American Journal of Sciences and Engineering Research
E-ISSN -2348 – 703X, Volume 3, Issue 1, 2020

A Study of Application of Tracers in Groundwater Hydrology

J.O. Jeje[1], O.O Fadipe[2]
[1]*Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife.*
[2]*Department of Civil Engineering, Osun State University, Osogbo.*

ABSTRACT: *Laboratory study was carried out to investigate the effect of acidic and alkaline characteristics of groundwater medium on three tracers (rhodamine B, eosin and potassium dichromate) commonly used for groundwater investigations. This is with the view to improving the criterion used in the selection of tracers for groundwater investigations. The factors considered are: the maximum tracer concentration, Cmax, which could be observed during the experiment, the time, tm, at which this occurs and the percentage of the tracer recovered during experiment. Others are the time, ti, of first detection of the tracer and time, tf, of total disappearance of tracer from the investigation area.A lysimeter apparatus of circular cross section with diameter, D = 45 mm was constructed and uniformly filled with coarse sand and fine gravel (each at a time). Throughout the column, steady water discharge (2.5 ml/min) at a pH value between the ranges of 5 – 8 was maintained, to carry the tracer solution through the soil column. Effluent from the bottom of the lysimeter were subjected to spectrometric analysis to determine tracer concentration.. The results suggest that rhodamine B is a suitable tracer for groundwater investigation in acidic medium but may not be suitable for alkaline medium. Values obtained for eosin showed the tracer to be good for investigation in both acidic and alkaline medium,while potassium dichromate as a tracer may be a good tracer in alkaline medium only.*

Keywords: *Tracers, rhodamine B, eosin, lysimeter, groundwater investigation and potassium dichromate.*

I. INTRODUCTION

There has always been a need to determine the direction and velocity of groundwater-flow when making groundwater investigations. The simplest and most indisputable way of doing this is to add a specific material, a tracer to the water and to observe its transport (Bigger and Nielson, 1960). Tracers, such as dyes and salts, were used for the first time in 1869 to find out the hydraulic connection between sinkholes and springs in karst (Freezer and Cherry (1979), to determine the origin of leakage water in a tunnel and to detect the source of the infected water. Nearly all ground water originates as rain or snowmelt that infiltrate through soil into flow system in the underlying geologic materials. The soil zone has a unique and powerful capability to alter the water chemistry as infiltration occurs through this thin, biologically active zone (Freezer and Cherry, 1979; Swarzenski et al., 2009). As the groundwater moves along flowlines from recharge to discharge areas, its chemistry is altered by effects of a variety of geochemical processes depending on the environmental conditions along the flow lines.

The selection of a tracer is entirely dependent on the type of aquifer to be investigated (Sanford et al., 2016). There are two big groups of aquifers: aquifers of permeable rocks or soils or aquifers consisting of bedrock with fractures and channels (Lambs and Moussa, 2013). There is always a great hazard of losses or retardation of the tracer. The most important hazard reactions usually come from dispersion, adsorption and ion exchange (Yeh et al., 2014; Buenning et al., 2016).

This project revealed, on a laboratory scale, the effect that acidic and alkaline characteristics of groundwater environment have on tracer properties usually taken into account when planning for groundwater investigations by tracer methods. These properties include: the amount and type of tracer that can be used for investigation in an environment, the extent to which tracers are retained by aquifer material, the time at which the tracer would first be detected at an observation point and also the duration of the investigation.

Received- 11-01-2020, Accepted- 19-01-2020

This research considered two groundwater environments: coarse sand and fine gravel environments, i.e. soil materials for aquifers of permeable rocks.

II. MATERIAL AND METHODS

Several laboratory experiments were carried out to investigate the effect of acidic and alkaline characteristics of groundwater environments on selected tracers (rhodamine B, eosin and potassium dichromate) commonly used for groundwater investigations.

2.1 Preparation of Standard Tracer Solution

0.01g of tracer was weighed into a clean 100 ml volumetric flask and distilled water was added to mark. The stock solution prepared had a concentration of 100 ppm. Solutions with varying concentrations (i.e. 1, 2, 3 …10 ppm for rhodamine B; 1, 2.5, 5.0 …12.5 ppm for eosin and 1, 5, 10, 20 and 60 ppm for potassium dichromate) were then prepared and 5 ml of each solution was pipetted into clean sample bottles and labeled.

