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Impact of Agro- pesticides (Nematicides) on Soil and Water Contamination

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Abstract: Agricultural pesticide use and its associated environmental harms is widespread throughout much of the world. Efforts to mitigate this harm have largely been focused on reducing pesticide contamination of the water and air, as runoff and pesticide drift are the most significant sources of offsite pesticide movement. Yet pesticide contamination of the soil can also result in environmental harm. Pesticides are often applied directly to soil as drenches and granules and increasingly in the form of seed coatings, making it important to understand how pesticides impact soil ecosystems. Soils contain an abundance of biologically diverse organisms that perform many important functions such as nutrient cycling, soil structure maintenance, carbon transformation, and the regulation of pests and diseases. Many terrestrial invertebrates have declined in recent decades. Habitat loss and agrichemical pollution due to agricultural intensification have been identified as major driving factors.

Keywords: Nematicides, soil polutiotion, water contamation, agriculture , adsorption.

Introduction:

In modern agriculture, pesticides ,plays a significante role in preventing diseases, insects , pestes , and weeds in enevaling stable, and hig production yield of crops ,and in raising the quality of agriculturl productdsPesticides are the substances used to control organisms which may adversely affect public health or organisms that attack food and other materials essential to mankind. Since it is impossible to know every property of every chemical, it is rather inevitable that some environ- mental damage will occasionally result from their use. However, this is no argument against their use so long as the benefit can be clearly shown to outweigh the damages. The important thing is to be aware that there is a finite risk of damage to minimize it by appropriate toxicity, testing of chemicals before they are applied on large scale and to ensure that the application is carried out correctly. When pesticides/nematicides are applied on a large scale, a constant watch must be kept for environment damage, if any.

In view of the fact that almost 50 per cent of the potential food produced is lost due to insect pests plant pathogens, rodents, birds and indeed phytonematodes thus, the use of pesticides has become absolutely essential. It is due to this fact that area under pesticide coverage has been rising (0.6 million hectare in 1950 to about 90.0 million hectare in 1985) steady over the years (Malhotra, 1988).

Combating the nematodes can be done in many ways but the use of nematicides is quite effective and cannot be replaced by any other method of nematode control. Chemicals are essentially usedunder such conditions where other methods of nematode control of- fer far less certainty of killing the nematodes, the nematicides are not likely to be dispensed with altogether. Nematicides have been found to be the most important tool to demonstrate the spectacular yield increase of various crops (Prasad, 1989; Mishra and Prasad, 1990).

Chemical control of nematodes in the soil is not a recent develop- ment. Julius Kuhn applied carbon disulfide (CS) to control the sugarbeet cyst nematode in Germany as early as the eighteen seventies. He became interested in this chemical after Baron Paul Thenard in 1869 had shown that CS, could be used successfully to control Phylloxera on vine, as a result of which soil fumigation with carbon disulfide became a standard practice in France to control soil insects in vineyards. In the USA, EA. Bessey experimented with CS, in 1906-1907 to control root-knot nematodes but the method proved impractical. Formaldehyde, cyanides and many other chemi- cals were found to have nematicidal properties but were all too expensive to be used. In 1919, the nematicidal quality of chloropicrin was discovered. The large quantity of chloropicrin developed surplus by the U.S.A. army after the end of World War I, were bought by the Hawaiian pineapple industry to kill noxious soil parasites in the pineapple plantations. The discovery more or less by change of DD (a mixture dichloropropene and dichloropropane) in 1943 by Walter Carter, an entomologist at the Hawaiian Pineapple Research In- stitute marked the beginning of large scale application of chemicals as nematicide. In 1945, EDB was brought in the market and the grower now has a few potent chemicals at his disposal to fight the noxious and on in present plant parasitic nematodes.

