present study showed that water quality is deteriorating at various locations of the beel and necessary steps are immediately required for sustaining the ecological balance of the wetland.

Keywords: Physico-chemical parameters; Water quality analysis; Deepor Beel; HYDRUS 1D

1. Introduction

Unsaturated zone or the vadose zone is defined as the zone between ground surface and groundwater table which contains solid soil particles, air and water. The unsaturated zone acts as a filter for the aquifers by removing unwanted substances that comes from the ground surface such as hazardous wastes, fertilizers and pesticides (Naveen et al., 2018). These matter motivates biological degradation, transformation of contaminants and sorption. Therefore, the vadose zone can be considered as a buffer zone protecting the groundwater. As a result of this, the hydrogeological properties of these zone are of great concern for the groundwater pollution. From the hydrological point of view, many processes are controlled by the vadose zone like transmission of water to aquifers, water on the surface and atmosphere. In view of such rising concerns, it has been found mandatory to study and model the water flow and transport of solutes in the vadose zone especially in the field of water resources planning and management and also in terms of water quality management and groundwater contamination (Saifadeen and Gladnyeva, 2012; Ali et.al, 2015; Bhattacharyya and Kapil, 2010). A broad range of models have been developed to describe the fate and transport of agricultural, industrial, and other contaminants in soils and groundwater. One such software is the Hydrus which is available in 1D, 2D and 3D form. (Simunek *et al.,* 2012). The Hydrus 1D software can simulate the transport of water, heat and solute in unsaturated, partially saturated and fully saturated porous media. The flow region may be composed of non-uniform soil. Flow and transport can occur in vertical, horizontal or in inclined direction. The model can also deal with heat and flux boundaries, boundaries controlled by atmospheric conditions as well as free and deep drainage boundary conditions.

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2. Graphical output for simulation

The overall mechanism involving the transport of solute from one point to another in the vadose zone is governed by the process of molecular diffusion and advection and mixing of these solutes take place by the process of mechanical dispersion. The HYDRUS model developed here is based on the experimental data that indicated the actual soil qualities, conditions of flow and various other parameters of the selected site. These input parameters which are required for the simulation of the HYDRUS-1D model were collected from a previous project outputs of *Kalita et al.,2019.*

2.1. Observation Points

The soil profile considered in this solute transport model is 200 cm in depth. Three observation nodes have been selected at different depth in vertical direction of the soil profile. These three observation nodes are designated as N1, N2 and N3. Observation nodes are located at different depths,

- N1 at 0 cm which the top surface of the soil profile.
- N2 at 90 cm which is taken at the junction between the two layers of soil.
- N3 at 200 cm which is the bottom boundary of the soil profile.

These selected locations along the soil profile provide the details about the variation of concentration of solute, pressure head, water content and water fluxes at different depth with respect to time.

2.1.1. Concentration of solute vs. time

The graph below represents the the varaition of solute concentration at different selected points with respect to time. The solute transport model developed in this study considered a solute concentration of 3.68 mg/cm^3 with a pulse duration of 20 days.

In fig.1, it shows that solute concentration at N1 keeps on increasing for the intial 20 days while the solute pulse is active at the upper Constant Flux boundary. There has been a decresing pattern of solute concentration at N1 after 20 days, which tends towards zero after about 40 days. This implies that the top surface of the soil profile becames solute free gradually after pulse activation duration. Had the pulse continued indefinitely, the entire profile would have containued to increase in concentration. The time taken by the solute for transport along the the soil profile is dependent on the different soil properties and hydraulic conductivities of the different layers of soil that is considered in this study. The concentration of solute at N2= 90 cm, starts from zero after about 5 days and increases gradually to reach peak value of 3.45 mg/cm^3 approximately as flowing water continues to carry solutes downward from the soil above this observation point and then decreases towards zero at around 65 days.

