Geochemical Modelling Of Kushawathi Watershed Area Chikkaballapur District, Karnataka.

Dr. T.M Mohan Kumar, Nanjundi Prabhu

Abstract: Water is a fundamental component of life. Groundwater is commonly used for residential, agricultural and irrigation activities. One of the major problems associated with the drinking water in the granitic terrain of Karnataka state, is enrichment of fluoride in groundwater. The study area, Kushavathi watershed is an over exploited area. In the Kushavathi basin, hydrogeochemical studies are performed throughout order to assess the value of groundwater for its suitability for domestic purposes. SWAT measures dissolved oxygen and carbonaceous biochemical demand for oxygen entering the main channel with surface runoff in this analysis. Nitrogen and phosphorus conversion and movement within a hydrological response system are modeled in SWAT based on cycles. The well-known schist belt of Kolar and Chikkaballapur containing rich gold deposits also contains in pegmatites fluorite and flour-apatite. Natural groundwater contamination with fluoride causes plant and human health irreparable damage.

Keywords: SWAT Model, Hydrologic Response Unit.

1 INTRODUCTION

Water is a basic ingredient of life. Groundwater is extensively used for domestic, industrial and irrigation activities. In many regions, recharge areas are near the surface and these may be significantly affected by agricultural, residential or industrial activity. Once the refuse of such activities contaminates groundwater, it becomes difficult and sometimes impossible to restore it to its initial quality. In the study area, groundwater is the only source of drinking water. One of the major issues associated with drinking water in the Karnataka state's granitic terrain is groundwater fluoride enrichment. Groundwater over-exploitation leads to loss of groundwater quality. The field of research, the watershed of Kushavathi is an over-exploited region. It is therefore imperative to control and assess the development of preventive measures against health hazards. The people living in the study area have reported negative changes in groundwater quality over the past few years.

A. Hydro Chemistry

Hydrochemistry is an interdisciplinary science that focuses on the water chemistry of the natural environment. The typical use of chemical properties in chemical hydrology is to provide information on the local distribution of water quality. Hydrochemistry can simultaneously be used to trace the origin and history of water. In determining its hydro chemical and pollution influence, such as atmospheric water (rainwater), surface water, and groundwater, it is necessary to simultaneously study the entire system. Hence, this describes a study that employs a spatial analysis technique to understand the fluid(water) quality panorama of the Kushavathi watershed.

B. Rainwater, Surface water & Ground water Chemistry

The atmosphere comprises of water vapors, particles of dust and various gaseous elements such as N2, O2, CO2, CH4, CO, SOx, NOx, etc. Rainwater's chemical composition indicates that rainwater is only moderately mineralized with clear electrical conductance (EC) usually below 50 S / cm, chloride less than 5 mg / l, and HCO3 less than 10 mg / l. The rainwater sulfate and nitrate levels may be high in areas near industrial hubs. Because of differences in the relative contribution of groundwater and surface water sources, the chemical composition of surface water is extremely variable. Bicarbonates are the most important among anions and make up more than 50 percent of total anions in terms of milli equivalent per liter (meq / l). In the case of cations, alkaline or calcium predominates but with increasing salinity the hydro chemical facies tend to change into mixed cations. or even to Na-HCO3 type. The percolating air downwards is not inert, and it is enriched in CO_2. Consequently, the chemical composition of groundwater can vary depending on several factors, such as rain rate, salt leaching, rainwater stay in the root and intermediate region, organic matter presence, etc. All the above variables have the overall effect that groundwater composition varies from time to time and from zone to zone

- *Dr.T.M Mohan Kumar is currently working as a Professor, school of civil engineering, REVA University, Bangalore, Karnataka, India E-mail: mohankumar.tm@reva.edu.in*
- *Nanjundi Prabhu is currently working as an Assistant Professor in civil engineering in NMIT, Bangalore, India E-mail: nanjundiprabhu@gmail.com*

2 SWAT (Soil and Water Assessment tool)

SWAT is a physically based watershed model that enables a long-term assessment of the effect of land management activities on air, sediment and agricultural chemical yields in a watershed with varying soil, land use and management conditions. The most important inputs for SWAT are climate, soil characteristics, topography, vegetation and land management practices to model hydrological and water quality in a waterfront. (Neitsch, 2002).
SWAT allows a basin to be subdivided into sub-basins to evaluate hydrology, weather, sediment yield, nutrients, pesticides, soil temperature, crop growth and agricultural management practices (Francos, Bidoglio et al., 2001).

