Journal of Applied Biology & Biotechnology Vol. 8(05), pp. 36-47, Sept-Oct, 2020
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2020.80505

Environmental risk assessment of pesticide use in Algerian agriculture

Nafissa Soudani[1*], Mohammed Belhamra[1,2], Adamu Y. Ugya[3], Nageshvar Patel[4], Laura Carretta[4], Alessandra Cardinali[4], Khaoula Toumi[5]

[1]Algeria Department of Agricultural Sciences, Laboratory of Diversity of Ecosystems and Dynamic Systems of Agricultural Production in Arid Zones D.E.D.S.P.A.Z.A., Mohamed Khider University of Biskra, Biskra , Algeria.
[2]Scientific and Technical Research Centre on Arid Regions C.R.S.T.R.A., Compus of Mohamed Khider University, Biskra, Algeria.
[3]Department of Environmental Management, Kaduna State University, Kaduna, Nigeria.
[4]Department of Agronomy, Food, Natural Resources, Animals and Environment DAFNAE, University of Padua, Padua, Italy.
[5]Belgium Laboratory of Pesticide Science, Gembloux Agro Bio Tech University of Liege, Gembloux, Belgium.

ARTICLE INFO

Article history:
Received on: March 12, 2020
Accepted on: May 18, 2020
Available online: September 14, 2020

Key words:
Environmental risk, Biskra Zibans, pesticide residues, PERI model, vegetables.

ABSTRACT

Different pesticides are widely used to protect the crops. However, they are considered to be one of the major causes of environmental pollution. Therefore, in this project, efforts are made to characterize the potential risks of pesticides applied, to study their effects on the environment, and to understand the local professional practices. A survey was conducted among market gardeners and farmers, in two main districts of Biskra Ziban, Algeria. Using pesticide environmental risk indicator model, an Environmental Risk Score (ERS), the final indicator of environmental risk (final indicator of ER), and the normalized final environmental risk were calculated for 18 pesticides, which are most commonly used. Six active ingredients had an ERS that reached a value of 5 and more. The highest final indicator of ER was obtained for the formulation based on the active substance diazinon (score = 120.00). Besides, the perception and attitude of farmers regarding risk from pesticide exposure were also observed and discussed. Consequently, the risk indicators allowed us to compare and identify the least environmentally hazardous pesticide among all the possible alternatives.

1. INTRODUCTION

In Algeria, horticulture is an important, dynamic, and vast sector. Biskra was the first regional producer of early season vegetables in the country [1,2] and contributes to 32% of national protected crop production [3]. In the past 20 years, the area covered by greenhouses increased 5-fold [4]. Till 2019, Biskra had registered 23,488 ha area of vegetables cultivated on the open field and 7,238 ha under greenhouse [5], whereas Ain Naga (East Ziban) and Doucen (West Ziban) have the largest total area dedicated to greenhouses, with 922 ha and 402 ha, respectively, in 2016.

During cultivation, vegetables and fruits require the use of a broad range of pesticides. Pesticides, when released into the environment, can follow many pathways [6]. Pesticides have a tendency to be sorbed to soil particles [7]; pesticides with high vapor pressures may be easily lost to the atmosphere or move downward into aquifers, whereas soluble pesticides are more leachable to soil and groundwater. Nevertheless, it may be lost as surface water runoff because of irrigation practices or rainfall [7,8]. Pesticides may be degraded and transformed by the biological and chemical processes such as photolysis, hydrolysis, oxidation, and reduction [7,9–12].

Pesticides benefit the crops, but they negatively impact the environment, particularly, when they move outside of the application site [13,14–16]. Biodiversity is mainly threatened by the intensive use of pesticides [17]. Besides, insecticides or herbicides can be toxic to the hosts of other organisms, birds, aquatic life, beneficial insects, and non-target plants [18,19–21]. Furthermore, pesticides can contaminate soil, water, turf, and

---

**Corresponding Author*
Nafissa Soudani, Department of Agricultural Sciences, Laboratory of Diversity of Ecosystems and Dynamic Systems of Agricultural Production in Arid Zones (D.E.D.S.P.A.Z.A.), Mohamed Khider University of Biskra, Biskra, Algeria. E-mail: nafissa.soudani @ univbiskra.dz

© 2020 Soudani, *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License -NonCommercial-ShareAlike Unported License (http://creativecommons.org/licenses/by-nc-sa/3.0/).

other vegetation [18,22,23]. Ideally, the applied pesticides should only be toxic to the target organisms and should be biodegradable and eco-friendly [24]. Unfortunately, this is rarely the case as most of the pesticides are nonspecific [25,26] and may kill the organisms that are harmless or useful to the ecosystem. In general, it has been estimated that only about 0.1% of the pesticides reach the target organisms, and the remaining bulk contaminates the surrounding environment [27,28]. Furthermore, nearly 50% of the pesticides, fungicides, and some herbicides can enter into the soil [12].

Considering the problem of contamination, the risk assessment of the impact of pesticides on the environment is deemed necessary. Several environmental impact assessment and pesticide risk indicators have been developed during the past 20 years [28,29–31], to assess the environmental and human health hazards and highlight the risk associated with unsafe pesticide use [32,33]. The environmental and health risk assessment related to pesticide use made possible via simplified pesticide risk indicators [10]. The examples of some pesticide risk indicators are the Environmental Impact Quotient, toxicity, human health, and persistency hazard rating system, and pesticide environmental risk indicator (PERI) [34].