2.2 The Effect of Acidic and Alkaline Characteristics of Sandy Groundwater Environment on Tracers

The soil involved was coarse sand; passing through sieve no. 10 (2.00 mm) and retained on sieve 0.6 mm aperture. The apparatus used include a lysimeter, spectronic 20 and UV Spectrophotometer. The soil sample was measured into the lysimeter and compacted with a 25 mm steel tamping rod. The prepared water solution at pH 5.0 was poured into the lysimeter in order to soak the soil to saturation(West and Dawson, 2014).. A volume of tracer solution at 1000 ppm was then injected on to the top surface of the lysimeter with the aid of a 10 ml syringe. Once the tracer solution was completely absorbed by the sample, the flow of water into the lysimeter was started. The tap control valve was put on and adjusted to give a constant discharge of 2.5 ml/min. samples of water flowing out were extracted at intervals of minutes and subjected to spectrophotometric analysis to obtain the absorbance value of the tracer solution. This value was then interpolated on the calibration curve of the tracer used to obtain the tracer concentration in the effluent. The sample taking was continued until the concentration of the tracer in the effluent reduced to zero.

This procedure was repeated with fresh sands for prepared water solutions at pH of 6.0, 7.0 and 8.0 and for each tracer.

2.3 The Effect of Acidic and Alkaline Characteristics of Gravelly Groundwater Environment on Tracers

The procedure is the same as described in section 2.2 above but here, the soil material in the lysimeter was fine gravel i.e. passing through sieve 6.00 mm aperture and retained on sieve 2.00 mm. the height of the lysimeter was increased to 500 mm because preliminary tests had shown that tracer flow in lysimeter of lower height filled with fine gravel would be too fast and may not be effectively handled. The initial concentration of the 10 ml tracer introduced to the top of the lysimeter at the start of the experiment was 100 ppm. The volume and concentration were determined from the preliminary tests.

III. RESULT AND DISCUSSIONS

The basic assumptions that were made are: the initial presence of tracer in the soil inside the lysimeter is negligible and all the tracer measurements observed are due to the injected tracers only; the soil media with pH 7.0 acts as the basis of comparison for all experiments; all discussions are made with reference to the initial amount of tracer introduced into the lysimeter (i.e. 10 ml of 100 ppm and 1000 ppm for fine gravel and sand media respectively); and the acidic and alkaline characteristics of the media are due only to the water solutions introduced to the lysimeter (Doveri and Mussi,2012).

3.1 Rhodamine B

It was observed that in sand columns, the maximum tracer concentration increases with the decrease in pH of the medium (Figure 1); this is 5.45 ppm at pH 7.0, rising to 7.08 ppm at pH 5.0 and dropping to 1.55 ppm at pH 8.0. The tracer took a long time to be first detected in alkaline medium. Also the tracer took a longer time to totally disappear from the acidic medium than it did in the alkaline medium.

The results follow the same trend in the fine gravel column but with lower values (Figure 2); the reason being that there are more voids in fine gravel than in sand which makes it easy for the tracer to pass through fine gravel faster than in sand.

The observed behaviour could be accounted for if one considers its chemical composition. Rhodamine B has its chemical formula as $C_{28}H_3N_2O_3Cl$ (Knutsson, 1964), it thus contains chlorine which is acidic in its structure.

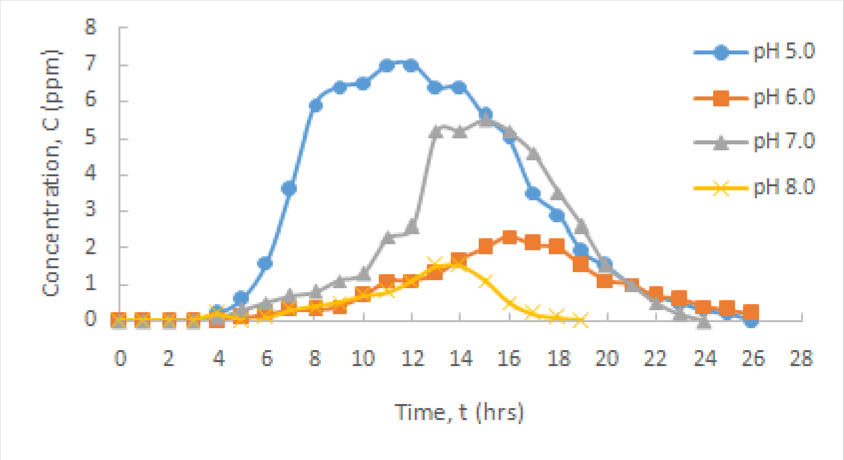

Figure 1: Concentration –Time curves of rhodamine B in the effluent from sand columns

