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Research Article

ENVIRONMENTAL EFFECTS OF PESTICIDES

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A R T I C L E I N F O

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A B S T R A C T

Different types of chemicals are used to get rid of the attack of the different types of pest and the insects on the plants and also on the important crops are also the ways to cause the air pollution. Because the biggest problem with aerial spraying is that the pesticides being released often miss their target and damage unintended areas. The environmental impact of pesticides is often greater than what is intended by those who use them. Over 98% of sprayed insecticides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food. Aerial spraying of pesticides leads to water, air, and soil contamination, which negatively impacts human, animal, and plant health. Pesticide traces can be found in the blood of residents living close to areas where aerial spraying took place. Health impacts are neurological and dermatological. In this paper a mathematical model is developed to estimate the pollutant concentration, when it travels through the plant canopies. The present model is discussed in a field, full of crops, by dividing the whole region into three parts. On estimating the concentration of pollutant, it is observed that, the level of pollutant is much lower in foliage region as compared to non – foliage region with dependent diffusivity.

INTRODUCTION

Population growth is directly associated with food supply and created greatest pressure on limited cultivated land. Significant strides have been made in agriculture production towards ensuring food security. Fertilizers and pesticides are very important inputs of modern day agriculture. The toxicity of pesticides is responsible for its effectiveness in controlling pests but manures have been in use of it to enhance the productivity of soil, to meet out the ever growing need of food. It can be injected into the soil as a fumigant or into irrigation water; or it can be sprayed onto the soil surface. Crops can be sprayed with boom sprayers or tunnel sprayers or by aerial application. During aerial pesticide application, some part of applied material is lost to the atmosphere in the form of fine droplets moving off-target through the air stream by spray drift. Spraying pesticides through spray nozzles produces a spectrum of droplets of different diameters. As they become smaller, they remain airborne longer and can be transported over regional, continental, or intercontinental distances. It has been estimated that as much as 40-60% of the applied material may ultimately reach the atmosphere.An excellent summary of main features involved in trapping of airborne material has been given byChamberlain [1]. The approach has gained much success and has been incorporated into many deterministic models concerned with the dispersion of airborne material e.g., Scriven and Fisher [2]. As particulate size also effect the settling velocity, for which the evidence of Chamberlain [3], Bache and Uk [4] suggests that sedimentation is likely to be a dominant trapping mechanism. The probabilistic approach is reviewed and developed to establish a general framework by Bache [5] for estimating the bulk trapping efficiency of a foliar canopy and to provide insight into the vertical distribution of material within canopy. But all these works were done by placing main emphasis on deposition velocity i.e., the particulate transport within the plant canopies with constant diffusion coefficient. While the environment is get affected by the remaining quantities of pesticides and insecticides after spraying of them and play a significant role in increasing the pollution level, and the turbulent diffusion of pollutants is also vary from place to place.

In this paper, effect of urbanization which is result of increased population on the environment is discussed. Keeping the above aspects in mind, a mathematical model is developed to estimate the pollutant concentration, when it travels through the plant canopies. The present model is discussed in a field, full of crops, in which spraying is done for protecting it from pests. The whole region is divided into three parts, in which region II is full of plant canopies while region I and III are without canopies. In this study, the diffusivity has been taken as function of height. The emphasis is placed on two main things, (I) the angle at which the pollutant incident on plant canopy, (II) varying settling velocity. On estimating the concentration of pollutant, it is observed that, the level of pollutant is much lower in foliage region as compared to non –

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foliage region and it goes on decreasing with increased vertical height.

Mathematical Model

Following a statistical view of particle capture introduced by Bache and Uk [4], the approach was developed for inclusion into the steady state turbulent – diffusion equations and it was shown that mass conservation could be expressed (Bache [5]) as,

$$u\frac{\partial C}{\partial x}-v_s\frac{\partial C}{\partial z}-\frac{\partial}{\partial z}\left(K(z)\frac{\partial C}{\partial z}\right)=$$

$$-\beta\left[uC\cos\theta+\left(v_sC+K(z)\frac{\partial C}{\partial z}\right)\sin\theta\right], \tag{1}$$

where, x, z refer to the downwind and vertical directions, u is the wind speed, v_s is the particle settling velocity, $K(z)$ is vertical eddy diffusivity coefficient dependent on z and C is the airborne concentration.