McBeth and Bergeson (1955) tested a new persistent nematicide, Dibromo-chloropropane (DBCP) for the control of various parasitic nematodes on several economically important crops. This nematicide had several advantages over earlier chemicals, therefore, in spite of ban on this nematicide on the basis of groundwater contamination and health hazards, still one can see a few publications in the research journals. DBCP is quite potent, long persistent and easy to apply under field conditions. It has plus point as it can be applied in the standing crops along with irrigation water. Subsequently, the ad- vent of high volatile compounds to low and then non-volatile com- pounds created problem of residues either in soil or water and ul- timately in the edible parts of plants.

Pesticidal Residues - A Source of Contamination

Physiochemical properties, nature of the substrates, and environmen- tal degradation determine the persistence of nematicides in soil. Nematicides reach the soil either by direct application to soil surface or by application to the crops. High concentrations of residues. deposit/persist in the soil by overall application than using lower dose of nematicides after coming in contact with soil, are governed by many factors. Effectiveness of chemical for the nematode control depends on soil type, nature of the chemical, soil moisture, soil pH and soil temperature. Different cultural practices may influence nematicide persistence in soil. There are many processes that in- fluence movement, persistence and activity of nematicides in soil. Prasad (1978) measured the vertical and horizontal movement of DBCP by taking the residual parameters. He observed that the movement of DBCP was mainly moisturedependent for the vertical movement and for hortizonal movement of nematicide, the soil tem- perature was equally responsible. Similarly, organic matter content in soil governed the longer persistence of DBCP. However, soil pH and steam sterilization did not affect the persistence of DBCP.

As early as in 1961, Gutemann et al. (1961) used a different ap- proach to measure bromine residues in plants grown in soil treated with DBCP. It was assumed that all bromine present was inorganic, although the method could probably be applied to organics as well. The sample was combusted in a schomiger flask and the hydrogen bromide formed was observed in water. Bromides were separated from chlorine on an ion exchange column and then determined colorimetrically. Turner (1964) described a simple laboratory tech- nique by which he determined the diffusion pattern of lethal con- centration of nematicides in soil. The best diffusion was obtained by vorlex followed by EDB, DBCP and CS,. Panagrellus redivivus was used as test organism in testing the soil diffusion pattern of DBCP when applied at eight inches depth in sandy soil. Ichikawa et al. (1955) reported that no nematicidal effect appeared when the soil samples were taken one week after treatment but increased from two weeks up to nine weeks. By the 5th week, the nematicide had spread 13 inches horizontally and by ninth week 15 inches vertically. They postulated that the time elapsing between the treatment and sam- pling is important. The effect of placement depth on the activity of DBCP was studied by Gilpatrick et al. (1956).

Pesticides are the substances used to control organisms which may adversely affect public health or organisms that attack food and other materials essential to mankind. Since it is impossible to know every property of every chemical, it is rather inevitable that some environ- mental damage will occasionally result from their use. However, this is no argument against their use so long as the benefit can be clearly shown to outweigh the damages. The important thing is to be aware that there is a finite risk of damage to minimize it by appropriate toxicity, testing of chemicals before they are applied on large scale and to ensure that the application is carried out correctly. When pesticides/nematicides are applied on a large scale, a constant watch must be kept for environment damage, if any.

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Residues in Soil

Methyl Bromide:

Since it is highly volatile brominated compound, only traces of bromine were detected from soil hence, it is applied in a closed chamber.

Telone (1, 3-D)

The decomposition rate of 1, 3-D in loam soil was determined to be about 3.5 per cent per day whereas the decomposition rate in sandy and peat soils was less than one per cent per day (Leistra, 1970). It was reported to have half life in soil of about 10 days however, the estimated rates of dissipation depend on various adaphic factors.

DBCP

It is potent nematicide having contact and low fumigant activity, therefore recommended for overall application. Prasad (1978) and Prasad et al. (1980) compared four methods of application of DBCP on its persistence, revealed that initial degradation was rapid in drench as compared to sprinkling, injection and granular (20G) ap- plication. Dissipation was quick in granular and drench application and the residues were confined up to 60 cm depth whereas the residues in order of 0.2 ppm were detected up to 90 cm depth in sandy loam soil.