2.1 WATER QUALITY PARAMETERS

SWAT estimates the amount of algae, dissolved oxygen and carbonaceous biochemical oxygen demand that reaches the main channel with surface runoff.

A. Carbonaceous Biochemical Oxygen Demand

The demand for carbonaceous biochemical oxygen (CBOD) determines the amount of oxygen needed to decompose the organic material transported in surface runoff. The SWAT loading function for the ultimate CBOD as cited by Neitsch (2002), Trinh (2000).

$$cbod_{surq} = \frac{2.7 \times orgC_{surq}}{Q_{surf} \times area_{hru}} \quad \text{…. 1}$$

It is possible to determine the amount of organic carbon in s urface runoff as:

$$\text{orgC}_{\text{surq}} = 1000 \left(\frac{\text{orgC}_{\text{surf}}}{100} \right) (\text{sed}) (\varepsilon_c : \text{sed}) \quad \text{….2}$$

The enrichment ratio (the ratio of the organic carbon concentration transported with the sediment to the soil surface layer concentration) in SWAT is determined using the relationship defined by Menzel (1980) for each storm event as follows. (Neitsch,2002):

$$\varepsilon c : sed = 0.78 \left(conc_{sed,surq} \right)^{-0.2468} \quad \text{….3}$$

The sediment content in the surface runoff is determined as follows:

$$conc_{sed,surq} = \frac{sed}{10 \left(area_{hru} \right) Q_{surf}} \quad \text{….4}$$

Smaller particles are handled more quickly than grosser particles. Due to the higher flow of smaller soil particles, the sediment load should contain a higher proportion of organic carbon in clay-sized soil particles than in the soil surface layer (Neitsch, 2002).

B. Dissolved Oxygen (DO)

Dissolved gases (mainly oxygen and carbon dioxide) are present in both surface and ground waters. Generally, surface water may be adversely impacted by human activities such as intensive livestock grazing and intensive farming. When organic matter, such as untreated human or animal waste, is placed in the surface water, dissolved oxygen levels decrease as microorganisms grow, the organic matter is used as an energy source and oxygen is consumed in the process. (Fetter, 1994). In SWAT, to determine the dissolved oxygen concentration of surface runoff, the oxygen uptake by the oxygen demanding substances in runoff is subtracted from the saturation oxygen concentration. The dissolved oxygen concentration of surface runoff can be determined as (Neitsch, 2002).

$$\text{Ox}_{\text{surf}} = \text{Ox}_{\text{sat}} - k_1 \, cbod_{surq} \frac{t_{ov}}{24} \quad \text{…. 5}$$

The oxygen saturation concentration can be calculated as:

$$Ox_{sat} = \exp\left[-139.34410 + \frac{1.575701 \times 10^5}{T_{wat,k}} - \frac{6.642308 \times 10^7}{\left(T_{wat,k}\right)^2} + \frac{1.24380 \times 10^{10}}{\left(T_{wat,k}\right)^3} - \frac{8.621949 \times 10^{11}}{\left(T_{wat,k}\right)^4} \right] \quad \text{….6}$$

C. Nutrients

Nutrient enrichment in water bodies has started to be seen as a major problem due to different human activities experienced in the basin such as an increase of human settlement in the drainage basin, clearing of forest for farming, development of urban societies and with consequential disposal of industrial and agricultural wastes (Kitaka, 2000).The fate and transport of nutrients in a watershed depend on the transformations the compounds undergo soil environment (Neitsch, 2002). Due to various processes such as conversion to nitrogen gas, an inert form of the nutrient that is eventually released into the atmosphere, a certain portion of the nutrients stored in the sub basin will be lost. SWAT models the full nutrient cycle for nitrogen and phosphorus as well as all pesticides used in HRU

D. Nitrogen cycle

There are three forms of nitrogen, organic nitrogen associated with humus, mineral forms of nitrogen held by soil colloids, and mineral forms of nitrogen in solution (Neitsch, 2002). The ability of nitrogen to vary its valence state makes it a highly mobile element. Predicting the movement of nitrogen between the different pools in the soil is critical to the successful management of this element in the environment (Neitsch, 2002). The organic and inorganic forms of N are input into the soil system via commercial fertilizers, livestock manure and plant residue.