Pesticide risk indicators can, therefore, inform users (farmers, extension agents, policymakers, regulatory agencies, and academia) about the environmental impact of different pesticides to promote a sustainable interaction of agriculture with the environment [10,29,34]. Simple indicators of pesticide hazard use even with rare data, which are easy to calculate and to communicate, are suitable [10]. Although there are several uncertainties in the capacity of these indicators to estimate the risk of pesticide use, they provide valuable information [34] when compared to costly environmental media sampling and monitoring for pesticides [35,36]. Accordingly, the use of these tools offers farmers a chance to minimize the environmental impact and human exposure to pesticide residues [37,38]. In this study, the PERI model has been employed to assess the potential environmental hazard which can occur from various pesticides applied on the horticulture of Ain Naga and Doucen districts of Biskra region during the 2016–2017 crop seasons and to highlight the local professional practices of farmers.

2. MATERIALS AND METHODS

2.1. Environmental Exposure Scenarios

An exposure scenario is a set of information describing the operational conditions of use (e.g., frequency of use, duration, and amount used per application) and the recommended risk-management measures suitable to ensure the adequate control of risk (e.g., storage and disposal of pesticides) [39]. To have a better understanding of the exposure scenario and professional practices, a survey was conducted from October 2016 to December 2017. It consisted of interviews with farmers in Ain Naga (East Ziban) and Doucen (West Ziban) of Biskra region, Algeria, where horticultural crops were mainly cultivated (Fig. 1).

These districts are characterized by a desert climate; the summers are very hot and dry, and the winters are cold. In 2015, the average annual temperature recorded was 22.77°C, the annual precipitation was 106.7 mm, and the average humidity was 44% [2]. Biskra's climatic conditions and vast agricultural lands are favorable for growing various types of crop production, particularly vegetable crops such as tomatoes, chili pepper, pepper, cucumber, eggplant, beans, zucchini, melon, etc., under greenhouses and open field farming systems. Nowadays, these districts are among the highest vegetable production suppliers of Algeria markets. To collect the quantitative data for statistical significance and to allow farmers to answer our questions quickly, as they are less likely to disengage, a questionnaire with close-ended questions was addressed to two professional categories. A total of 96 vegetable farmers and 20 pesticide sellers were randomly selected and interviewed. They were requested to answer a questionnaire on the most commonly used pesticides, their knowledge about pesticide application, their perception of environmental problems linked to their occupation, and their management of phytosanitary products. The suppliers were given questions about the most widely used pesticides on crops and the recommendations of use for farmers.

The survey data were entered and coded. The descriptive statistics were processed as frequencies and percentages using SPSS software ver. 24. Later, Wilcoxon or Mann–Whitney U-test, which is a non-parametric test, was chosen to compare the final indicator of environmental risk (final indicator of ER) of actives substances (n = 18) for each district to see whether a set of data that come from the same or similar cases are significantly different from each other [40]. For this purpose, we used two-sample t-test at $\alpha = 0.05$ to compare the mean values of both the districts. The t-test was performed using RStudio ver. 3.6.1.

2.2. Environmental Risk Assessment Methodology

PERI model was developed as a part of the International Organization for Standardization-14001-certification process [9,34,41]. To analyze deeply the environmental consequences of the use of pesticides and to characterize the risks, the PERI model was applied to 18 different chemicals, which are the most frequently used among farmers of Ain Naga and Doucen.

PERI combines variables from groundwater, surface water, and air compartments in one equation to obtain an ERS [34]. The detailed information about the PERI model was obtained from the American Farmland Trust Center for Agriculture in the Environment [9]. This model uses a ranking methodology that assesses pesticide properties and toxicity values on a 1–5 scale [42]. Based on the different parameters and variables, for each substance, an ERS [9,34] was calculated by the following equation:

$$ERS = (GUS \times Kh) + (B + W + D + A + S)/5 \times Kow/10 \qquad (1)$$

where groundwater ubiquity score (GUS) is the GUS, Kh is the Henry's constant, Kow is the partition coefficient. B, W, and D are the lethal concentration values (LC50) for bees, earthworms, and Daphnia, respectively. A is the effective concentration (EC50) for algae, and S is the soil microbe scores [28,43]. All the parameters used for the PERI model implementation were collected from the Pesticide Properties Database (PPDB), National Center for Biotechnology Information (NCBI), and Algeria Phytosanitary Index-2015.