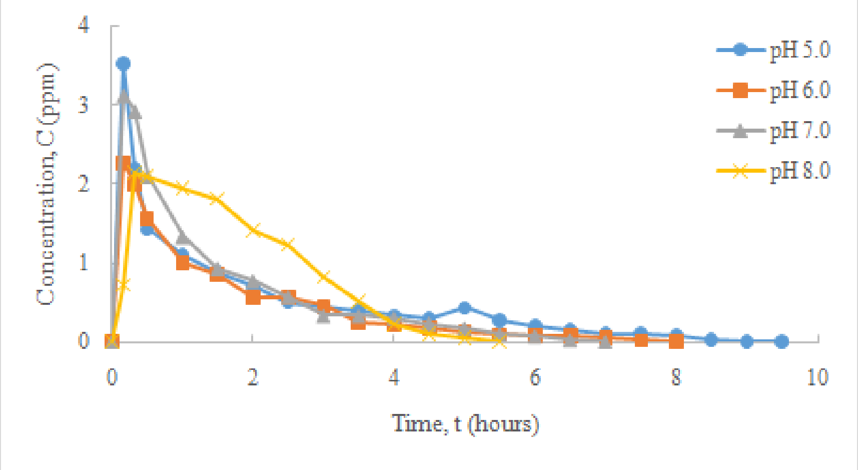

Figure 2: Concentration –Time curves of rhodamine B in the effluent from fine gravel columns

3.2 Eosin

In sand columns, the maximum concentration of eosin observed 11.1 ppm at pH 7.0, this increased to 12.0 ppm at pH 5.0 and decreased to 9.2 ppm in the sand column with pH 8.0 (Figure 3). The time at which the maximum tracer concentration was observed remained constant at 1 hour for all pH of interest. The percentage of the tracer recovered was very low but increased with the decrease in pH of the medium.

The time taken by the tracer before it was first detected is low for acidic medium, 0.27 hour at pH 5.0 and 0.50 hour at pH 8.0. The time required for the tracer to totally disappear from the soil column was observed to be higher for acidic medium than for alkaline medium. It was observed that fine gravel columns follow the same trend (Figure 4).

The chemical formula for eosin is $C_{20}H_6Br_4Na_2D_5$. It can thus be said that this tracer is seriously affected by both acidic and alkaline medium; the degree of the effect being dependent on how much of Br^- or Na^+ are being exchanged for ion of the minerals present in the soil (Kabeya *et al*., 2014; Eastoe .and Rodney, 2014).