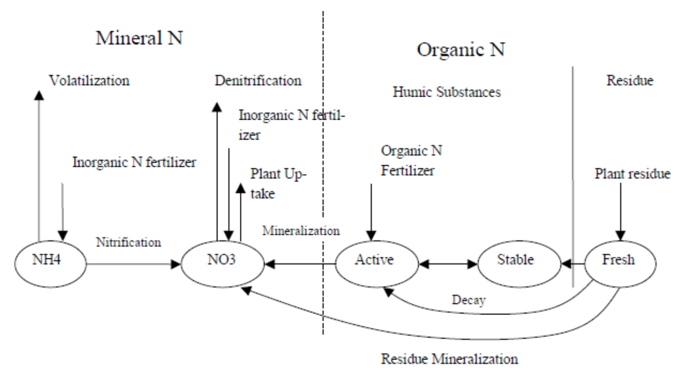

Fig. 1 *SWAT Soil Nitrogen and Processes that Move Nitrogen in And Out of Pools (Neitsch, 2002).*

E. Phosphorous Cycle

The three main forms of phosphorus in mineral soils that fertilizers, manure or residue applications may add to the soil are organic phosphorus associated with humus, insoluble forms of mineral phosphorus, and soil phosphorus available in plants (Neitsch, 2002).

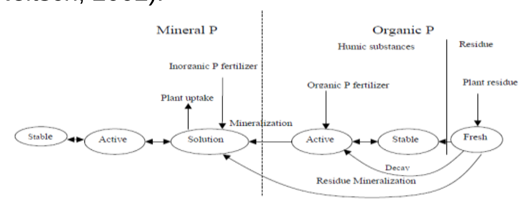

Fig. 2*. SWAT Soil Phosphorus and Processes that Move Phosphorus in And Out of Pools (Neitsch, 2002).*

SWAT tracks six different soil pools of phosphorus in which three pools are inorganic forms of phosphorus, while the other three pools are organic phosphorus.

F. Nitrate Movement

Through ground runoff, lateral flow and percolation, the nitrate in the soil can be transported. To calculate the amount of nitrate exchanged through water in SWAT, the concentration of nitrate in mobile water is first measured. This concentration is then exacerbated by the amount of water flowing through each track to gain the loss of nitrate mass from the surface of the soil.

The concentration of nitrate in the mobile water fraction is calculated as:

$$Conc_{NO_3,mobile} = \frac{NO_{3ly} \exp\left[\left(\frac{-w_{mobile}}{(1-\theta_e)SAT_{ly}}\right)\right]}{w_{mobile}} \quad .... 7$$

The amount of mobile water in the soil is the amount of water lost due to surface runoff; it is calculated as lateral flow or percolation:

$$W_{mobile} = Q_{surf} + Q_{lat,ly} + w_{perc,ly} \quad ....8$$

$$W_{mobile} = Q_{lat,ly} + w_{perc,ly} \quad .... 9$$

Finally, the nitrate removed in surface runoff from the top 10 mm of soil is calculated as:

$$NO_{3\,surf} = \beta_{NO_3}\left(Conc_{NO3,mobile}\right)Q_{surf} \quad ....10$$

G. Organic N in Surface Runoff

The organic nitrogen attached to the soil particles via commercial fertilizer and livestock manure may be transported by surface runoff to the rivers and lake. As cited by Neitsch (2002), the amount of organic nitrogen transported with sediment to the stream is calculated with a loading function. SWAT calculates the movement of organic nitrogen in surface runoff as:

$$orgN_{surf} = 0.001\,conc_{orgN}\left(\frac{sed}{area_{hru}}\right)\varepsilon_{N,sed} \quad ....11$$