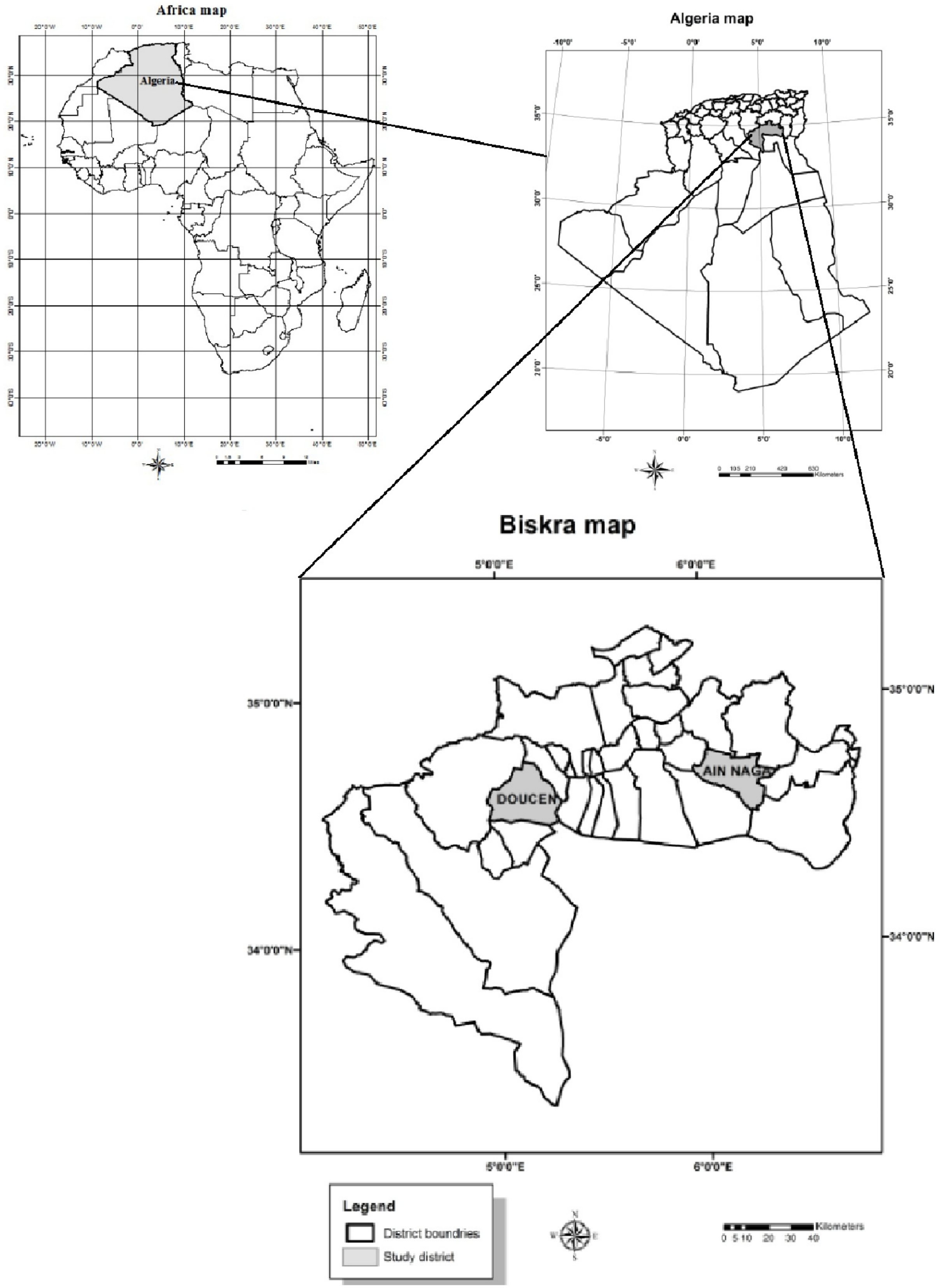

Figure 1: Location of the selected study districts: Ain Naga (East Ziban) and Doucen (West Ziban) of Biskra region, Algeria. These maps were produced using ArcMap Version 10.6.1 (ESRI, 2018).

According to the American Farmland Trust (AFT) [9], the final indicator of ER was determined using the following equation, to have a more realistic risk characterization:

$$\text{Final Indicator of ER} = \text{ERS} \times (\text{Actual Application Rate}/\text{Standard Application Rate}) \quad (2)$$

Finally, to interpret easily the values obtained from the calculation of the final indicator of ER and to compare the risk of the selected pesticides commonly used in Ain Naga and Doucen, it is necessary to normalize these values. For each active substance and formulation, the highest final value was considered for the calculation of the normalized risk values. Then, the normalized risk values were obtained by dividing each value of the final indicator of ER by the maximum value determined for each district [34].

3. RESULTS AND DISCUSSION

3.1. Lesson Learned from the Farmers' Observations and Interviews

Concerning pesticide use, a total of 120 chemical products and 56 active ingredients (AIs) were found to be in use during the survey period in Ain Naga district, whereas 92 products and 41 AIs were applied in Doucen district. However, only 18 AIs were commonly used in both the districts. In accordance with the finding of Bueno et al. [26] and Muhammetoglu et al. [34], the intensive agricultural activities involve incessant pesticide application, particularly for vegetable crops grown under greenhouses. The first lesson learned from the survey is the use of a large number of different pesticides on crops by growers. In line with Toumi et al. [14], it may be due to the intensity of pest infestation and diseases, the lack of pesticide alternatives, the disrespect of maximum residue limits, and the need for products with high commercial value at harvest.