Here,

$$\theta=\tan^{-1}\frac{v_s}{u},$$

defines an angular trajectory under quiescent conditions and β is the absorption coefficient defined on a Lagrangian basis. For a disperse canopy, β is specified by,

$$\beta=P_x\sin\theta+P_z\cos\theta, \tag{2}$$

where,

$$P_x=f_x\rho,$$

is the probability of capture in making a vertical transition (assuming perfect capture), and

$$P_z=E_if_z\rho,$$

is the probability of capture in making a horizontal traverse; E_i is an impaction coefficient and terms $f_x\rho, f_z\rho$ refer to the projected areas of foliage in the horizontal and vertical directions respectively with ρ the foliage density (foliage area per unit volume) and f_x, f_z foliage structure coefficients as introduced in Bache and Uk [4]. The forms of P_x and P_z, as used in equation (2), apply to foliage elements of a given type, and it may be necessary to specify β as a summation over the different components e.g., leaves and branches for a multi–element system.

When advection is neglected, equation (1) reduced to,

$$\frac{d^2C}{dz^2}+f(z)\frac{dC}{dz}+g(z)C=0, \tag{3}$$

with

$$f(z)=\frac{v_s}{K(z)}+\frac{1}{K(z)}\frac{dK(z)}{dz}-\beta\sin\theta, \tag{4}$$

and

$$g(z)=\frac{-\beta}{K(z)}\sqrt{(u^2+v_s^2)}. \tag{5}$$

Solution to equation (3) – (5) can be obtained with knowledge of basic aerodynamic features and an estimate of the canopy adsorption characteristics given by equation (2).

For the required purpose whole area full of vegetative canopies of height h is subdivided into three regions as represented in figure (1).

As shown in figure (1), region (I) the constant flux zone i.e.,

$$\beta=0,$$

and $K(z)$ is taken as constant, i.e.,

$$K(z)=K.$$

Using above values, equation (3) – (5) in region (I) are given by,

$$\frac{d^2C_1}{dz^2}+\frac{v_s}{K}\frac{dC_1}{dz}=0, \tag{6}$$

where, C_1 is the concentration of pollutant in region I with,

$$f(z)=\frac{v_s}{K}$$

And

$$g(z)=0.$$

In region II, $b\le z\le h$ denotes the foliage crown, within which transport is described by using equation (3). In this region, diffusivity is taken as dependent on vertical distance (z), i.e.,

$$K(z)=az^{\alpha},$$

therefore, for region II, equations (3) – (5) can be rewritten as ,

$$\frac{d^2C_2}{dz^2}+\left(\frac{v_s}{az^{\alpha}}+\frac{\alpha}{z}-\beta\sin\theta\right)\frac{dC_2}{dz}-\frac{\beta}{az^{\alpha}}\sqrt{(u^2+v_s^2)}C_2=0, \tag{7}$$

where, C_2 is the concentration of pollutant in region II, with,

$$f(z)=\frac{v_s}{K(z)}+\frac{1}{K(z)}\frac{dK(z)}{dz}-\beta\sin\theta,$$

or

$$=\frac{v_s}{az^{\alpha}}+\frac{\alpha}{z}-\beta\sin\theta, \tag{8}$$

and,

$$g(z)=\frac{-\beta}{az^{\alpha}}\sqrt{(u^2+v_s^2)}. \tag{9}$$

Now at last in third region, it is assumed that, $\rho\to 0$ i.e., $\beta\to 0$

and,

$$K(z)=az^{\alpha},$$

therefore, equation of transport in this region is given by,

$$\frac{d^2C_3}{dz^2}+\left(\frac{v_s}{az^{\alpha}}+\frac{\alpha}{z}\right)\frac{dC_3}{dz}=0, \quad (10)$$

where, C_3 is the concentration of pollutant in region III, with,

$$f(z)=\frac{v_s}{az^{\alpha}}+\frac{\alpha}{z}, \quad (11)$$

and

$$g(z)=0. \quad (12)$$

Boundary conditions are given by,

$$C_1=C_0, \qquad z=0, \quad (13)$$

$$\frac{dC_3}{dz}=0, \qquad z=H, \quad (14)$$

and the matching conditions at the two boundaries of region I – II and II – III are given by,