SWAT measures the accumulation ratio (or the ratio of organic nitrogen expressed with the sediment to soil surface concentration) using the relationship defined by Neitsch (2002) in which the enrichment ratio is logarithmically related to sediment concentration. The equation used to calculate the nitrogen enrichment ratio, εNsed for each storm event is:

$$\varepsilon_{Nsed} = 0.78\left(conc_{sed,surq}\right)^{-0.2468} \quad ....12$$

The concentration of sediment in surface runoff is calculated:

$$conc_{sed,surq} = \frac{sed}{10\ area\ Q_{surf}} \quad .... 13$$

H. Soluble Phosphorous Movement

Diffusion is the primary mechanism for soil phosphorus movement (Neitsch, 2002). The mobility of phosphorus is smaller than nitrogen. The ground runoff will only partly interact with the solution P deposited in the top 10 mm of the soil due to the low mobility of solution phosphorus. The amount of solution P transported in surface runoff is calculated as:

$$P_{surf} = \frac{P_{solution,surf} * Q_{surf}}{\rho_b * depth_{surf} * k_{d,surf}} \quad ....14$$

The coefficient of phosphorus partitioning is the ratio of soluble phosphorus concentration in the top 10 mm of soil to soluble phosphorus concentration in surface runoff. (Neitsch, 2002).

I. Organic and Mineral P Attached to Sediment in Surface Runoff

Through surface runoff attached to soil particles, organic and mineral P can be transferred to the main channel. A loading function cited by Neitsch calculates the amount of phosphorus conveyed to the stream with the sediment. (2002).

SWAT measures the phosphorus enrichment ratio for each storm event using the Menzel (1980) relationship in which the enrichment ratio is logarithmically related to the sediment concentration.

The equation used to calculate the phosphorus enrichment ratio, ε_{psed} for each storm event is:

$$\varepsilon_{Psed} = 0.78 * \left(conc_{sed,surq}\right)^{-0.2458} \quad ....15$$

The concentration of sediment in surface runoff is calculated as:

$$conc_{sed,surq} = \frac{sed}{10 * area * Q_{surf}} \quad .... 16$$

3. Primary and Secondary water quality Data Collection and Analysis

In the present study, grab or catch sampling has been adopted to collect surface water & groundwater samples. The samples thus collected were transported to the laboratory. The samples were analyzed following Standard Methods (APHA, 1995).

I. Climate and Hydrological data

The Kushavathi Watershed has no perennial rivers and hence the availability of surface water for irrigation, domestic and industrial purposes is limited. Groundwater is being extensively exploited for use. The Pattern of Rainfall in Kushavathi watershed during 2001-2010 is studied. The excess annual rainfall recorded in the year 2010.

II. Pore Size distribution

The pore system of a medium represents the fluid conduits and is formed by the packing of many discrete particles. Normally the size of the particles is considered small. In the present work, sieve analysis is carried out at Chikkaballapur, Bagepalli & Gudibande study areas. On the arithmetic scale the average percent finer is plotted and on the logarithmic scale the grain size is plotted. It presents the gradation curves obtained after the sieve analysis was carried out in all the four experimental sites. The effective grain size, D10 , is the size corresponding to the 10 percent line on the grain-size curve. The uniformity coefficient Cu and coefficient of curvature Cc of a sediment is a measure of how well or poorly sorted out.

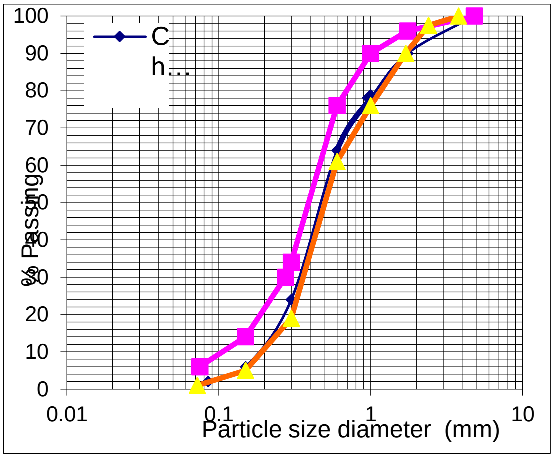

***Fig.3**. Soil Grade Curves For Experimental Sites*

III. Characterization of soil

For the development of models, and for estimation of parameters, a detail soil characterization study such as physical and chemical properties is required. The soils from the study sites were sampled and subjected to essential chemical and physical tests using standard test procedures (Jackson,1958).