3.1.1. Pesticide application

Farmers have used the same AIs, which are found in various formulations. As a result, the repeated application not only could cause a significant contamination of the environment and terrestrial ecosystems but also allows the pests to develop resistance to AI [44,45]. The majority of the farmers used the rate of applications recommended by retailers. This explains the direct contact between the suppliers and the farmers and their major role to convince them. Especially, the majority of farmers (over 70% in Doucen and more than half in Ain Naga) did not read or follow instructions on pesticide labels as shown in Table 1 because they were unable to read and understand the meaning of the labels that could be written in foreign language or the instructions were too long and complicated.

3.1.2. Farmers' practices on storage and disposal of pesticides

As shown in Table 1, farmers differ in their way of storing pesticides, their disposal of the leftover of pesticides, and the empty containers. More than half of the farmers bought the products and handmixed the amount of pesticides that is needed for the application. The other farmers stored their pesticides in a non-landscaped building (around 20% of farmers of both the districts combined). Only 10 and 12 respondents reported storing their chemical products in an adequate location in Ain Naga and Doucen, respectively. Concerning the disposal of residual pesticide solutions, almost half of the farmers in both the districts discard the rest of mixtures on the field or floors. About 21 and 19 respondents reported finishing until the last drop, and only a few of them reuse the rest for the next application. Nearly 53% and 69% of farmers located in Ain Naga and Doucen, respectively, reported that the common way of disposing the empty pesticide containers was discarding on-farm. The other respondents reported that they buried, burned, or reuse them for other purposes.

In Algeria, the use of pesticides in agricultural lands is not very different from other developing countries, namely, Senegal [46], Iran [47], Togo [48], Tanzania [49], Ghana [50], Kuwait [51], Burkina Faso [52], Tunisia [53], and Vietnam [54].

The results obtained confirm the farmers' lack of knowledge of the appropriate approach for storing pesticides and disposal of residual pesticide solutions, expired pesticides, and empty pesticide containers. Furthermore, the discarding of residual pesticide solutions, expired pesticides, empty pesticide containers, and storing pesticides on the farm in inappropriate areas can increase the potential for higher environmental contamination through leaching, runoff, or evaporation.

3.1.3. The level of knowledge and awareness of farmers about pesticides

Knowledge of farmers and their perception about pesticide use and its risks on both human health and environment are shown in Table 1. According to this survey, 57% and 67 % of farmers located in Ain Naga and Doucen, respectively, are not well informed about human health and environmental risks of pesticide use. In concordance, to Belhadi et al. [4] and Boukhalfa et al. [55], the majority of them thought that these products are not dangerous. Only a few of them (two respondents in Ain Naga and four in Doucen) believed that these products might harm the environment, but contrary to the expectations, this did not significantly change their practices or attitudes toward safe pesticide use. Regarding the use of pesticides, farmers frequently follow unsafe habits. It may be owing to their insufficient level of instruction and their weak comprehension of the secure application of pesticides as noted by Jallow et al. [51] and Mubushar et al. [56]. Besides, farmers highly pay attention to incomes from their crops instead of their own health or environment [57]. Considering the purpose of use, more than 50% of farmers interviewed on both the areas to find pesticides indispensable to prevent or control pests and diseases to eliminate or reduce the yield losses and maintain the high product quality.

According to their responses, the farmers have the poor levels of knowledge on pesticide application and are unaware of the risk of unsafe use of chemical products and their negative impacts. Some Algerian studies had highlighted the possible pesticides' effects on human health, such as perturbations of the reproductive hormones, inflammation, oxidative stress, metabolic perturbations, and prostate cancer [58–60], and on the environment, such as the threatening of the existence of bees [61,62].

Table 1: Pesticide use patterns and farmers‘practices.

Pesticide application	**Frequency *n* (%)**	
How do you choose your phytosanitary products?		
Experience	16(34%)	14(29%)
Neighbors recommendations	11(23%)	7(14%)
Retailer recommendations	20(43%)	28(57%)
Do you read, understand and follow pesticide labels?		
Yes	22(47%)	14(29%)
No	25 (53%)	35(71%)
Do you respect the recommended dose?		
Always	41(87%)	38(78%)
Sometimes	6(13%)	11(22%)
Farmers’ practices on storage and disposal of pesticides	Frequency *n* (%)	
Where do you store pesticides?		
Buy and mix only needed pesticides	28(60%)	26(53%)
Non-landscaped building	9(19%)	11(22%)
Open shed	10(21%)	12(25%)
What do you do with the unused leftover pesticides?		
Dispose in the field	23(49%)	25 (51%)
Finished until the last drop	21(45%)	19(39%)
Reuse for the next application	3(6%)	5(10%)
What do you do with empty pesticide containers?		
Discard on-farm	25(53%)	34(69%)
Buried on-farm	7(15%)	5(10%)
Burned on-farm	15(32%)	9(18%)
Reuse for other purposes	-	1(2%)
The level of knowledge and awareness of farmers about pesticides	Frequency *n* (%)	
Are you well informed about pesticides (proprieties, safe use)?		
Yes	3(6%)	3(6%)
No	27(57%)	33(67%)
Not really	17(36%)	13(27%)
Do you think pesticides are hazardous?		
Yes	37(79%)	33(67%)
No	10(21%)	16(33%)
Why do we use pesticides in agriculture?		
It is very important to protect the crops	24(51%)	30(61%)
Lack of alternatives	12(26%)	19(39%)
All	11(23%)	-
Do you think that pesticides affect human health and/or the environment?		
Human heath	17(36%)	17(35%)
Environment	2(4%)	4(8%)
Human health and environment	17(36%)	12(24%)
Nothing to report	11 (23%)	16 (33%)

3.2. Environmental Risk Assessment

3.2.1. Hazard identification and characterization

Eighteen AIs used in Ain Naga and Doucen districts, their classification based on the targeted pest species, their physicochemical and toxicological parameters, and their classification, labeling, and packaging (CLP) for predicting environmental fate and risk are shown in Table 2.

