Modelling Of Soil Urea Distribution Coefficient

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ABSTRACT

Urea is the most important fertilizer used worldwide for agricultural purposes. When applied to soils, it is weakly adsorbed by soil particles, and tends to concentrate in the soil solution, hence it is prone to losses. In this paper an attempt is made to model, urea distribution coefficients, of four different soils viz. loam, salty clay, salty clay loam and silt loam soils, with soil pH, Action Exchange Capacity (CEC) and clay fraction. Urea distribution coefficient was found to have increasing relationship whilst pH and CEC were found to have inverse relationship.

Keywords— Model, soil, urea, clay

I. INTRODUCTION

Urea is one of the most important Nitrogenous fertilizers, utilized all over the world due to advantages such as [1, 2],

- It is cheap
- It can be blended with other fertilizer such as DAP
- Can be applied as solid or as solution

Urea is weakly adsorbed by soils. Hence, when broadcast as pills or in the form of powder, the urea distributes heavily in the soil solution rather than get adsorbed by the soil particles. This helps in the diffusion and the subsequent spread through the agricultural field, but urea in solution is prone to losses such as leaching loses and surface run off losses.

Adsorption distribution coefficient (K_d) can be defined as the ratio of soil adsorbed urea to the concentration in soil solution. There are practically no available mathematical models that can correlate soil urea adsorption distribution coefficient with the soil parameters such as soil pH, Cation Exchange Capacity (CEC) and the clay content.

Caption Exchange Capacity (CEC) [3] is the total capacity of a soil to hold exchangeable cations. CEC is used as a measure of fertility, nutrient retention capacity and the capacity to protect groundwater from cation contamination. The quantity of positively charged ions that negatively charged clay mineral can accommodate is expressed as milli-ion equivalent per 100g or more commonly as mill equivalent (meq) per 100g.

Soil pH plays an important role in many chemical and biological processes that takes place in the soil. It can significantly affect plant nutrient availability by controlling the chemical forms of nutrient. Higher clay soils generally possess alkaline pH. Soil particles are grouped according to their sizes into what are called soil separates (fractions). These separates are typically named clay, silt and sand. Soil texture classification is based on the percentage of soil separates present in a soil. As per United States Department of Agriculture (USDA) classifications, clay particles have diameter of less than 0.002mm, silt particles have diameters in the range of 0.002 and 0.05mm.

The largest particles are sand particles, which are larger than 0.05mm in diameter. Clay content is the determinant of the fertility of a soil and is a key parameter in modeling. The soil texture triangle is a diagram often used to figure out soil textures. As per USDA classifications, twelve soil textures are defined and they are shown in the soil texture triangle presented in Figure 1.

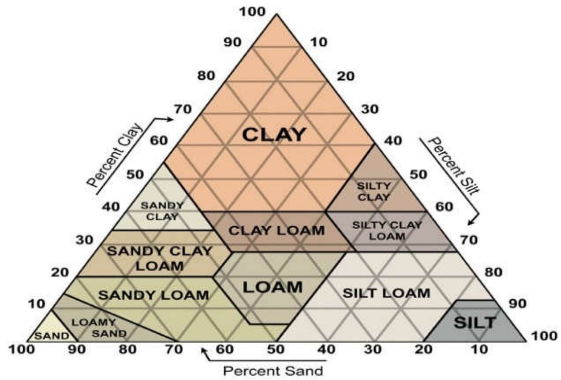

Fig 1: Soil triangle

Soil parameters such as pH, CEC and clay content are extensively evaluated for different types of soils and are studied as a part of soil characterization. However, soil urea distribution in wet soils is not studied, although it is essential to know how this fertilizer redistributes itself upon application in agricultural soils between the soil solution and the adsorbed state. Knowledge of distribution coefficient helps in optimization of urea application rate from the perspective of curtailing the loss of urea occurring in the agricultural fields. More the urea in soil solution, more it is prone to leaching and runoff losses.

Hence, an attempt has been made in this paper to model urea distribution coefficient with soil parameters pH, CEC and clay content using the data available for four different types of soils. With the help of a model, just with the easily evaluated parameters such as CEC, pH and clay content, we can assess the urea distribution coefficient in soils. Polynomial model (equation 1)

$$y = a\, x_1^m x_2^n x_3^p \ldots \qquad (1)$$

Was chosen for the modelling purpose since regression is easy to perform and the model is simple. Modeling was carried out using Mat lab software.