3.1 Quality of Ground Water

The chemical, physical and bacterial characteristics of water determine its usefulness for domestic, irrigation and industrial purposes. The analysis shows that all water samples slightly alkaline in nature. The collected water sample conductance varies from 115 to 1640 micro mhos/cm.TDS value ranges from 200 to 1075, is present in study area. Fluorine occurs widely with an average concentration in the earth's crust of about 300-ppm. The analysis indicates that the fluoride and Nitrate concentration is beyond the permissible limit in some villages. The samples show the sulphate concentration varies from 10 to 650 ppm. The analyzed water samples indicate that the groundwater in this area is, in generally hard. But, at some places, it is very hard, viz. Gangarekaluvu(652ppm), Chickpayalagurki(800ppm), Anarthanahalli(850ppm) and Doddipalli (512ppm).

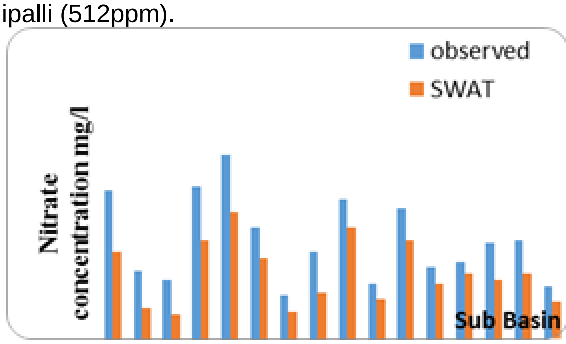

***Fig.3.1**. Observed and SWAT Concentration*

3.2 Quality Index

The Water Quality Index (WQI) was determined using the method of determining the suitability of groundwater for drinking purposes suggested by Tiwari and Mishra (1985) and Pradhan (2001). WQI was computed using the formula given in equation (1) and a water quality index map was prepared.

$$WQI=Antilog\ (\sum W^{n}_{n=1}.\log_{10} q_n) \quad ....16$$

where, weightage factor W is computed using equation

$$W_n = K/S_n \quad ....17$$

where, Sn = Standard value of the parameter
K = constant = (∑Wnn=1 1/Si)
Si = Standard value of the parameter.

Quality (q) is determined on the basis of the formula in the equation

$$q_{ni} = \{[(V_{actual} - V_{ideal}) / (V_{standard} - V_{ideal})] * 100\} \quad ......18$$

where,
q_{ni} = quality rating of i^{th} parameter for a total of 'n' water quality parameters
Vactual = value of the water quality parameter obtained from laboratory analysis.
Vstandard = value of the water quality parameter obtained from standard tables
Videal for pH = 7 &
for other parameters it is equivalent to zero.

