

Estimating the Degradation Half-life of Herbicides in the Soil Using Computer-developed Models

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Abstract The researchers carried out this study in order to develop an appropriate model for estimating the degradation half-life of soil-applied herbicide. The results of the effect of pH and time on the degradation of atrazine in untreated Ningi soil of Bauchi State, Nigeria, was used as the input to a Minitab computer programme. The software or programme was used to develop the model for estimating or forecasting the degradation half-life of the herbicide in the soil. The developed model: $T_{1/2}(\text{days}) = 175 - 5.63C(\text{ppm}) - 12\text{pH}$ was found to be remarkable and provided insight as to how long half of the initial Concentration of the applied herbicide would remain un-degraded. This obviously would be an invaluable index in estimating the extent of persistence of the herbicide in the soil, water (due to leaching through the soil profile) or even plant uptake.

Keywords: herbicides, half-life, model, forecast, minitab

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1. Introduction

Herbicides are applied to the soil with the hope of obtaining a season-long weed control, be it in the agronomic and horticultural crops, turf and industrial weed management [1]. It is desirable for the herbicides to control weeds during the season of application but they should not remain long enough to affect subsequent crop growth [2]. Neither should they persist long enough to be adsorbed by edible plants or food crops nor be leached onto our water bodies, which may eventually lead to toxicity of consumers [3].

It has been reported that the intensive application of herbicides have resulted in the contamination of the atmosphere, ground or wastewater and agricultural products [3]. There is also the direct pollution of food and food products as well as the biological system [4]. Further reports also showed that 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food [5]. Many users are inadequately informed about potential short and long-term risks, and how to overcome such problems are not always made [6].

Herbicides belonging to the triazine family such as atrazine and simarine are known to be persistent and harmful to organisms even at micro levels [7]. The potential of herbicides to persist in the soil however varies according to the soil type, climate and herbicidal properties [1]. The scope of this work was however, centred on the soil factors since over 90 percent of the persistence of the triazine herbicides depend largely on

this. These soil factors are further categorized into physical, chemical and microbial.

Soil composition is a physical factor that measures the relative amount of sand, silt, clay (soil texture) and the organic matter content of the soil. The chemical properties of the soil include pH, cation exchange capacity (CEC) and nutrient status. The microbial aspects include the type and abundance of soil microorganisms present, which could degrade the herbicides [1]. The triazine herbicides are particularly affected by soil pH, an important part of the soil chemical makeup. Lesser amounts of these herbicides are adsorbed or held to soil colloids at higher soil pH, so they remain in the soil solution which are then available for plant uptake [1,8], the origin of the problems of persistence in the soil and ultimately underground and wastewater pollution with auxins and dioxins, their active constituents. These constituents are very toxic and may result in fatality even at low concentrations [1].

It should be noted that the greater problem with the use of herbicides in agricultural practices in developing countries lie largely in the inability of farmers to predict their persistence [9,10,11]. This work therefore attempts to use computer-based, Chemo metrical principles to develop appropriate models that could predict to a reasonable degree of certainty, the persistence of the herbicide as a function of its degradation half- life.

2. Materials and Methods

The degradation of atrazine (10 ppm) in untreated Ningi soil of Bauchi State, Nigeria, was determined by varying the time, and pH as reported by [12]. The obtained results

were then fed into a computer installed with the Minitab11 statistical software.

With the aid of this software, the model for forecasting or predicting the degradation half-life of the herbicide (atrazine) was developed.

3. Results and Discussion

Table 1. Effect of pH and Time on the Degradation of atrazine in untreated Ningi Soil of Bauchi

pH	Time(days)	Atrazine Concentration (ppm)
4.0	120	2.26
5.0	90	3.30
8.0	60	3.57
9.2	30	6.10
10.0	0	10.00

The Developed Model is:

$$T_{1/2}(\text{days}) = 175 - 5.63C - 12.0pH$$

Where; $T_{1/2}$ is the degradation half-life of the herbicide, C and pH are the initial herbicide Concentration and soil pH respectively. The numbers 5.63 and 12 are the coefficients of correlation for the concentration and pH terms respectively, while 175 is the constant term. The degradation half-life of the herbicide could be simulated using the above model provided the pH of the soil and the initial concentration of the herbicides are known or measured. Soil pH can have a significant effect on the adsorption of herbicides. pH is a measure of the availability of hydrogen ions (H^+) in solutions. In acidic conditions, atrazine may pick up H^+ from the solution, causing it to take up a positive charge. This positive charge increases the attraction between the herbicide molecule and the negatively charged soil colloids, while the converse is true for basic or high pH [1,13].

The development of the model using pH and herbicide concentration as the predictors was based on the fact that mathematical models was dependent largely on the fundamental concepts of physical systems which are described by a few measurable variables that could easily be determined [14]. Furthermore, to establish the credibility of models, the models must rely on physical laws rather than transfer functions for which the parameters have been found [15].

Specifically speaking, this model would at 95 % confidence level, predict the half-life of atrazine when applied to Ningi soil at any given soil pH and initial herbicide Concentration. Statistical analysis also showed that the error margin with this model was minimal, just 1.7% implying high degree of reliability. Additionally, it also showed that the variables overall were not only statistically significant ($P \leq 0.009$) but were also highly correlated.

4. Conclusion

The developed model; $T_{1/2}(\text{days}) = 175 - 5.63C - 12pH$ could indeed be used to estimate the half-life of the herbicide at 95% confidence level. This model would predict or estimate the half-life of atrazine or simarine or any of the herbicides of the triazine family because their persistence is largely dependent on the soil pH . The

significance of this model is that farmers specifically and scientists at large would be able to predict how long these herbicides would persist thereby having a pre-knowledge of possible adsorption by vegetation, and leaching into underground and wastewater. This invariably would boost the monitoring of pollution by the use of these herbicides.

Supposing a farmer applies an herbicide, say, atrazine of 10ppm in order to control weed in his farm with a soil pH of five, then the $t_{1/2}$ would be about 58.7days by using this model. That is after 59 days, the concentration of the herbicide would have reduced to half (5ppm).

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