II. MATERIALS AND METHODS

Soil urea (adsorbed) concentration (mg-urea/mg-soil) and soil solution urea concentrations (mg-urea/mL soil urea solution) were estimated as follows [4]. Five grams of the sterile and dry soil was mixed with 20mL urea solutions of different concentrations (0.02 to 0.50 g/mL) in sealed tubes, incubated at 28^0C for 48 hours to equilibrate the mixture. Care was taken to ensure that temperature was maintained at 28 ± 0.5^0C during equilibration, since small variation of temperature can lead to precipitation on account of change in solubility especially at high concentrations. Soil slurry was centrifuged and the separated solution was filtered. Separated wet soil was dried at 60^0C to evaporate water of adsorption. Urea present in the dried soil and the soil solution were analyzed by colorimetric method [5]. Soil pH was determined as per IS 2720 (part 26)-1987 [6], by preparing a slurry of soil in water (30:70) and determining the subsequent pH of the supernatant.

Caption Exchange Capacity (CEC) was estimated [3] by equilibrating a dry soil sample with 0.05N HCl so as to exchange cation with H+ ions and subsequently titrating the HCl solution against standard lime water using bromothymol blue indicator. Clay content and soil texture was characterized using Indian Standard IS2720 (part 4) 1985 [6]. Slurry containing dry soil sample passing through 75µm sieve and sodium hexametaphosphate in a 1000mL measuring cylinder were subjected to sedimentation and settling was monitored using a soil hydrometer. Diameter of the particle (Dp) in suspension at any sampling time is calculated using Stake's equation. Percentage of particle, N, with diameter less than or equal to Dp is calculated and plotted against Dp (µm). Clay content is obtained by reading the value of N at Dp of 0.002mm.

III. RESULTS AND DISCUSSIONS

The following results (Table I) were obtained for the parameters as reported previously [3, 4]

TABLE I
PROPERTIES OF VARIOUS SOILS

Characteristic	**Silty Clay**	**Silty Clay Loam**	**Loam**	**Silt Loam**
Clay content (fraction)	0.51	0.30	0.13	0.05
CEC, meq /g	25.2	20.30	17.35	9.94
pH	8.19±0.2	6.94±0.11	5.17±0.2	6.02±0.11
Distribution coefficient, K_d (mL/g)	0.4217	0.5156	0.6699	0.72

The model predicted K_d vs. exptl. K_d is plotted in Figure 2. Although the relationship between parameters pH, CEC, clay content and soil organic content with K_d is very complex and difficult to model mathematically, a model was developed based on the data obtained in the study. Among the parameters considered affecting urea adsorption in soil, three parameters viz. pH, CEC and fraction of clay content (Table1) were chosen for fitting an empirical correlation with K_d as discussed above. Soil organic content did not correlate well with urea adsorption. The fitted empirical correlation with R^2 of 0.9999 is,

$$K_d = 9.7260\ pH^{-0.795}\ CEC^{-0.4438}\ \text{clay content}^{0.0503} \quad (2)$$

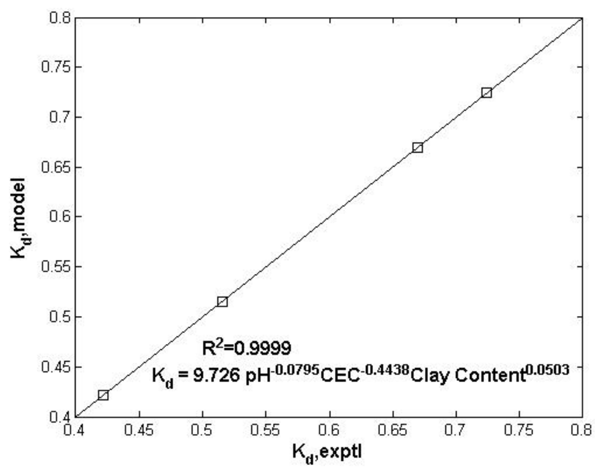

Fig 2: Model predicted K_d vs-a-vis exptl K_d

As can be seen equation (2), an excellent fit is observed amongst the parameters. An inverse relationship of K_d with pH and CEC can be observed, while clay content shows increasing relationship with K_d. Hence, alkaline pH and higher values of CEC tends to concentrate urea in soil solutions, whilst increasing the clay content has a positive effect on entrapping the fertilizer within the clay matrix.

IV. CONCLUSIONS

Soil urea distribution coefficient (K_d) was modelled with CEC, pH and clay content based on the data for four different soils. It was found that an excellent fit of K_d with the three parameters were observed and an inverse relationship was observed with CEC and pH whilst an increasing relationship was observed with clay content.

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