Distribution, dissipation and leaching of ^{14}C-Carbofuran in a moroccan sugar beet field soil

Benicha M.[1,2]*, Azmani A.*[3]

[1] *INRA, Lab. résidus de pesticides, 78, Bd Mohamed Ben Abdellah, Tanger, MOROCCO*

[2] *Département de chimie, Faculté des sciences, Tétouan, B.P. 2121, MOROCCO*

[3] *Faculté des sciences et Techniques de Tanger, MOROCCO*

Abstract

Carbofuran is used in Morocco mainly to control rootworms on many crops like sugar beet cultivation. A laboratory study was conducted to examine the distribution, dissipation and leaching of ^{14}C-[U-ring] Carbofuran using soil columns over a period of 168 days in a clay soil of sugar beet cultivation. The soil has no history of Carbofuran use. The dissipation of 14C-Carbofuran showed a low rate of downward movement; the major radioactive residues (more than 82% of recovered activity) were confined to the top 10 cm of the soil column, with majority as bound form. The amount of radioactive residues present in the lower layers increased slowly with time. However, this was accompanied by a relatively rapid and gradual loss in the total radioactivity recovered from the whole soil column. Bound residues increased in general, and binding was higher in 0-10 cm soil layer than other ones with 64 % of total bound, indicating that carbofuran has high tendency to bind to this soil. At the end of the experiment, distribution of carbofuran residues was as follow: about 53% of applied dose, was lost (by mineralization and/or volatilization), 26.5% was found in the 0-10cm, 13.9% in the 10-20cm and only 6.8% in the 20-30 cm layer while only 3.9 % of applied dose was leachated out the column. indicating that carbofuran movement seemed to be confined to the top 30 cm soil layer. The time required for loss of 50% of radiocarbon was estimated to be approximately 148 days.

Key words : Carbofuran, dissipation, leaching, soil column

ملخص

يعتبر الكربوفوران Carboufuran من مبيدات الحشرات الأكثر استعمالا في العالم. وفي المغرب يستعمل في عدة زراعات ومن بينها زراعة الشمندر للقضاء على ديدان التربة. و قد أجريت هذه الدراسة على هذا المبيد في تربة حقل شمندري بمنطقة اللوكوس لمعرفة مدى تبديد وتلاشي هذا المبيد وتوزيعه في التربة وحلوله في الماء (lixiviation) وذلك باستعمال التربة على شكل أعمدة داخل مخاريط من البلاستيك PVC. ومن أجل الفهم الجيد لهذا المبيد تم إنجاز هذه الدراسة التي دامت 168 يوما باستعمال التقنيات النووية (^{14}C-Carbofuran) . وقد أظهرت النتائج أن حركة هذا المبيد العمودية ضعيفة نسبيا بحيث أن أغلبية هذا المبيد (أكثر من 82%) منحصرة في الطبقة 010 سم الأولى من أعمدة التربة بينما كمية المبيد تكبر في الطبقتين 20 و30 سم ببطيء مع مرور الوقت كما أظهرت الدراسة كذلك على أن كمية كبيرة جدا من المتبقيات تقدر بحوالي 38,8% من الكمية الأصلية توجد على شكل متبقيات متلاحمة (bound residues) مع التربة قد يكون لها انعكاسا سلبيا على البيئة والإنسان. في آخر التجربة كان توزيع المبيد على الشكل التالي : 26.5% في الطبقة دون 10 سم ، 13,9 في الطبقة 10-20 سم و 6,8% في الطبقة 20-30 سم بينما فقط 3,9% قد خرجت من العمود (lessivée) الشيء الذي يؤشر على أن حركة هذا المبيد في هذه التربة حسب ظروف التجربة قد لا يشكل خطرا على تلوث المياه بينما كمية من المبيد التصقت مع التربة قد تكون بذلك مشكلة تلوث للبيئة إذا ما علمنا أن درجة تسمم هذا المبيد عالية جدا.

الكلمات المفتاحية : كاربوفوران، تلاشي، حلول، أعمدة تربة.