In general, the chemical products applied on crops have the tendency to disseminate into four major compartments of the environment: soil, air, water, and biota [63].

The AIs are deliberately released into the agricultural environment, via spray drift, runoff, or drainage [64–66], where they might cause undesired side effects not only to terrestrial ecosystems, including vertebrates (birds and mammals), invertebrates (bees), and soil organisms (earthworms, microorganisms, and non-target plants) but also to aquatic ecosystems.

The fraction of AI that will move into each compartment is governed by the physicochemical properties of pesticides. Factors such as pesticide application pattern, pesticide mobility, absorption, adsorption, solubility, Kow, chemical, physical, and biological process, rainfall intensity, irrigation strategy, soil type, landscape, and field slope are crucial for the environmental fate and persistence of pesticides in the environment [7,67,68]. The soil half-life ($t_{1/2}$) as a measure can define the persistence of pesticides on soil, and based on this parameter, pesticides are divided into three categories. There are non-persistent pesticides ($t_{1/2}$ less than 30 days), moderately persistent pesticides ($t_{1/2}$ between 30 and 100 days), and persistent pesticides ($t_{1/2}$ more than 100 days) [7,69,70].

Among the AIs under the study, six are persistent (chlorantraniliprole, fenbutatin oxide, hexaconazole, indoxacarb, imidacloprid, and triadimenol), whereas the others are moderately persistent (abamectin, cypermethrin, hexythiazox, hymexazol, and linuron) or non-persistent. Pesticides stick to soil particles, and this characteristic is defined by the sorption coefficient (Koc) [70], and in this study, the insecticide (Cypermethrin) has the highest Koc. The higher value of Koc refers to the greater sorption of pesticide in soil, and therefore, lesser the availability for the microbial degradation and its use by the plant [68,69]. The GUS is an empirically derived value that relates to pesticide persistence and sorption in soil [71]. The GUS can help to identify the vulnerable areas and may be used to rank pesticides for the potential to move toward groundwater [72]. Eight AIs (cypermethrin, fenbutatin oxide, trifloxystrobin, hexythiazox, fluazifop-p-butyl, mancozeb, indoxocarb, and thiacloprid) with a GUS less than 0.1 have an extremely low potential to move toward groundwater. However, the insecticide chlorantraniliprole, with a GUS greater than 4.0, has a very high potential to move toward groundwater. As mentioned by Ochoa and Maestroni [45], cypermethrin, mancozeb, and abamectin could contaminate groundwater. Besides, according to CLP, the insecticide imidacloprid having a high potential to move toward groundwater is very toxic to aquatic life, with long-lasting effects.

Kh (Henry's law constant) describes the concentration of pesticide in air (vapor pressure) divided by the concentration in water (solubility) [69]. The higher the Kh, the greater the likelihood that a pesticide volatilizes from moist soil [69]. Therefore, it indicates that the main route of poisoning could be inhalation, especially at high values [68]. Kow is used to describe the transfer of a substance from an aquatic environment to an organism and the bioaccumulation potential of this substance [73–76]. Highly soluble pesticides are more likely to be washed-off from the soil by runoff or to be moved below the root zone through leaching. Besides, the acute toxicity to bee, earthworm, daphnia, and algae was examined for 18 most commonly applied pesticides to characterize the hazard. Acute systemic toxicity evaluates the adverse effects that occur following exposure of organisms to single or multiple doses [77]. Bees are essential pollinators of many plants in natural ecosystems and agricultural crops [78]. Earthworms provide key soil functions that favor many positive ecosystem services [79]. Daphnia is a ubiquitous link in the ecological food chain [80]. Algae are common inhabitants of surface water and are important in soil and associated environments such as irrigation and drainage systems, lakes, and ponds [81]. All these organisms are important for agro-ecosystem sustainability. According to the CLP (Table 2), almost all AIs have potential acute and/or chronic hazardous effects for the ecosystems and environment. The majority of AIs are very toxic to aquatic life, especially with long-lasting effects.

3.2.2. Environmental risk characterization

Table 3 shows 18 AIs, which are mostly used in Ain Naga and Doucen districts, and their scores of parameters useful to calculate pesticide (ERS score) (GUS score, Kh score, Kow score, B score, W Score, D score, and A score). Soil microbial toxicity value was excluded when calculating the ERS scores due to the lack of references; thus, only the available values related to the toxicity of algae (A), bee (B), daphnia (D), and worm (W) were considered [9,34].