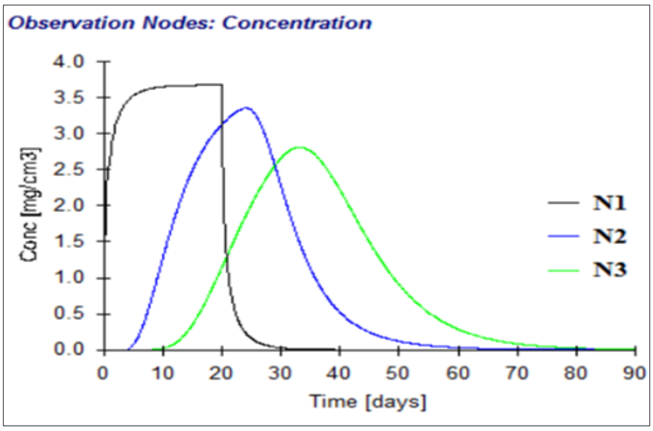

Figure 1 Solute concentrations versus time at selected observation points (N1- 0 cm, N2- 90 cm, N3- 200 cm)

The transport of solute along the soil profile towards the bottom boundary N3 takes about 9 days. After 9 days, the solute starts to break through the N3 observation point which is the lower layer of the soil profile. The solute concentration at the bottom boundary reaches its peak at around 35 days and then starts a decreasing trend in concentration towards the end of the simulation period. It is to be noted that the peak value for different obsevation point is reducing, as the solute moves towards greater depth.

2.1.2. Pressure Head vs. time

The graph shows how the pressure heads varies with time at the selected observation points, i.e N1- 0 cm, N2- 90 cm and N3- 200 cm. In this study, initially a pressure head of -100 cm was assumed, which varied as the wetting front approaches the selected nodes. Moreover, the timing is variation of pressure heads at selected points are based on the hydraulic properties of the soil profile provided in the pre-processing stage of the model. When the wetting front approaches a certain depth, the pressure head increases from the initial value of -100 cm and eventually reaches 0 cm, which is equal to the imposed positive pressure head at the surface as presented in HYDRUS-1D model.

From the graph it can be seen that the wetting front passes from the surface towards the selected nodes N2 and N3 at times of approximately 5 days and 8 days approximately.

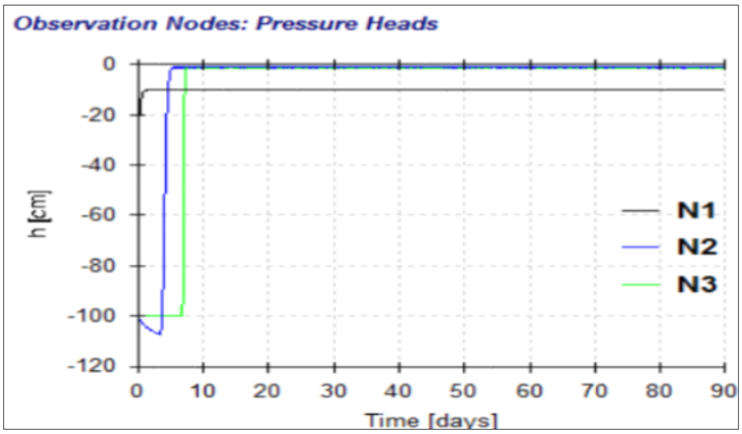

Figure 2 Pressure heads versus time at selected observation points

2.1.3. Water content vs. time

This graph below represents how water content in soil profile varies with time at different observation points. In this study, the saturated water content for the two layers of soil has been obtained according to the properties and composition of the soil as given in the HYDRUS software package.

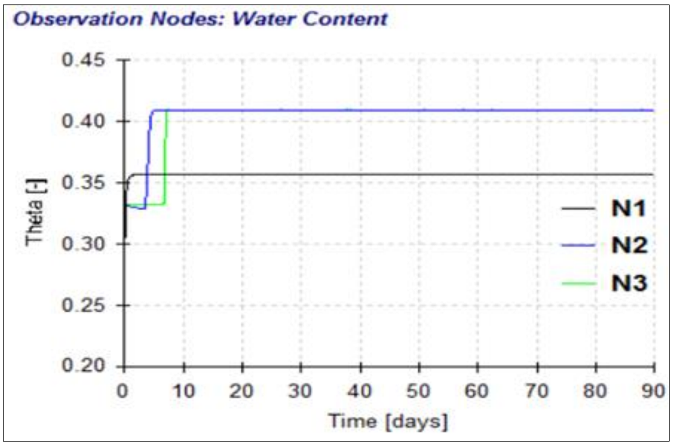

Figure 3 Water content in soil versus time at selected observation points

The above graph indicates the increase of water content at top surface at N1 during initial period and then reaches a constant value after saturation due to the constant upper water flux condition. At points N2 and N3, the water content increases from a lower value than the initial surface water content but increases to a peak value of 0.41 after 4.5 days and 8 days respectively. After saturation is reached, the water content at different observation points N1, N2 and N3 remains constant for the entire simulation period.