Résumé

*Le carbofuran est utilisé au Maroc principalement contre les nématodes des racines asso-
ciées sur la culture de la betterave à sucre. Une étude a été conduite pour examiner la distri-
bution, la dissipation et la lixiviation du carbofuran-^{14}C en utilisant les colonnes de sol sur
une période de 168 jours. Le résultat montre un mouvement descendant faible du carbofuran;
la plupart de la radioactivité (plus de 82%) est limitée à la couche 10 cm de la colonne dont
la majorité est sous forme de résidus lies. A la fin de l'expérience, seulement 8.5% de la dose
appliquée était sous forme extractiblem alors que la plupart de la radioactivité (38.8% de la
dose initiale) était sous forme liée avec 24.94% de la dose initiale concentrée dans la couche
0-10 cm. La distribution finale après 168 jours était :26.5% dans la zone 0-10 cm, 13.9%
dans la couche 10-20 cm, et seulement 6.8% dans la couche 20-30 cm alors que seulement
3.9% a été lixiviée de la colonne. Le temps de disparition de 50% de radiocarbone a été es-
timé approximativement à 148 jours.*

Mots clé : Carbofuran, dissipation, lixiviation, colonne de sol

Introduction

Insecticides are an indispensable part of modern agricultu re on the basis of environmental considerations. The increase use of pesticides in the world over the last 40 years has lead to increase the potential to contaminate surface and groundwater systems (Berg, 1975). This contamination is emphasized by the improper use of these chemicals.

Movement of pesticides in soils is a complicated process. It is considered among the important influencing factors that can be used to predict the contaminating level of the environment. It depends on several factors including the characteristics of the pesticide (solubility, decay constant etc), and the amount of water travelling through and off the soil from the time the pesticide is applied until degradation (Bowman et al., 1994). Other important associated factors are soil type, soil moisture and soil hydrological properties. The greater the soils ability to hold water the less runoff and percolation will occur resulting in the pesticide remaining in the soil profile for microbial degradation. Determination of mobility of pesticides is essential in the evaluation of their potential hazard to the environment, particularly surface and ground water resources.

The persistence of a pesticide in soil depends on the dissipation processes. Dissipation includes degradation along with other physical processes, that may govern pesticide dissipation, include leaching, microbial and thermal degradation, chemical decomposition, runoff, volatilisation and plant uptake (Bosch et al., 2000).

Leaching is an important means of dispersion of pesticides in soil. There are many factors that can affect leaching potential. These include chemical variables such as sorptive partitioning behaviour and persistence, environmental variables such as rainfall (Cohen et al., 1984), as well as physical and chemical characteristics of the soil such as soil porosity/permeability, texture and organic matter (Komal et al., 2001; Achik et al., 1991; Cohen et al., 1984) because of their effect on pesticide adsorption (Novak et al., 1998; Bowman, 1991). Type of formulation, method and rate of application can also affect the leaching of pesticides (Bowman, 1992).

The ability of a pesticide to leach has been extensively investigated, mainly in terms of the likelihood for residues to contaminate groundwater resources (Racke et al., 1997; Bowman, 1991, 1992; Bowman et al., 1994). Pesticides that are highly water soluble, relatively persistent, and not readily adsorbed by soil particles have the greatest potential for movement and are most vulnerable to groundwater contamination. In subsoils where less microbial activity occurs, degradation rates are generally smaller. Therefore, as pesticides are leached to lower depths, they become more persistent (Trabue et al., 1997; Buyanovsky et al., 1993). This can be significant if the area is irrigated soon after pesticides application, since such event may leach the chemical before the surface organisms degrade it. Due to reduced biological activity in the lower soil profile, the probability of groundwater contamination greatly increased (Buyanovsky et al., 1993).

Carbofuran (2,3-dihydro-dimethyl-7-benzofuranyl methylcarbamate) belonging to the N-me-thylcarbamate class of pesticides derived from the basic carbamic acid moiety, is a versatile broad spectrum systemic insecticide, nematicide and acaricide, registered for use on a variety of crops such as sugar beet, sugar cane, rice, corn, peanuts, cotton, strawberries, potatoes (Chapa-lamadugu and Chaudhry, 1992). It is particularly as a soil treatment for control of many soil in-sect pests (Venkateswarlu et al., 1977; Felsot et al., 1982), and consequently has attracted much attention as a potential alternative to the persistent and toxic chlorinated hydrocarbon insecti-cides.