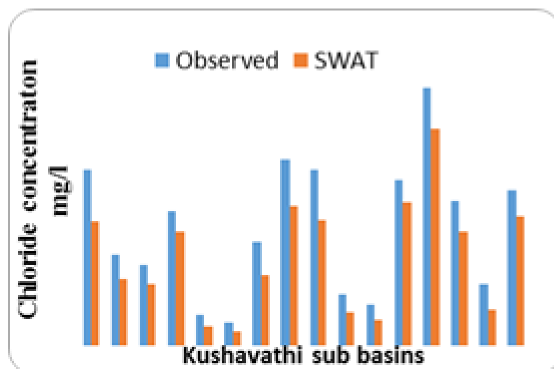

***Fig.3.2**. Comparison Between Observed and SWAT Concentration*

3.3 Fluoride Contamination

In the Kushavathi watershed, fluorosis has been reported in several areas and this has prompted the need to study the spatial distribution of Fluorides in the Groundwater of Kushavathi watershed. A research project on control of fluoride in groundwater initiated a study on the dilution of fluoride by increased artificial recharge; increased recharge is achieved through removal of impermeable silt layer deposited over years in the bed of a tank located in Pathapalya village in Kolar district of Karnataka. The study indicates that there is an appreciable rise in water table as well as significant reduction in fluoride level in groundwater after desiltation of the tanks. The evaluation points out that due to increase in infiltration of surface water having low concentration of fluoride from the tank bed area, considerable reduction in fluoride content in groundwater in the influence area had taken place (Madhav et al, 2000)

3.4 Geo-chemistry of Flouride

In the pegmatites, as in Figure 6.5, the well-known Kolar schist belt containing rich gold deposits also contains fluorite and fluorapatite. The deep borewells drilled to a depth of 200 m have revealed high levels of fluoride in Bagepalli taluk at a temperature of 6 mg /l (Suryanarayana & Gupta, 1997).

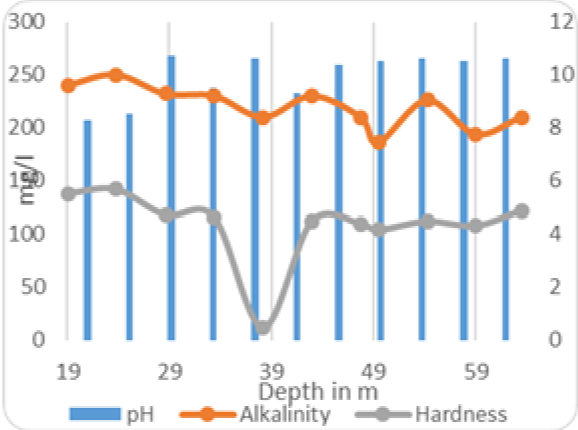

Fig. 3.3 *Variation of pH, Alkalinity and Hardness along the depth*

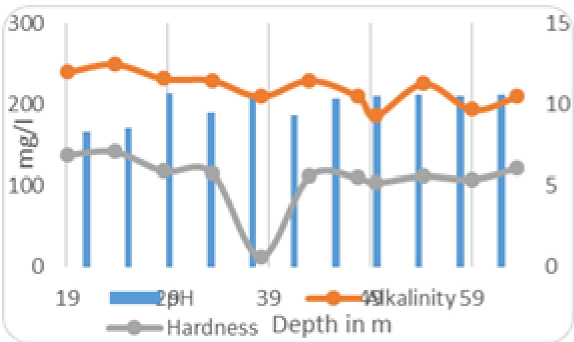

Fig. 3.3.1 *Variation of Fluoride along the depth*

3.5 Health status

Natural contamination of groundwater by fluoride causes irrepairable damage to plant and human health. High oral fluoride intake results in human physiological disorders, skeletal and dental fluorosis, changes in thyroxine and kidney damage (Grandjean, et. al., 1992). High levels of fluoride inhibit germination since ultrastructural malformations, decrease photosynthetic efficiency, alter membrane permeability, decrease productivity and biomass and trigger other physiological and biochemical disorders (Miller, 1993Even though water contained fluoride well within the permissible limits, it was observed in children. In comparison, Coaster (1968) recorded for several generations without harmful effects to a community using groundwater containing 10-14 mg / l fluoride in northern Tanzania. It is therefore important to revise the fluoride standard in India

4 CONCLUSIONS

These results showed that if properly calibrated, the SWAT system can be used effectively in semi-arid regions to support water management policies. Watershed models have become a major tool to solve a wide range of ecological and water quality problems. In addition, the model's performance can be improved by adding some other climate data such as solar radiation, precipitation, and wind. It is recommended that the optimized model be used to evaluate and monitor other water basin elements, such as the analysis of land and climate change impacts on water resources, water quality, sediment and agricultural chemical yield.

Many physical and chemical defluoridation methods have been developed to treat high fluoride waters. The best alternative to traditional methods of defluoridation is biological defluoridation. These approaches would be cost-effective, and biodegradable would be the material used.

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