The use of a PERI model to estimate the environmental hazards associated with pesticides, frequently used in the regions under the study, revealed ERS scores ranging from 1.28 to 6.13 (Table 3). An ERS score of 5 and more is reached for six pesticides (linuron, hexaconazole, triadimenol, chlorantraniliprole, imidacloprid, and diazinon). The fungicide triadimenol and the herbicide linuron had the highest environmental risk, with an ERS score of 6.13 and 5.88, respectively, whereas the insecticide thiacloprid has the lowest value (1.28). Triadimenol, chlorantraniliprole, and imidacloprid have a higher GUS score than other pesticides and could potentially contaminate groundwater. Kh score was the same for all pesticides. Ten AIs have a Kow score of 5, whereas the others had a Kow score of 1. Concerning the toxicity to bees, seven insecticides, including the acaricides (imidacloprid, diazinon, indoxacarb, abamectin, cypermethrin, acetamiprid, and thiaclopirid), a fungicide (mancozeb), and an herbicide (metribuzin), were found to be the most toxic in our study.

As a general rule, insecticides could represent a serious threat to bees for the simple reason that bees are insects and, therefore, susceptible to any poison designed to kill insects [78]. The intensive usage of herbicides harms the flowering plants [82], bee colonies, and productivity [83]. Moreover, combining pesticides such as insecticides and fungicides can be more harmful and deadly to bees [84]. Concerning W score, the majority of AIs have a moderate toxicity to earthworm. Eight AIs have a higher D score than other pesticides and could potentially cause a problem among daphnia species. For algae, seven AIs have an A score of 5. Various degrees of toxicity are found among 18 AIs, and the emphasis is given that the two districts are zones at environmental risk.

To have a more realistic risk characterization, the final indicator of ER was determined. As shown in Table 4, the final indicator of ER was calculated for each applied chemical product. The values of the final indicator of ER in Ain Naga were ranged from 0.04 to 120.00, whereas, in Doucen, it ranged from 0.08 to 105.20. The higher values can be the result of the disrespect of doses recommended in the labels and/or because of the toxicity and the physicochemical properties of the active substances. Besides, as shown in Table 4, the same active ingredient can be found in many commercial formulations, with different standard application rates (Phytosanitary index 2015).

Table 2: List of the eighteen most used AIs in Ain Naga and Doucen districts with their biological activity, their physicochemical (Soil half-life, Koc, GUS, Kow, Kh) and toxicological properties (LC50 for Bees, earthworm and Daphnia, and EC50 for Algae (PPDB, 2018; NCBI, 2018), and CLP Classification according the EU Pesticides database (EU database, 2019).

Pesticides AIs	Biological activity[a]	DT50[b]	Koc[c]	GUS[d]	Kow[e]	Kh[f] (Pa m^3/mol)	LC50[g] Bees (mg/bee)	LC50 Worm (mg/kg)	LC50 Daphnia (mg/L)	EC50 Algae (mg/L)	CLP[h] Classification
Abamectin	I	25	5,638	0.25	4.40	2.70 × 10-03	1 × 10-06	33	0.00	> 1.59	H400, H410
Acetamiprid	I	1	200	0.40	0.80	5.30 × 10-8	8.09 × 10-03	9	49.80	> 98.30	H412
Chlorantranili- prole	I	597	362	4.22	2.86	3.20 × 10-9	>0.10	>1,000	0.01	>4.00	–
Cypermethrin	I	22	307,558	−2.00	5.55	0.31	2.30 × 10−05	>100	0.00	>0.06	H400, H410
Diazinon	I	9	609	1.14	3.69	6.09 × 10−2	9 × 10-05	65	0.00	6.40	H400, H410
Fenbutatin oxide	I	365	–	−2.96	5.15	2.70 × 10-3	>0.20	>500	0.04	>0.00	H400, H410
Fluazifop-p-butyl	H	1	3,394	0	4.50	0.04	>0.20	>500	>0.62	>0.67	H400, H410
Hexaconazole	F	122	1,040	2.05	3.90	3.33×10-4	>0.10	414	>2.90	>1.70	H411
Hexythiazox	I	30	–	0.03	2.67	1.19 × 10-02	>0.11	>105	>0.47	>0.40	H400, H410
Hymexazol	F	30	–	2.63	0.30	1.40 × 10-04	>0.10	281.90	28	36.00	H412
Imidacloprid	I	191	–	3.74	0.57	1.70 × 10-10	3.70 × 10−06	10.70	85	>10.00	H400, H410
Indoxacarb	I	113	4,483	0.72	4.65	6 × 10−05	8 × 10−05	>625	0.17	0.07	H400, H410
Linuron	H	57	842.80	2.21	3.00	2 × 10−04	>0.12	>1,000	0.31	0.01	H400, H410
Mancozeb	F	0.05	998	−1.45	2.3	6.17 × 10−02	>0.08	>299	0.07	0.04	H400
Metribuzin	H	7	37.90	2.06	1.75	0.25 × 10−04	>0.08	427	49	0.02	H400, H410
Thiacloprid	I	0.88	–	−0.07	1.26	4.8 × 10−10	17.32 × 10−05	105	85.10	60.60	H400, H410
Triadimenol	F	250	750	3.34	3.18	3.5 × 10−06	>0.2	>390	51	9.60	H411
Trifloxystrobin	F	0.34	–	−0.30	4.50	2.30 × 10−3	>0.11	>1,000	0.01	0.00	H400, H410

[a] I = Insecticide, including acaricide, F = Fungicide; H = Herbicide.