Although less persistent, carbofuran is of environmental concern and become a threat both for human health and the environment, because of its high mammalian toxicity having an oral LD50=8 mg/Kg for rat (Tomlin, 1994), and LC50=0.2-0.8 mg/L for fish (Jinhe et al; 1989), and of its high potential to contaminate ground waters (Cogger et al., 1998; Jaramillo et al., 2000). Its use under granular formulations was banned in USA by EPA since 1994 (Jonson and Lavy, 1995). This concern is heightened by the facts that Carbofuran residues have been detected in surface water (Shahane, 1994), in groundwater (Coger et al. 1998), and in wells (Bouchway et al. 1992).

Carbofuran was found to be degraded chemically and by microorganisms. The degradation oc-curs by hydroxylation at the benzylic carbon to give 3-hydroxy and 3-ketocarbofuran under upland conditions (Jinhe et al., 1989; Ou et al., 1982) and via hydrolysis to form phenols and bound residues i.e. carbofuran phenol, 3-hydroxy- and 3-ketocarbofuran, under flooded-soil conditions (Venkateswarlu and Sethunathan, 1978; 1979; Volner et al., 1980; Jinhe et al., 1989).

Degradation is an important process affecting the fate of a pesticide in the environment. There are several factors which affect the degradation and dissipation of Carbofuran in soil such as temperature (Parkin and Shelton, 1994; Cogger et al., 1998), soil type (Getzin, 1973), soil pH (Getzin, 1973), soil moisture (Cogger et al., 1998; Moj_sevic et al. 1996; Parkin and Shelton, 1994), soil microorganisms (Ramanand et al., 1988b), soil depth (Bouchway, et al, 1992; Tra-bue et al., 1997), rate and application method (Jinhe et al. 1989).

Hydrolysis is the primary mechanism of carbofuran degradation in soil and water under neutral to basic conditions (Getzin, 1973). A significant part of this insecticide remains in the form of bound residues in the soil, plants, and fish tissues (Vollner et al., 1980; Jinhe et al., 1989).

Literature shows variability in dissipation rates in soils. Getzin (1973) observed that half-life of Carbofuran varied from 3 weeks to more than 50 weeks and its persistence was influenced by soil pH and soil sterilization. Bosh et al. (2000) showed a rapid dissipation of carbofuran in sandy soils. Yen et al. (1997) reported that carbofuran tend to dissipate more easily in silty clay loam than in clay soils. Felsot and Wilson, (1980) and Felsot et al. (1982) reported that carbofu-ran degraded very rapidly in soil and dissipated rapidly in field because of the environmental factors such as runoff and low soil adsorption coefficient. McCall et al. (1980) classified carbo-

furan as 'highly mobile'. Cogger et al. (1998) reported that Carbofuran is a potential leaching risk when applied to permeable soils, overlying shallow, unconfined aquifers. Lallah and Wandiga (1996) reported that climatic factors such as temperature and rainfall, influence greatly on dissipation of carbofuran. Yen et al. (1997) reported that biodegradation is an important factor in the dissipation of Carbofuran and suggested that the porosity of the soil is an important factor affecting the mobility of carbofuran. Ramanand et al. (1988a) reported that leaching of carbofuran was retarded under puddle conditions of paddy soil. This was due to slow percolation rate of the insecticide.

The vast and intensive agricultural use of pesticides in some Moroccan zones has important implications for the contamination of the groundwater system, which is used both for human consumption and for crop irrigation. Areas such Loukkos, (northwestern) have high rainfall (leaching vulnerability), and intensive horticultural production. Therefore, many pesticides, such as Carbofuran, are extensively used in these zones (DPVCTRF, 1999). So this contamination of aquifer systems is an increasingly serious problem. Improper applications exacerbate the problem. According to our knowledge, no studies on carbofuran residues have been conducted in Morocco with 14C labelled insecticide. Therefore, it is very expected that these areas can exhibit high levels of pesticide residues. With the increasing population, efforts are being made to intensify sugar production to reach the self-sufficiency. This will result in an increase in the use of Carbofuran. Carbofuran residues and its toxic metabolites are therefore of great concern in terms of their persistence, mobility, dissipation, and toxicity to the human life. Thus a survey becomes essential to understand the extent of the pesticide distribution in the various components of the ecosystem.

To determine the extent of Carbofuran dissipation, degradation, and leaching in soil we conducted this experiment through soil columns under laboratory conditions during 6 months.

Materials and methods

1. Soil

Soil samples were taken randomly from different sites of a sugar beet field (Loukkos) to a depth of 30 cm and mixed thoroughly. The soil, which has no history of Carbofuran use, was air dried, grounded, sieved through 2 mm then stored in plastic bags at room temperature for 2 days before treatment.