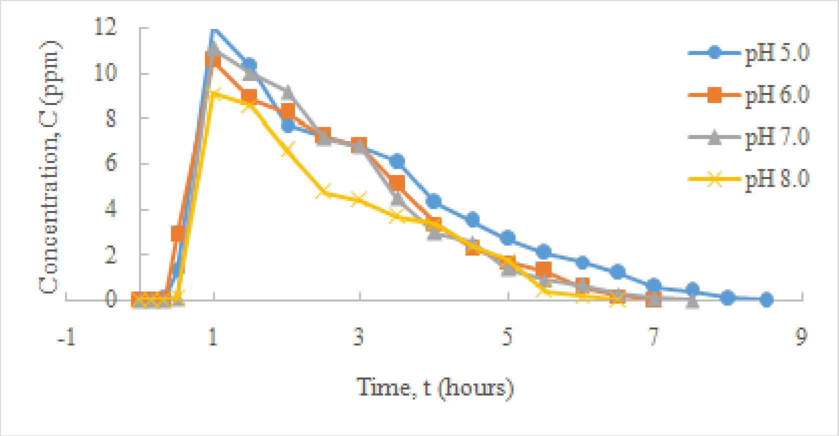

Figure 3: Concentration –Time curves of eosin in the effluent from sand column

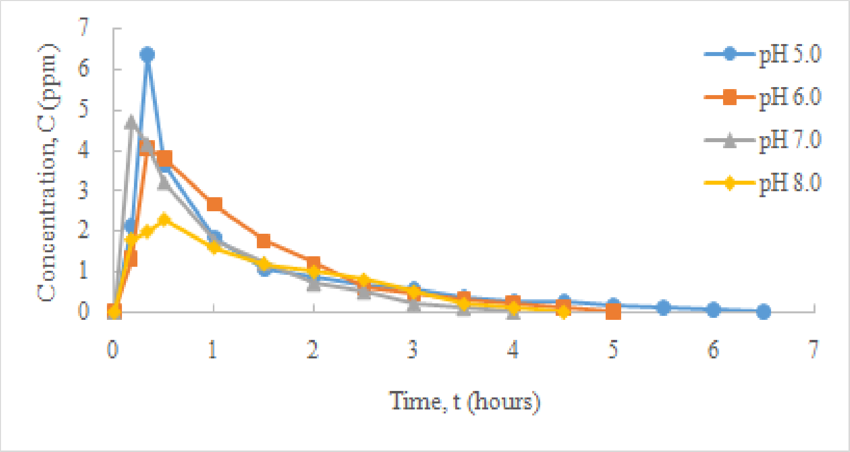

Figure 4: Concentration –Time curves of eosin in the effluent from fine gravel columns

3.3 Potassium dichromate

In sand, the maximum concentrations observed are: 58.25 ppm at pH 7.0, 61.25 ppm at pH 8.0, 53.00 ppm at pH 6.0 and 45.50 ppm at pH 5.0 (Figures 5 and 6)s. The time at which these maximum concentrations were observed remained constant at 1 hour. The time required for the tracer to totally disappear from the soil column was observed to be higher for acidic medium than for alkaline medium.

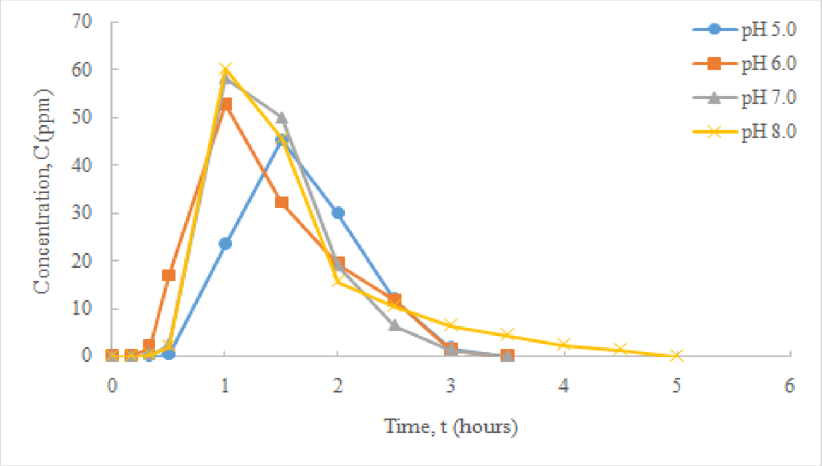

Figure 5: Concentration –Time curves of potassium dichromate in the effluent from sand column