Movement and distribution of DBCP was studied in three soil types (Prasad and Sethi, 1986) indicated that whereas it took one day for almost uniform distribution of DBCP in all four layers in sandy loam soil, it took 14 days for red and three days for black soil for similar distribution. Mortality of root knot nematode larvae was found to be directly proportional to the concentrations of DBCP residues in soil as tested by bioassay technique.

Diazinon

Rapid loss of diazinon during the first week was followed by a much slower decline. Approximately, 50 per cent of the diazinon applied disappeared two to four weeks after application (Munsen, 1970) and more than 6 per cent was lost after 2-3 months. As far as the leach- ing is concerned, about 95 per cent was retained in 0-4 inch soil layer and the rest at depth between four and eight inches. It did not leach into lower soil zones but remained where applied.

Mephosfolan

The initial deposits of mephosfolan in 0-15 cm soil were 6.4, 14.4 and 32.5 ppm following applications at the rate of 1, 2 and 4 kg a.i./ha respectively. The rate of dissipation from three dosages was almost alike. The rate was faster up to seven days when 84.4 and 85.1 per cent of nematicide was lost, after which it proceeded at a slower rate. In 30 days, 96.6 to 99.2 per cent mephosfolan was lost from the dif- ferent treatments. No detectable residues were found in any treat- ment on the 45th day. Significant reduction of all plant parasitic nematodes was observed at two and four kg treatments (Prasad et al., 1982)

Phenamiphos

Mchor (1987) studied the persistence of phenamiphos in sandy loam soil with amendments which enhanced its residual longevity. Under field conditions, phenamiphos confined to top 10 cm following broad- cast treatment in April months. Furrow application at 2.0 kg/ha in November with pea and 1.5 kg/ha in following March with Okra showed initial residues of 4.03 and 2.83 g/g respectively in top 15 can soil. The residues persisted beyond 120 days of furrow application in colder month but up to 45 days of broadcasting and 90 days of furrow application in warmer months.

Quinalphos

Gopal et al. (1988) evaluated quinalphos at the rate of 50, 100 and 150 g/g applied alone and in combination with jute caddis indicated low penetration of root-knot nematode on soybean crop. Residues in soil showed that wherever the residue was less than 0.5 ppm, penetra- tion of larvae into roots were not hampered. The residues in order of concentrations after one hour were found to be 0.85, 1.82 and 2.75 ppm in 50, 100 and 150 µg/g respectively. The persistence of quinal- phos was dose dependent. This could be attributed to initial application and adsorption of the chemical to the soil particles. Since the chemical is polar in nature the possibility of its adsorption is high and might to some extent explain the persistence of the might to some extent explain the persistence of the chemical up to 21 days.

CARBAMATE NEMATICIDES

Aldicarb

The persistence of aldicarb in a clay loam soil was influenced by the application rate. Aldicarb showed half lives of 18 and 23 days in a soil when applied at two and four kg a.i./ha respectively (Malik and Yadav, 1979), the half life of aldicarb at 1.5 kg a.i./ha was 17 days in sandy loam soil (Dixit et al., 1976). The degradation of aldicarb in soil to its oxidation products, sulfoxide and sulfone followed first order Kinetics (Fig. 18.1). Further, Meher et al. (1987) reported aldoxycarb in shoot was dose dependent. Its residues rapidly translocated downwards and exuded into the soil with maximum residues on 7th days under field conditions. Earlier, Meher et al. (1986) applied al- dicarb in microplots as broadcast and in furrows and observed rapid degradation of residues up to 15 days and afterwards slow process of degradation was noticed. Anaerobic conditions and temperature generally increased the persistence of aldicarb.