Chemical

[U-phenyl-^{14}C] Carbofuran (specific activity 1.12GBq/mmol) was purchased from the Institute of Isotopes of the Hungarian Academy of Sciences via the International Atomic Energy Agency

(IAEA). The chemical was determined to be more than 98% radiochemically pure by TLC before use. [U-phenyl-^{14}C] Carbofuran was diluted with unlabelled carbofuran (to specific activity: 4.08 MBq/mmol) before application. Carbofuran (98.8%), 3-OH-Carbofuran (>98%) and 3-keto-Carbofuran (>98%) and carbofuran phenol (>97%) analytical standards where purchased from Sigma Aldrich. All the reagents used in the study were of analytical or scintillation grade. All the solvents used were residues, HPLC, or analytical grades.

Soil Column Study

Hard PVC tubes (30 x 7 cm) open at both ends, were used. 1.3 kg soil (dry weight basis) was insert into each tube. The tubes were driven into 4 plastic tanks containing each about 4 Kg of the same soil (4 tubes per tank), 3 cm was left above the soil surface to prevent run-off water. The soil was kept always moist (60 % field capacity) during the experiment and the tubes were left undisturbed for 1 day before applying pesticide. 6.24mg (3.12mCi) of technical carbofuran (4.81 ppm) with a specific activity of 0.5 mCi/mg, was applied to each tube, and the surface of the soil was covered with a small layer of soil.

Sampling of cylinders

The first two cylinders were carefully removed and wrapped in plastic bags immediately after pesticide application for determination of the initial residues (100%). The other cylinders were sampled in duplicate at 7, 14, 28, 56, 84, 126, and 168 days after treatment. The columns are pullet out, frozen at -21°C in a horizontal position until analysed. The frozen soil samples were pushed out of the column and sectioned into 10 cm layers. Each section was separated. At the end of the experiment, soil samples were taken from the tanks to assess the amount of radioactivity that had leached from the soil columns to the tanks. Three samples were taken from each tank, sample was replicated twice. For all samples, soil was air-dried, grounded and thoroughly mixed on a circular shaker for 8 h, then stored in plastic bags at 0°C until analysed. Total weight and moisture content of soil samples were noted.

Extraction and analysis

Analyses were made for total, extractable, and bound residues. For total and bound residues analysis, 500 mg soil samples was combusted in a Harvey Biological Oxidizer, OX 600 and radioassayed using liquid Tricarb 1000 TR HP scintillation counter (LSC). For extractable residues, 50 g (dry weight basis) soil samples were extracted in a Soxhlet extraction apparatus with methanol for 10 h (5-6 cycles/h). Methanol was concentrated to 10 mL with Rotavapor, Buchï, Switzerland at 30°C, and 1 mL methanol extract was mixed with toluene based scintillator and radioassayed using LSC. The internal standardization technique was used to correct for quenching effect.

Résults and discussion

The soil used was clay and has the following characteristics (Table 1).

Table 1. Physical and chemical characteristics of the soil used.

pH (water)	pH (KCl)	Organic matter.(%)	Total(%) Nitrogen	Clay(%) (<2 um)	Silt(%) (>2,<50um)	Sand(%) (>50 um)	texture
7.8	7.3	2.14	0.22	50.2	35.6	14.2	Clay

Dissipation of ^{14}C-carbofuran residues in soil

The data given for the dissipation of 14C-Carbofuran, over a period of 168 days from the clay soil using soil column are shown in figure 1.
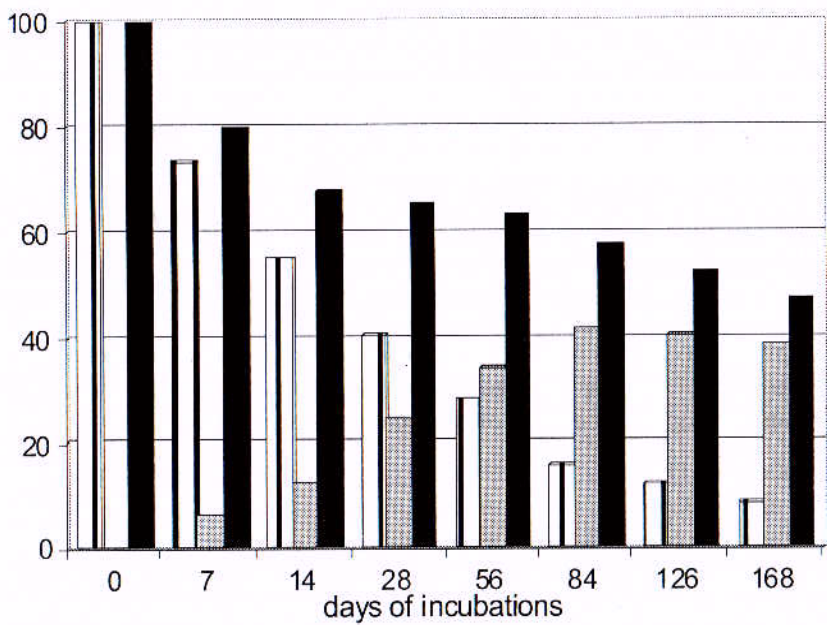