2.2. Profile Information

The profile information command displays solute concentration, water content and other parameters versus depth at selected Print Times. In this study, simulation of model is done for a period of 90 days, so on equal duration six numbers of print times are selected. These print times are noted at T1= 15 days, T2= 30 days, T3= 45 days, T4= 60 days, T5= 75 days and T6= 90 days.

2.2.1. Concentration vs. Depth

In this study, the solute transport model was developed with a input of initial solute concentration equal to 3.68 mg/cm^3. The pulse duration of solute concentration is assumed for 20 days.

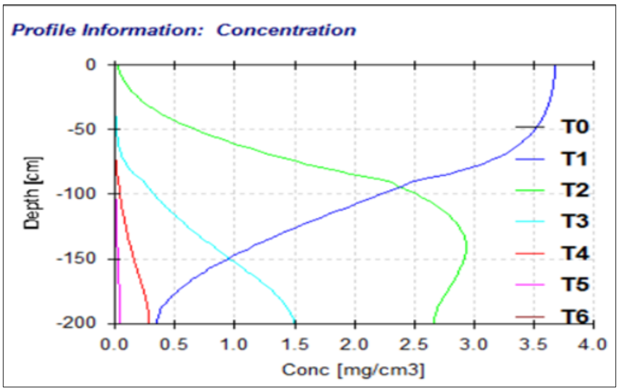

Figure 4 Variation of concentration of solute with time

The above graph shows that at T1= 15 days, there is a declination in the concentration peak along the depth of the profile due to solute dispersion. The solute concentration at 15 days is highest at the surface and it gradually decreases with as the depth increases. At the bottom boundary at 200 cm, the solute concentration is proximate to zero.

At T2= 30 days, due to solute dispersion, the concentration of solute at surface is almost zero. As depth increases the concentration of solute increases and is maximum at depth near to 150 cm, then it escapes the bottom boundary with a concentration of approximately 2.7 mg/cm^3.

Similarly, with passing of days, the concentration near the surface becomes zero and it goes on increasing towards the bottom boundary, as it can be seen with T3, T4 and so on but with a lower concentration than it was initially present. It is to be noted that with a pulse duration of 20 days, the rate at which the solute concentration is lowering with depth is not appreciable. Thus, it indicates that if the concentration of harmful metal in the dump yard area is injected for a long duration, it is clear that the concentration of such solute might continue to disperse into the ground water storage.

2.2.2. Water Content vs. Depth

The graph here shows the variation of water content along the depth of soil. The water content at T0= 0 day, is the initial water content that is given to the model.

Water content in the soil profile represented by T1= 15 days, shows increase in amount. This increase in water content is based on the contact upper water flux boundary condition that is applied in the HYDRUS-1D model. Moreover, there is an abrupt change in the water content at the interface (at a depth of 90 cm from the surface of the soil profile) between the two soil types. The water content being not continuous along the soil depth is due to the different water retention properties (and thus retention curves) and hydraulic conductivity of the two materials.

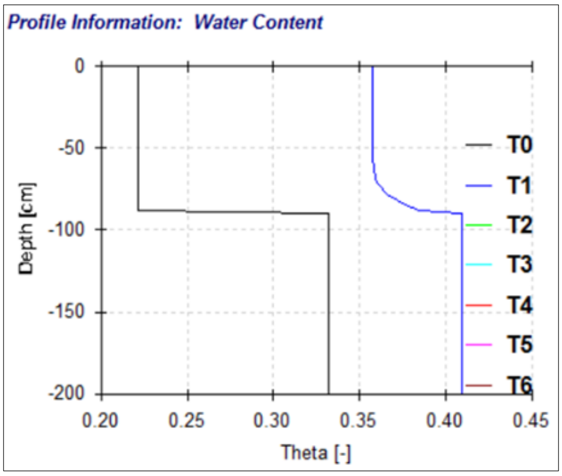

Figure 5 Variation of water content with time

2.2.3. Solute Flux vs. Time

The graphs below represent influx of solute at the soil profile and efflux of solute through the lower layer with respect to time. In the pre-processing stage of the development of HYDRUS-1D model, a solute concentration of 3.68 mg/cm^3 given as initial concentration with pulse duration of 20 days.