Gupta and Singh (1987) applied aldicarb at 1.5 and 2.5 kg a.i./ha in soil and its residues fall from 9.75 to 3.4 ppm at lower dose and from 17.35 to 4.45 ppm at higher dose. After 60 days, no measureable trace of aldicarb was observed.

Oxamy!

There are various reports on the adsorption which indicate its longer persistence in soil. Photodegradation of Oxamyl was studied by Dureja et al. (1988) and isolated six metabolites in two solvents. These were tested against root-knot nematode. Meloidogyna incog- nito subsequently observed the penetration of larvae in cowpea plants. The observation showed that oxamyl on exposure to sunlight losses its activity against root-knot nematode but there was not much difference against penetration activity.

Carbofuran

Bioassay studies showed that carbofuran persisted with little or no loss of toxicity to nematodes for 12 hours (Prasad, 1989b). The half life was calculated to be 35 days in sandy soil, whereas it exhibited long half life of 50 weeks in neutral or acidic soils (Harris, 1969). Carbofuran and its metabolites, 3-Ketocarbofuran, 3-Keto car- bofuran phenol, 3-hydroxy carbofuran phenol and carbofuran phenol reached non-detectable level after 60 days of application of 1.0 kg. a.i./ha in soil (Fig. 18.2) (Thirumurthy et al., 1975). 3-hydroxy carbofuran, the major metabolite reached maximum level by 20 days. and then disappeared rapidly.

Carbofuran residues in field persisted for 105 days in top 15 cm soil up to 15 g/g level. The rate of dissipation followed the first order reaction and half life for the first 60 days when 89 per cent of residues had already dissipated, was 19.5 days. A faster rate of dis- sipation after 60 days could be attributed to the rapid growth rate in plant weight during the experimental period (Meher et al., 1985). Moreover, there was no leaching of residues beyond a depth of

15 cm despite regular irrigation at 15-20 days intervals. The residue dis- sipated faster up to 7th day as about 82 per cent lost in sandy loam soil.

RESIDUES IN WATER

Indian literature on the nematicidal residues in water is scanty and scarce.

Since 1, 3-D or DD are highly volatile and insoluble in water,Persistence of DBCP was longer in moist condition of soil (Prasad, 1978). The translocation studies indicated towards this poin that along with irrigation water, the molecules of DBCP was taken by the plants (Prasad and Sethi, 1980). In vitro studies on persistence o phenamiphos under two moisture levels revealed that the nematicidepersisted beyond 60 days with faster rate of dissipation of phenamiphos at higher concentrations of 2.0 and 3.0 g/g soil as compared to lower level of 1.0 µg/g and showed an average half life of 10.3 days under 15 per cent moisture condition and 22.4 days under flooded conditions (Mcher, 1987).

Aldicarb was strongly adsorbed to moist soil, it is a physical rather chemical process and use largely due to Van der Waals force or hydrophobic bonding. The movement of aldicarb was negligible un- der field conditions. In heavy irrigated fields, only minute quantities reached beyond 120 cm; aldicarb fulfoxide and sulfone were retained at the top 30 cm in loam and humic soil (Leistra and Smelt, 1981).

Bull et al. (1970) studied the rate of 20 ppm of aldicarb in four soil types at three moisture levels (0, 50 and 100%) field capacity and at three soil pH (6, 7 and 8). No significant differences were attributed to pH tested. Aldicarb and its toxic metabolites (aldicarb sulfoxide and aldicarb sulfone) were relatively stable in all dry soils. Of the moisture regimes, 50 per cent level permitted maximum oxidation of aldicarb to its sulfoxide and sulfone derivatives, although faster rate of dissipation to non-toxic products like oxime sulfone, cxime sulfoxide, nitrite sulfoxide and nitrite sulfone occurred at 100 per cent moisture level.