Figure 1. Distribution of 14C in extractable, bound residues and total recovery of14C-carbofuran in clay soil column at various time intervals after application.

Two columns were analysed at zero time to determine the actual applied dose that was consi-dered to be 100%. The data showed that the 14C-activity declined from 100% at zero time to 47.3 after 168 days. Likewise, the extractable residues declined rapidly with time to a lower concentration (8.5%) after the same period. Conversely the unextractable residues increased in general with time and reached a maximum of 41.6% at 84 days after application.

The recovery of radioactivity was quite good ; 7 days after application, the total recovered 14C-activity represented about 80% of applied dose. However, more than 20% of the applied dose was unaccounted for (this may be due to volatilization and/or mineralization). At this time, the average total extractable radioactive residues from the soil columns represented 73.4%. Afterwards, a gradual and relatively rapid loss of extractable radioactive residues in the whole column was observed. By day 56, the extractable residues represented, on average, 28.4% of applied dose. This level continued to drop with time, reaching a lower percentage of 8.5% of applied dose at the end of the experiment.

Often dissipation of pesticides follows a 2 compartments pattern with a rapid-loss phase followed by a slow process. The data obtained indicated that the dissipation seems to follow a biphasic patter; in the first 56 days, the loss of radiocarbon was rapid; about 38% of applied activity. The residues do not get adsorbed/bound strongly and get dislodged easily by various physical processes including vaporisation/volatilisation as a major process (Zayed et al., 2001). However, leaching and adsorption/binding may also contribute to this phase. The second phase is a slow process associated with a long steady decline in concentration, probably associated with diffusion into less accessible adsorption sites (Zayed et al., 2001). The estimated time required for loss of 50% (overall t50) of radiocarbon from the whole column was approximately 148 days. Half-lives calculated for the initial rapid and the later slower phases were approximately 60 and 280 days respectively.

In term of extractable residues, in general, there was a relative rapid dissipation of Carbofuran with time from 100% to 47.3% at the end of the experiment. The trend shows a biphasic pattern similar to that of the total radioactivity. In the first 56 days, the dissipation of carbofuran was very rapid, with an average of disappearance rate of 1.3% / day ($0.06\mu g/d$) (about 71.6% of applied activity was degraded). Then the rate of dissipation slows down from this time to the end of the experiment to reach a lower concentration with an average rate of 0.18 % / day (about $0.01/\mu g/d$) (about 90% of applied dose was degraded).

Concerning the bound residues, a rapid binding of carbofuran was observed between the period from 28 and 84 days. The bound residues levels went up to 24.8% of the applied dose after 28 day, and was over 34% after 56 days while the maximum binding was detected after 84 days with more than 41%. This indicates a high tendency of carbofuran to bind to soil. This agrees with the findings of other researchers who also reported high levels of bound residues formation (Ghanem et al., 1997; Jinhe et al. 1989). Beyond 84 days, the amount of bound residues decreased slowly to reach 38% at the end of the experiment. This slow decrease in bound residues may be due to the release of the bound residues probably through soil microorganisms (Getzin, 1973; Khan et Ivarson 1981).

Similar results were obtained by other researchers. Getzin (1973) observed slight decrease in soil bound radioactivity of carbofuran toward the end of the experiment and suggested that bound 14C was slowly converted to CO2.14C-bound DDT residues in soil were also reported to be readily released by microorganisms Zayed et al (1994). Zayed et al. (2001) reported slow release of 14C-bound residues of carbaryl and suggested that bound residues undergo successive processes of binding and release probably through soil microorganisms.