[b] DT50 = Half-life in soil (day).

[c] Koc = Soil sorption coefficient.

[d] GUS = Groundwater ubiquity score.

[e] Kow = Partion coefficient.

[f] Kh = Henry's constant.

[g] LC50 = Lethal concentration value.

[h] CLP = Classification Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006. H400 = Very toxic to aquatic life; H410 = Very toxic to aquatic life with long lasting effects; H411 = Toxic to aquatic life with long lasting effects; H412 = Harmful to aquatic life with long lasting effects.

Table 3: Pesticide ERS calculated using the PERI model for eighteen AI commonly used in Ain Naga and Doucen districts and GUS, Kh, Kow, algae (A), bee (B), daphnia (D) and worm (W) values used in the calculations.

Active substances	ERS	GUS score	Khscore	Kow score	Bscore	Wscore	Dscore	Ascore
Thiacloprid	1.28	1	1	1	5	2	2	2
Mancozeb	1.40	1	1	1	5	1	5	5
Acetamiprid	2.33	2	1	1	5	4	2	2
Hexythiazox	2.38	2	1	1	4	2	5	4
Trifloxystrobin	2.63	1	1	5	2	1	5	5
Fluazifop-p-butyl	2.75	1	1	5	4	2	4	4
Fenbutatin oxide	3.00	1	1	5	4	2	5	5
Cypermethrin	3.13	1	1	5	5	2	5	5
Abamectin	4.00	2	1	5	5	3	5	3
Indoxacarb	4.00	2	1	5	5	2	4	5
Hymexazol	4.25	4	1	1	4	2	2	2
Metribuzin	4.35	4	1	1	5	2	2	5
Diazinon	5.00	3	1	5	5	3	5	3
Imidacloprid	5.30	5	1	1	5	3	2	2
Chlorantraniliprole	5.33	5	1	1	4	1	5	3
Hexaconazole	5.50	4	1	5	4	2	3	3
Linuron	5.88	4	1	5	4	2	4	5
Triadimenol	6.13	5	1	5	2	2	2	3

Pesticides are listed in ascending order of ERS.

Table 4: The AIs most commonly used in Ain Naga and Doucen, the chemical products, and the correspondent final indicator of ER.

Active substance	Commercial formulation	Final indicator of ER	
		Ain Naga	Doucen
Abamectin (AB)	Vertimec, Medamec, Romectin, Tina,Vapcomic	4.00	4.00
	Biok 1.8 Ec, Limactine,Transact 18Ec, Metry	2.64	2.64
	Bactimec	5.71	5.71
Acetamiprid (AC)	Aceplan 20 SP,Mopistop, Morspilan 20 SP, Rustilan	11.18	9.32
	Cetam 20% SL	5.59	4.66
	Picador 20% SL	2.80	2.33
	Ghazal 20 SP	4.66	3.87
	Acetin 20 SL	2.80	2.33
Chlorantraniliprole (CL)	Coragen 20	3.57	7.09
Cypermethrin (CY)	Arrivo 25% Ec, Cypermethrine 25 Ec, Cypra-Plus, Sherpa 2GC	15.65	23.48
	Cym 25	2.10	3.13
Diazinon (DI)	Diazinon	120.00	40.00
Fenbutatin oxide (FE)	Mitrus Dumper	0.33	0.33
Fluazifop-p-butyl (FL)	Fusitop,Fluazifop	1.38	2.75
Hexaconazole (HE)	Agrivil	27.50	20.63
	Hexar 50 Ec, Hexavil 5 Sc	11.00	8.25
Hexythiazox (HX)	Acarol 10 Wp	23.80	19.04
Hymexazol (HY)	Tachigazole,Tachigaren 30 SL	12.75	4.25
	Himexate 30 SL	3.19	1.06
Imidacloprid (IM)	Confidor Supra, Fidor Super 70	21.20	17.65
	Commando	5.30	2.65
Indoxacarb (IN)	Zinad 15 SC	40.00	80.00
	Arizonate	0.04	0.08
Linuron (LI)	Etalon	0.98	1.94
Mancozeb (MA)	Dithane M 45,Manco 80 Riva,Mancophyt	1.75	1.75
	Manco 80 Wp	1.40	1.40
Metribuzin (ME)	Turbo, Ribuzine	3.73	6.21
	Metribuzell 70 WP	2.87	4.83
Thiacloprid (TH)	Calypso	2.12	2.12
Triadimenol (TR)	Trifidan 25	30.65	61.30
	Vidan 25	6.13	10.18
Trifloxystrobin (TF)	Flint 50 XG	26.30	105.20

Furthermore, all the farmers randomly selected from both districts were applying different doses. The statistical analysis revealed that there was one extreme value among Ain Naga data sets and three extremes values among all Doucen data sets of the final indicator of ER. The Wilcoxon rank-sum test (Mann–Whitney U-test) was computed for independent samples less than 20. The Wilcoxon rank had a value of 155.5, the confidence interval is between −10.722 and 9.4399, and the difference of median is −0.505 from Ain Naga to Doucen. As well, the *p*-value = 0.8494 (higher than 0.05), so there is no statistically significant difference between farmers localized in both the districts.