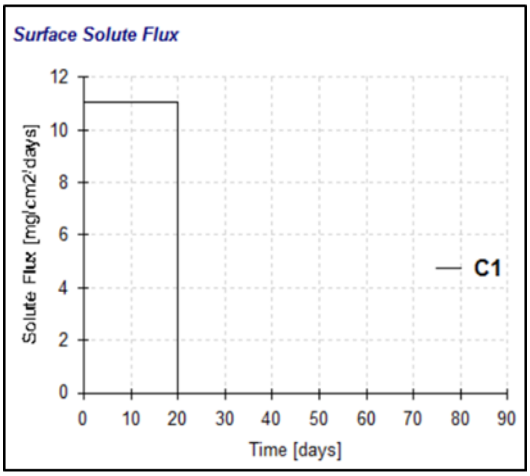

Figure 6 Influx of solute vs time

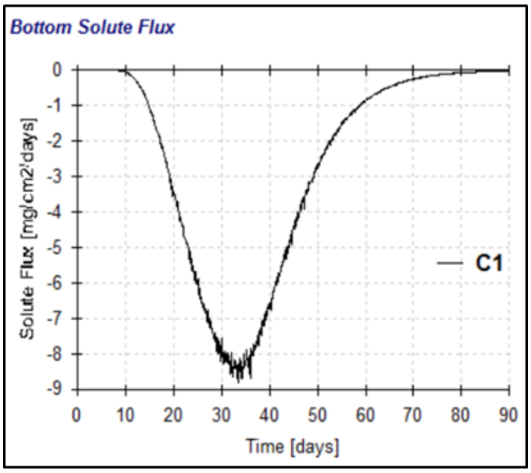

Figure 7 Efflux of solute Vs time

The variation of the solute influx on the surface and bottom layer are shown in the above graph. HYDRUS-1D model considers the solute fluxes to be positive when entering the transport domain and negative when leaving the transport domain. This convention of the HYDRUS model is totally opposite to that of water flow, which are always positive upwards and negative downwards.

The above graph displays that the influx of solute into the surface is constant for the 20 days and then it tends to zero. The influx of the solute attains a constant value of 11.04 mg/cm^2/day. The constant value of influx resulted from the input of initial concentration of 3.68 mg/cm^3 and the upper constant flux of -3 cm/day for a period of 20 days (i.e., 3.68 mg/cm^3 x 3 cm/day = 11.04 mg/cm^2/day).

The efflux of solute through the bottom layer started nearly after 9 days. The efflux gradually increases and reaches a peak value after 35 days approximately. After this point, the bottom solute efflux decreases corresponding to the fact that there was no influx of solute at the top surface after 20 days. The sum of the influx and efflux curves at any time defines the amount of solute stored within the soil profile.

3. Conclusion

The results that were obtained from the study clearly points towards high concentration of certain parameters in sites closer to dumpyard, a low to moderate increase or decrease from standard limits in other sites. From the results obtained it can be seen that waste water generated by industry or house hold, and water flowing through the agricultural land may also affect the water quality. However, the water near to the dump site is showing some frequent changes in water quality parameters with change in seasons. At site 1 i.e. the water area near the Municipality dumping zone, it is evident that water tends to be acidic, higher iron concentration, increasing hardness and turbidity and lower in D.O level than the other sampling sites which were subjected to less pollutant matter. Moreover, the concentrations tend to be towards the extreme side during February – March duration at site 1 and 2. Since the results of site 1 which is near the dumping zone are not appreciable, the solute movement model was developed using HYDRUS-1D with the highest iron concentration recorded in this study. HYDRUS-1D model is considered as an accurate tool for the transport models and the model was prepared with input indexes such as constant recharge flux, practical iron concentration, prevailing top and bottom boundary condition and movement of the solute through a soil column of the Deepor Beel. The model shows that if the concentration of different parameters goes on increasing in the water of Deepor Beel, it is quite clear that the solute might transport through the soil towards the ground water storage. The model did act as a convenient tool in knowing the how the solute interacted with soil properties in its vertical movement with respect to time and depth. Thus, it can be concluded that through the detailed testing of specified parameters at different sites, the water quality of Deepor Beel near the municipal dumping zone at Boragaon is deteriorating gradually. With further increase of dump waste flowing into the Deepor Beel, the water quality might be subjected to such a level of degradation that purification will not be possible. Moreover, the effect of the poor water quality on the biodiversity is noteworthy situation. Last but not the least, the contamination of the groundwater storage due to the movement of harmful solutes from the dumpyard must not be ignored.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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