The present results show that within the experimental set-up, there is a substantial loss in the applied 14C-activity which increased with time as is evident from the 7 day samples (figure 1). This difference loss in recovery of radioactivity is a clear indication of biodegradation of pesticide although some losses may be due to volatilization. Study on biodegradation of carbofuran, using biometer flask, will be of interest.

Downward movement of carbofuran through soil column

Table 2 summarizes the results of 14C-carbofuran vertical distribution using soil column. The downward movement of carbofuran is relatively slow; at the end of the experiment, 168 days after application, near 39% of applied dose (82% of recovered radioactive residues) were bound to the soil. Moreover, 26.5% of applied activity (56 % of the total recovered radioactive residues found in the whole soil column) was concentrated in the upper 10 cm soil layer from which 95% was under bound form, indicating a relative high binding tendency of carbofuran to this soil.

7 days after application, most radioactivity was concentrated in the upper zone that contained about 80% of applied activity. Some binding already occurred and was 6.2%. At this time, no radioactivity was detected beyond this zone. After 14 days of incubation, small amounts of extractable and bound 14C-residues could be detected in the next 10-20 cm zone. After 28 days, the amount of extractable residues in the upper 10 cm-zone were decreased from 52.3% at 14 days to 34%, while that of unextractables were decreased to 18.5% indicating a relative moderate rate of dissipation of carbofuran from the surface soil layers. At this time, 14C-residues were detected throughout the whole column. After 56 days 72% of the initial radioactivity was degraded/dissipated in soil, during this period more bound residues were formed and amounted to 34.4% and the higher concentration of residues was still associated with the upper 10 cm zone with 42.6% of the initial activity (68% of recovered activity). The maximum binding was detected in the upper 10 cm 84 days after application of the insecticide with 41.6% of applied dose. The highest binding

was still associated with the upper 10 cm zone throughout the time of the experiment. During the period from day 84 to 168 (12 weeks), the 14C-bound residues in the upper zone declined by 7.7%: from 41.6% to 38.8% of applied dose.

Residues present in the 10-20 cm layer of the soil increased slowly up to 16.13 at 126 days and declined to 13.96 % of initial activity from which 9.6% were under bound form at the end of the experiment (table 2), while, 7.8 % of applied activity (4.7% as bound) had moved down to the 20-30 cm layer of the column indicating that Carbofuran residues is very adsorbed to the soil. At the end of the experiment, the 14C-bound residues represented the major portion of 14C-activity in the whole column with 38.8% of applied activity (82% of recovered activity), and around 3.9% of applied dose (1.8% as bound) had moved below 30 cm leaching column.

More of carbofuran residues were found in the top 10 cm of the soil even after 168 days, and more than 90% of applied activity was degraded and the distribution of 14C-activity through

the column was as follows: 26.55% of applied activity in 0-10cm soil layer, 13.9% in 10-20cm and 7.8% in 20-30cm sections, while 3.9% was leachated out the column.

The half-life of carbofuran reported in the literature ranged from 30 to 100 days. Our data showed that 14C-Carbofuran persist in this soil for a longer time with an estimated half-life approximately of 148 days. This may be due in part to the formation of bound residues, which are known to persist for long periods of time in soil (Szeto et Price, 1991; Zayed et al; 1994).

Under the present experimental conditions, the results indicated that there did not seem to be any significant leaching of the pesticide out of the column into the tanks (only 3.9 %). Indeed movement of the insecticide seemed to be confined to the top of 30 cm (length of the column) with more than 63% of recovered activity, in the 10 cm soil layer. The data also showed that whatever the insecticide percentage leaching out the column, most of it with 24.94% of applied dose (52.7% of recovered activity) was bound to the soil surface (0-10 cm). Therefore, there is little risk of ground water contamination with carbofuran in this type of soil although Carbofuran was reported to be a fairly mobile pesticide in most soils (Felsot et Wilson, 1980; McCall et al., 1980).