$$C_1=C_2=C_b, \qquad z=b, \quad (15)$$

$$K_1\frac{dC_1}{dz}=K_2\frac{dC_2}{az}, \qquad z=b, \quad (16)$$

and

$$C_2=C_3=C_h, \qquad z=h, \quad (17)$$

$$K_2\frac{dC_2}{dz}=K_3\frac{dC_3}{dz}, \quad z=h, \quad (18)$$

where, diffusivity coefficients in region I, II and III are denoted by K_1, K_2 and K_3, and given by $K_1= K$, $K_2 = K_3 = az^{\alpha}$ respectively.

Method of Solution

Region I

On solving following equation in region I,

$$\frac{d^2C_1}{dz^2}+\frac{v_s}{K}\frac{dC_1}{dz}=0,$$

the value of concentration of pollutant in this region is given by,

$$C_1=\frac{Ae^{-fz}}{-f}+B, \quad (19)$$

where, A and B are arbitrary constants, and,

$$\frac{v_s}{K}=f.$$

Region II

Letting α = 1/2, equations (7) - (9) are reduced to,

$$\frac{d^2C_2}{dz^2}+\left(\frac{v_s}{a\sqrt{z}}+\frac{\alpha}{z}-\beta\sin\theta\right)\frac{dC_2}{dz}-\frac{\beta}{a\sqrt{z}}\sqrt{\left(u^2+v_s^2\right)}C_2=0, \quad (20)$$

with,

$$f(z)=\frac{v_s}{a\sqrt{z}}+\frac{1}{2z}-\beta\sin\theta,$$

$$g(z)=\frac{-\beta}{a\sqrt{z}}\sqrt{\left(u^2+v_s^2\right)},$$

where, functions f and g further reduced to,

$$f(w)=\frac{2v_s}{aw}+\frac{2}{w^2}-\beta\sin\theta, \quad (21)$$

and

$$g(w)=\frac{-2\beta}{aw\sqrt{\left(u^2+v_s^2\right)}}, \quad (22)$$

by transforming independent variable (z) as,

$$w=\int_0^z\frac{dt}{\sqrt{t}} \quad (23)$$

$$=2\sqrt{z}.$$

On putting values from equations (21), (22) and transformation (23) in equation (20), it is further reduced to,

$$\left(\frac{4}{w^2}\frac{d^2C_2}{dw^2}-\frac{4}{w^3}\frac{dC_2}{dw}\right)+\left(\frac{2v_s}{aw}+\frac{2}{w^2}-\beta\sin\theta\right)\frac{2}{w}\frac{dC_2}{dw}+\left(\frac{-2\beta}{aw}\sqrt{\left(u^2+v_s^2\right)}\right)C_2=0,$$

or

$$\left(4w\frac{d^2C_2}{dw^2}\right)+\left(\frac{4v_s}{a}w-2\beta\sin\theta w^2\right)\frac{dC_2}{dw}-\frac{2\beta}{a}\sqrt{\left(u^2+v_s^2\right)}w^2C_2=0.$$

The solution of the above equation is given by,

$$C_2=a_0+a_1t+a_2t^2+a_3t^3..........$$

$$=a_0+a_1\left(2\sqrt{z}-b\right)+a_2\left(2\sqrt{z}-b\right)^2+a_3\left(2\sqrt{z}-b\right)^3+........$$

$$=a_0\left[1+\frac{qb}{4}\left(2\sqrt{z}-b\right)^2+\frac{q}{24}\left(2-2rb+pb^2\right)\left(2\sqrt{z}-b\right)^3+.....\right]$$

$$+a_1\left[\left(2\sqrt{z}-b\right)+\frac{(pb-2r)}{4}\left(2\sqrt{z}-b\right)^2+......\right]$$

or

$$= a_0 P(z) + a_1 Q(z), \tag{24}$$

where,

$$P(z) = 1 + \frac{qb}{4}\left(2\sqrt{z} - b\right)^2 + \frac{q}{24}\left(2 - 2rb + pb^2\right)\left(2\sqrt{z} - b\right)^3 + ... \tag{25}$$

and

$$Q(z) = \left(2\sqrt{z} - b\right) + \frac{(pb - 2r)}{4}\left(2\sqrt{z} - b\right)^2 + ... \tag{26}$$