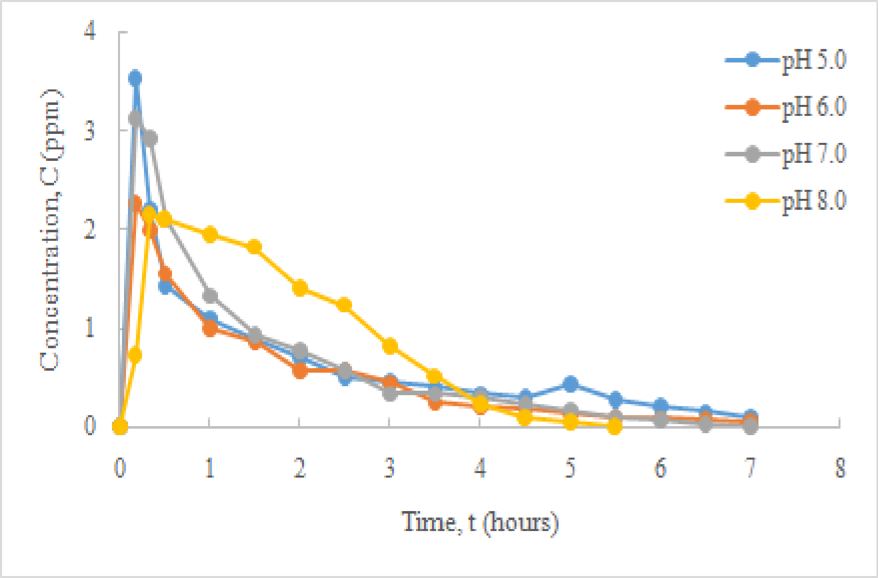

Figure 6: Concentration –time curves of potassium dichromate in the effluent from fine gravelcolumns

IV. CONCLUSION

For the same amount of each of the tracers used in the experiment for each soil medium considered, the effect studied varies from one tracer to another. In sand medium, the highest percentage of rhodamine B recovered is 96.05% at pH 5.0, 55% of potassium dichromate was obtained at pH 8.0 and 40.78% of eosin was obtained at pH 5.0. Other parameters studied also varies.

It was concluded that rhodamine B is a good tracer for investigation in acidic medium, eosin is good for both acidic and alkaline groundwater medium, although it gives a better result when used in acidic medium; and potassium dichromate is a good tracer for investigation in alkaline medium.

It is recommended that before a tracer for investigating a groundwater system is selected, water and soil samples from the area should be tested with different tracers. The tracer that gives the best result should then be used for the investigation.

V. REFERENCES

1. Bigger, J.W. and Nielson, D.R. (1960). Radioisotopes and labelled salts in soil-Water movement, *Soil-moisture and Irrigation Studies,* Proc. Panel IAEA, Vienna.
2. Buenning, N.H.; Stott, L.; Kanner, L.; Yoshimura, K.(2016) DiagnosingAtmospheric Influences on the Interannual 18O/16O Variations in Western U.S.Precipitation. *Water 5*, 1116–1140.
3. Doveri, M and Mussi, M.(2012). Water Isotopes as Environmental Tracers forGroundwater Flow Understanding: An Application on Fractured Aquifer Systems in the Scansano-Magliano in Toscana area (southern Tuscany-Italy). *Water (6)* 2255–2277.
4. Eastoe, C.J. and Rodney, R.(2014). Isotopes as Tracers of Water Origin in and Near a Regional Carbonate Aquifer: The Southern Sacramento Mountains, New Mexico. *Water*, *6*, 301–323.
5. Freezer, A.R. and Cherry, J.A. (1979). '*Groundwater*'. Prentice Hall Inc. Eaglewood Cliffs, New Jersey.
6. Kabeya, N.; Shimizu, A.; Zhang, J.J.; Nobuhiro, T. (2014)Effect of Hydrograph separation on Suspended Sediment Concentration Predictions in a Forested Headwater with Thick Soil and Weathered Gneiss Layers. *Water 6*, 1671- 684.
7. Lambs, L. and Moussa, I.(2013). Air Masses Origin and Isotopic Tracers: A Study Case of the Oceanic and Mediterranean Rainfall Southwest of France. *Water*, *5*, 617–628.
8. Sanford, W.E.; Aeschbach-Hertig, W.; Herczeg, A.L. (2016). Insights fromEnvironmental Tracers in Groundwater Systems. *Hydrogeol. J. 19*, 1–3.
9. Swarzenski, P.W.; Baskaran, M.; Rosenbauer, R.J. (2009). Edwards, B.D.; Land, M. A Combined Radio- and Stable-Isotopic Study of a California Coastal Aquifer System. Water 5: 480–504.

10. Yeh, H.F.; Lin, H.I.; Lee, C.H.(2014). Identifying Seasonal Groundwater Recharge Using Environmental stable isotopes. *Water*, *6*, 2849–2861.

11. West, G.J., and Dawson, T.E. (2014).*Understanding Movement, Pattern and Process on Earth through Isotope Mapping*; Springer: New York, NY, USA, ISBN 978-90-481-3353-6; pp. 1–487.*Water*, *6* **3269.**