These results are in agreement with the findings of other researchers; Felsot et al. (1982) reported that the movement of carbofuran in soils is relatively limited. Bosh et al., (2000) reported that the movement of carbofuran was limited to the top 25 cm of the soil profile 30 days after application, and 96% of the carbofuran had degraded. Similar result was obtained by Ghanem et al. (1997). They reported that movement of carbofuran in a silty clay soil is confined to the tope of 25 cm and most of the insecticide residues were bound to the soil surface, 120 days after insecticide treatment. Under a loamy clay soil, Lallah and Wandiga (1996) reported that most of carbofuran residues was found in the 20-30 cm clay loam soil layer after 111 days of treatment indicating that there is very little risk of ground water to contaminated with carbofuran. However in flooded soil, most of carbofuran residues were found in the top 10 cm even after 111 days presenting a potential danger due to surface water contamination. Jinhe et al., (1993) reported that most of carbofuran residues were found in the 0-10 cm soil layer from 5 to 93 days after application although the amount below 10 cm soil layer increased to 12% by the end of the experiment, carbofuran residues increased slowly in lower layers.

Table 2. The vertical distribution of Carbofuran residues in the PVC columns with time as percent of the total radioactivity (values are means of triplicates, values between parenthesis are SD, applied activity=100%)

Days after treatment	Extractable (%)				Bound (%)				Total (%)			
	10 cm	20 cm	30 cm	Total	10 cm	20 cm	30 cm	total	10 cm	20 cm	30 cm	total
0	100	0	0	100	0	0	0	0	100	0	0	100
7	73,4(±5.02)	0	0	73,40	6,2(±0.78)	0	0	6,2	79,6(±3.27)	0	0	79,6
14	52,3(±3.51)	2,98(±0.67)	0	55,28	11,34(±2.02)	1,24(±0.48)	0	12,58	63,64(±4.31)	4,22(±0.55)	0	67,86
28	34,41(±4.51)	5,76(±1.21)	0,15(±0.12)	40,32	18,50(±1.11)	6,15(±0.32)	0,10(±0.05)	24,75	52,91(±4.78)	11,91(±0.69)	0,35(±0.1)	65,07
56	18,05(±2.9)	8,03(±1.66)	2,31(±0.47)	28,39	24,53(±1.23)	7,53(±0.23)	2,35(±0.12)	34,41	42,58(±3.57)	15,56(±1.33)	4,66(±0.34)	62,80
84	9,11(±2.55)	73(±1.14)	1,12(±0.94)	15,96	28,24(±3.21)	10,35(±1.31)	3,05(±1.11)	41,64	37,35(±1.43)	16,08(±1.56)	4,17(±0.91)	57,6
126	4,82(±0.97)	3,66(±0.87)	3,47(±0. 75)	11,95	25,89(±2.44)	12,47(±1.11)	2,25(±0.74)	40,61	30,71(±1.54)	16,13(±2.03)	5,72(±1.88)	52,56
168	1,61(±0.36)	4,32(±0.63)	3,11(±0.64)	8,52	24,94(±4.53)	9,64(±0.87)	4,71(±1.01)	38,81	26,55(±2.62)	13,96(±1.75)	7,82(±1.27)	48,33

Inversely, some workers have found that carbofuran may leach significantly (Ramanand et al., 1988a; Achik et al. 1991; Johnson et Lavy 1995; Cogger et al. 1998) and seems to be capable of contaminating the groundwater (Jaramillo et al., 2000; Yen et al. 1997).

The extractable residues of the whole column treated with carbofuran 6 months following application of the insecticide amounted to 9.4% of total 14C-residues. The TLC analysis of these residues proved to contain carbofuran phenol (as major metabolite) and 3-keto-carbofuran while Carbofuran was the major component of the extractable residues.

Conclusion

In conclusion, under the present experimental conditions, the results indicated that the dissipation of carbofuran was generally slow. Carbofuran can be considered to be moderately and relatively persistent in this clay soil. This may be associated with the remarkable soil binding capacity of carbofuran (82 % of the recovered activity). Therefore, there did not seem to be any significant leaching of the insecticide out of the column into the tanks (3.9%). Indeed, movement of the insecticide seemed to be confined to the top of 30 cm because most activity of the residues (56 % of recovered) were found in the top 10 cm layer of soil presenting great danger/threat to the environment (specially to surface water) although, the possibility of groundwater contamination is unlikely to occur. In addition, although binding to soil make the residues less available and less toxic, their accumulation in soil could pose environmental problems and become a threat for both human and environment. Characterization and identification of these residues is essential in assessing their toxicological significance. Carbofuran may present great concern to the environment. Therefore, care should be taken, especially when the area of sugar beet cultivation received high rainfall and/or irrigation immediately after insecticide application.

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