Region III

With $\alpha = \dfrac{1}{2}$, equation (11) is reduced to,

$$f(z) = \frac{v_s}{a\sqrt{z}} + \frac{1}{2z},$$

or

$$= \frac{2v_s}{aw} + \frac{2}{w^2},$$

with $w = 2\sqrt{z}$.

Using above value of f(z) in equation (10), it is reduced to,

$$\frac{4}{w^2}\left[\frac{d^2C_3}{dw^2} + \left(\frac{v_s}{a}\right)\frac{dC_3}{dw}\right] = 0,$$

with $w = 2\sqrt{z}$.

Now, solution of the above equation is given by,

$$C_3 = \frac{A_1 e^{-\left(\frac{v_s}{a}\right)w}}{\left(-\frac{v_s}{a}\right)} + B_1,$$

or

$$C_3 = \frac{A_1 e^{-\left(\frac{v_s}{a}\right)2\sqrt{z}}}{\left(-\frac{v_s}{a}\right)} + B_1. \tag{27}$$

Now for calculating constants appeared in C_1, C_2 and C_3 given by above equations, using boundary conditions and matching conditions, it is found that,

$$A_1 = 0. \tag{28}$$

$$B_1 = C_h. \tag{29}$$

$$A = \frac{(C_0 - C_b)f}{e^{-fb} - 1}, \quad B = \frac{C_0 e^{-fb} - C_b}{e^{-fb} - 1}. \tag{30}$$

$$a_0 = \frac{C_b Q(h) - C_h Q(b)}{Q(h)P(b) - Q(b)P(h)},$$

$$a_1 = \frac{C_b P(h) - C_h P(b)}{Q(b)P(h) - Q(h)P(b)}. \tag{31}$$

On putting values of constants, the concentration of pollutant in all the three regions is given by,

$$C_1 = \frac{(C_0 - C_b)f}{e^{-fb} - 1}\left(\frac{e^{-fz}}{-f}\right) + \frac{C_0 e^{-fb} - C_b}{e^{-fb} - 1}, \tag{32}$$

$$C_2 = \frac{C_b Q(h) - C_h Q(b)}{Q(h)P(b) - Q(b)P(h)}\left[1 + \frac{qb}{4}\left(2\sqrt{z} - b\right)^2 + ...\right] + \frac{C_b P(h) - C_h P(b)}{Q(b)P(h) - Q(h)P(b)}\left[\left(2\sqrt{z} - b\right) + ...\right], \tag{33}$$

$$C_3 = C_h.$$

(34)

Since concentration of pollutants in all the three regions are known in terms of C_b and C_h, i.e., the concentration of pollutant at z = b and z = h, respectively. Therefore, for finding the values of C_b and C_h, the matching condition are used and the value is given by,

$$C_h = \frac{\left(Q(h)P_h' - P(h)Q_h'\right)\left(Q(h)P(b) - Q(b)P(h)\right)KfC_0}{a\sqrt{b}\left[\left(Q(h)P_h' - P(h)Q_h'\right)\left(P(b)Q_b' - Q(b)P_b'\right)\left(1 - e^{fb}\right) - \left\{\left(Q(h)P_b' - P(h)Q_b'\right)\left(1 - e^{fb}\right) + Kf\left(Q(h)P(b) - Q(b)P(h)\right)\right\}\left(P(b)Q_h' - Q(b)P_h'\right)\right]}, \tag{35}$$

$$C_b = \frac{\left(P(b)Q_h' - Q(b)P_h'\right)\left(Q(h)P(b) - Q(b)P(h)\right)KfC_0}{a\sqrt{b}\left[\left\{\left(Q(h)P_b' - P(h)Q_b'\right)\left(1 - e^{fb}\right) + Kf\left(Q(h)P(b) - Q(b)P(h)\right)\right\}\left(P(b)Q_h' - Q(b)P_h'\right) - \left(Q(h)P_h' - P(h)Q_h'\right)\left(P(b)Q_b' - Q(b)P_b'\right)\left(1 - e^{fb}\right)\right]}. \tag{36}$$

After putting the values of C_b and C_h in equations (32) – (34) the concentration of pollutants can be found in the three regions.