Oxamyl was readily leached by rainfall especially in sandy loam soil. This would indicate that equillibrium was attained rapidly be- tween the mobile and stationary phases which presumably reflects a low degree of aggregation of the soils and the week adoption of oxamyl. Its photodegraded products were found to be equally effec- tive against root-knot nematode (Dureja et al., 1988).

Carbofuran was relatively more persistent in sterile soil whereas soil moisture lowers the persistence. The degradation was faster in flooded soil than in non-flooded soil. Rajagopal and Sethunathan (1984) clearly indicated that carbofuran was rapidly hydrolysed to carbofuran-phenol within five days in flooded soil. Carbofuran ap- plied to the root zone of rice crop persisted longer than when applied. in flooded water.

Application technology including application through furrow, basin and sprinkler irrigation was investigated in relation to residual toxity. Earlier irrigation studies clearly showed the potential for water to enhance downward movement of nematicides in soil profiles. DD injected at rates up to 1,420 kg ai/ha to depths of 45 cm followed by basin or sprinkler irrigation penetrated to depths of 2.4 m would be in the vadose zone or down to the water-table in many areas (Baines et al., 1959).

DBCP and EDB were shown to be biologically, not physically degraded in soil. If EDB or DBCP escape with a minimal amount of biological degradation in upper soil horizons they may be transported to lower levels in the soil profile where biodegradation is low. There were reports that DBCP despressed sperm counts of workers in manufacturing plants and that the compound was a carcinogen led to inspection of well water for possible contamination. Numerous wells in the U.S.A. and Hawaii found to be contaminated with unsafe level of DBCP (Holden, 1986). Use of DBCP in California was suspended in 1977 and all use in the U.S.A. was cancelled in 1976. Groundwater on Long Island, New York was found to be contaminated with al- dicarb or aldicarb residues in August 1979 (Zaki et al., 1982). Groundwater in a number of States has been shown to be con- taminated with many organic chemicals including the nematicides DBCP, EDB, DD, aldicarb and carbofuran (Thomason, 1987).

Finding nematicides in groundwater in the U.S.A. has serious im- plications for nematologists and all citizens. Environmentalists and industry people alike are calling groundwater contamination the en- vironmental issue of the eighties. Much contaminated water is in shallow aquifers not suitable for domestic purposes.

Major efforts have been made to predict the movement of pes- ticides in the unsaturated and saturated zones of soil. If we are to prevent environmental contamination by nematicides and to conserve their use for the future, newer formulations which is easily degradable after certain period of time coupled with lower dose of the nematicide has better future. Thomason (1987) emphasised the use of chemigation and must join with soil physicists, hydrologists and irrigation engineers to develop precise protocols for use of irriga tion methods in different agro-ecosystems. Such chemicals which contaminate the groundwater, could be used in conjuction with seed and soil treatments. Activity over a range of nematode and host com- binations would be desirable since commercial development is condi tioned by significant market potential. The overall effort should be to refocus the target for nematicides from the soil host nematode matri to the simpler host nematode system and in so doing minimise the opportunities for environmental contaminations

Conclusions:

Pesticides are often considered a quick, easy, and inexpensive solution for controlling weeds and insect pests in urban landscapes. However, pesticide use comes at a significant cost. Pesticides have contaminated almost every part of our environment as pesticide residues are found in soil and air, and in surface and groundwater across the nation, and urban pesticide uses contribute to the problem. Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms to insects, plants, fish, and birds. Contrary to common misconceptions, even herbicides can cause harm to the environment. In fact, weed killers can be especially problematic because they are used in relatively large volumes. The best way to reduce pesticide contamination (and the harm it causes) in our environment is for all of us to do our part to use safer, non-chemical pest control (including weed control) methods. In order to control water pollution by other elements such as sewage or industrial wastes, the effluents should not be allowed to dump into water reservoirs without proper pretreatment. Further, the constant monitoring and analysis of water by appropriate agencies is essential to avoid any kind of water contamination.

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