RESULT AND DISCUSSION

Here concentration profiles have been plotted to analyze the variation of concentration level in the region for different parameter values. The values of different parameters used in this case are as follows (Bache, [5]),

$f_x = f_z = 0.2$, E = 0.02, u = 0.3m/s.

In figure (2), the concentration profiles are plotted against incident angles in region I, i.e. $0 \le z \le b$ (7.5 m.) with constant settling velocity (v_s) for varying vertical height using equation (32). Here concentration of pollutant decreases with the increase of angle of incidence (θ) for the range θ = π/6 to π/3. It can be seen that it has a minima at θ = π/3 and further it increases as the angle increases from π/3 to π/2. Therefore it can be concluded that, the absorption of pollutant is maximum at θ =π/3 and thus pollution is minimum in the atmosphere at this angle. It can also be depicted that on varying vertical height (z), all the lines coincides for different values of z and there is only a single line. It implies that, if the pesticides come in this region, there is no absorption and all the particles remain in the atmosphere, i.e., there is negligible reduction in concentration of pollutants as the vertical height increases.

In figure (3), change in concentration of pollutant is plotted against vertical distance for θ = π/4 with varying settling velocity. It can be referred from the figure that the value of concentration of pollutant decreases as the settling velocity increases and the lowest value is found at v_s = 1.0 m/s. Also it can be seen that, the concentration of pollutant goes on decreasing in vertical direction at lowest settling velocity and remains almost constant at higher settling velocity. In figure (4), concentration of pollutants is plotted against incident angles in region II, i.e. $b \leq z \leq h$ (15 m.), for constant settling velocity with varying vertical height using equation (33). It can be seen that, concentration of pollutants has a minimum value at $\theta = \pi/3$ and the value increases as the angle increases to $\pi/2$, similar to figure (1), which implies that the pollution is minimum at oblique incidence in the atmosphere. It can also be conclude that, the concentration of pollutants decreases as the vertical height increases, because of the region is full of plant canopies.

Figure (5), illustrates the change in concentration of pollutant against vertical distance at different settling velocities for $\theta = \pi/4$. It can be referred from the figure that as the value of settling velocity increases concentration level decreases in vertical direction and is lowest at higher velocity. It can also be seen that concentration of pollutants decreases steeply for $z \leq$ 12.5m., and for $z >$ 12.5m. the decrease is marginal, i.e., it can be concluded that, there is significant decrease in pollution level in dense foliage region.

CONCLUSION

Agriculture is a necessary human activity that interacts with air, it benefits from good quality air, and it contributes air pollutants. Agriculture needs air that is free of excessive amounts of such constituents as ozone, dust, suspended pesticides and odors. But agriculture may also contribute these substances to the air, as insecticides and pesticides are excessively used to enhance the productivity, and the remaining quantities of them are offensive or even threatening to human and environmental health in downwind areas.

Therefore, a study is made in this paper to protect air environment and to estimate the concentration of pollutant after spraying on crops. For the purpose an approach was developed for inclusion into the turbulent diffusion equation with dependent turbulent diffusivity coefficient. The model is solved by dividing the whole area of interest into three regions, in which the second region is full of plant canopies. It can be concluded from the above study that pesticides left after spraying play a vital role in polluting the atmosphere. The study shows that, oblique incidence of pesticides can increase its absorption in canopies and reduces its quantity in atmosphere. On the other hand, higher settling velocity of pollutants also reduces its quantity in the atmosphere. So by taking these measures, the remaining quantities of pesticides can be reduced to a higher level by which the goal of protection of environment can be achieved.

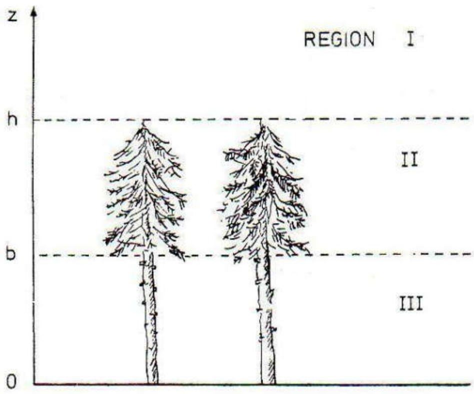

Figure 1 Schematic representation of the adsorption regions within the canopy of a pine forest.

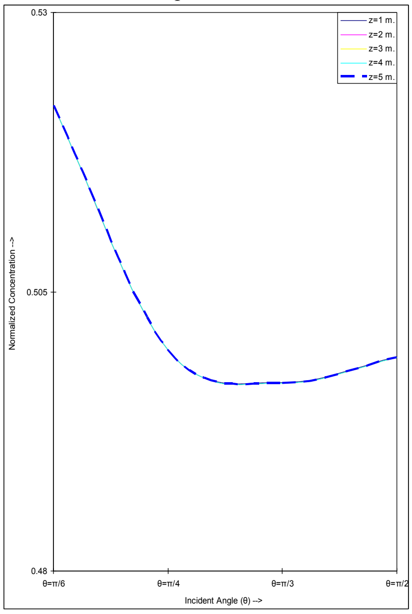

Figure 2 Concentration of pollutant in region I for different values of θ, at varying vertical height.

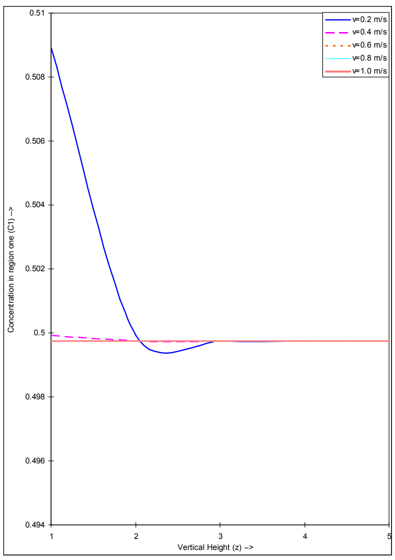

Figure 3 Concentration of pollutant in region I at $\theta = \pi/4$ for different settling velocity.

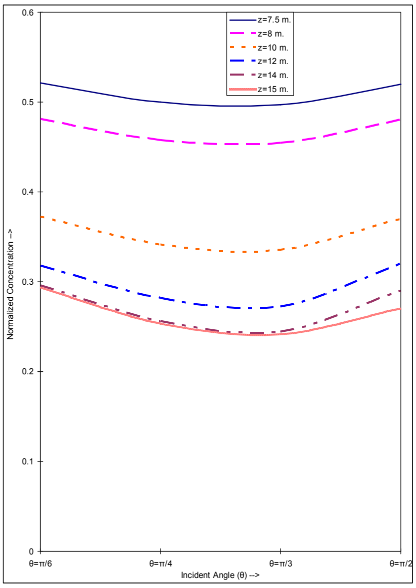

Figure 4 Concentration of pollutant in region II for different values of θ, at varying vertical height.

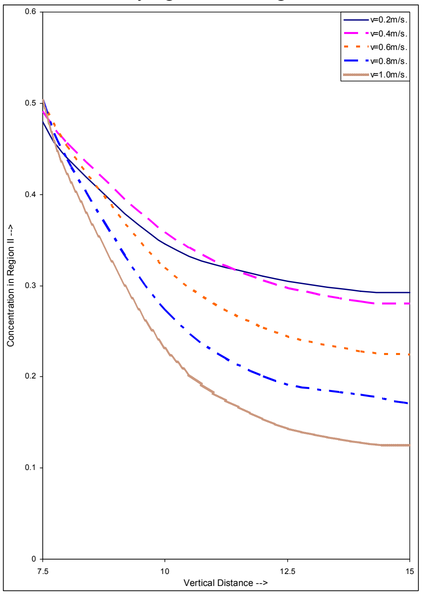

Figure 5 Concentration of pollutant in region II at $\theta = \pi/4$ for different settling velocity.

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