Similarly, the highest final indicator of ER of 18 AIs was considered for the calculation of the normalized risk values (Fig. 2). A comparison of all the values obtained showed that diazinon in Ain Naga and trifloxystrobin in Doucen had the highest normalized risk values. According to CLP (Table 2), both diazinon and trifloxystrobin are very toxic to aquatic life, especially with long-lasting effects (EU database, 2019).

Trifloxystrobin is a broad-spectrum strobilurin fungicide commonly used around the world. The literature and toxicity studies available on this compound and its pertinent metabolites showed a low level of risk to non-target eukaryotes, terrestrial plants, arthropods, earthworms, and other soil macro- and microorganisms [85]. The long-term and frequent application of trifloxystrobin may cause high risk (acute and chronic) to aquatic organisms (i.e., fish, invertebrates, and algae) [86], to bird [87] and a low acute risk to honeybees and mammals considering all routes of exposure [85]. Trifloxystrobin could affect reproductive health, lifespan, and embryonic and larval development [88,89]. Besides, its use has a potential risk to humans [88], and the long-term skin contact could induce an allergic reaction and dermal sensitization [87,90].

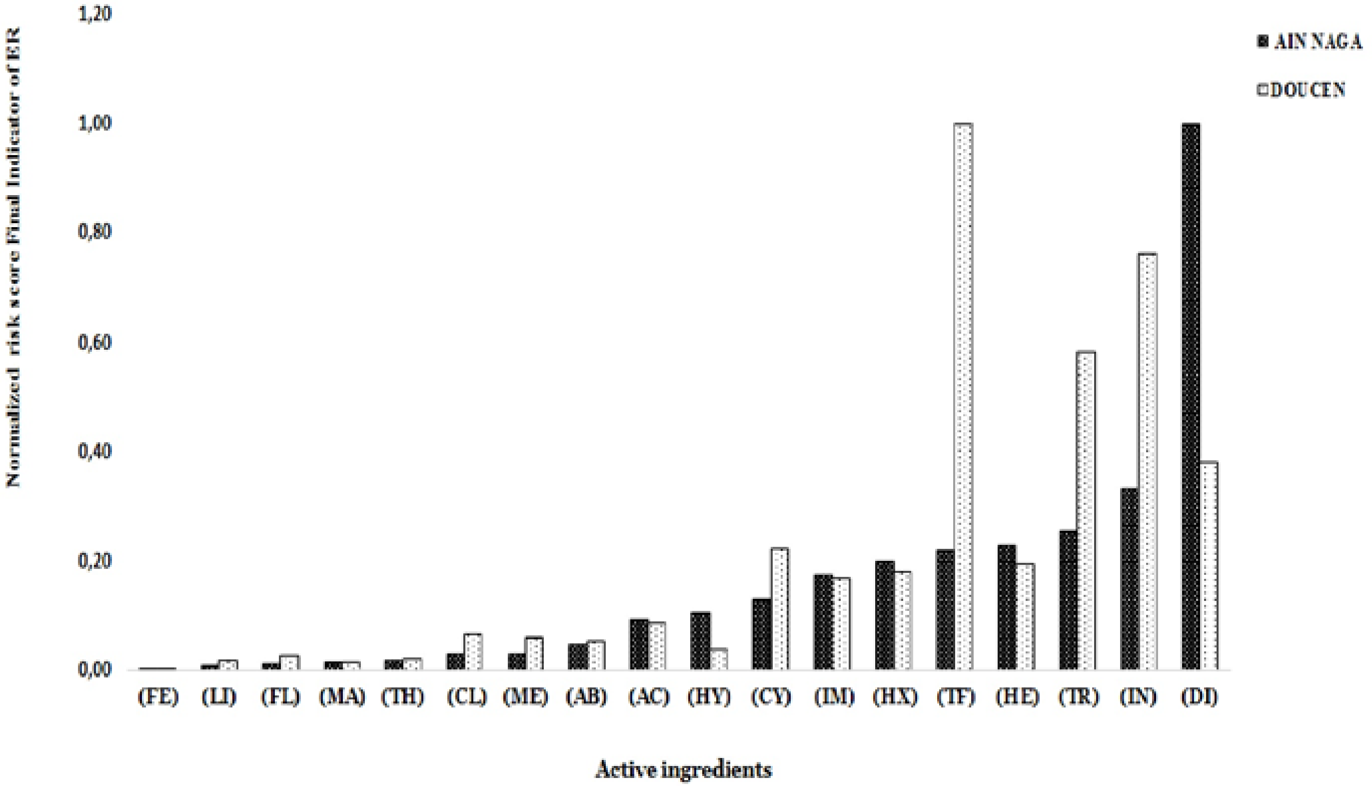

Figure 2: Graph of the normalized risk scores of the final indicator of ER of the 18 AIs.

A large variety of mammals are highly sensitive to diazinon toxicity. Larkin and Tjeerdema [91] and Pham and Bui [92] indicated that, besides the ecological repercussions, diazinon exhibits acute toxicity, reproductive, cytotoxic, and genotoxic damages, and different injures to specific target tissues and organs, which is characterized by a complex biological fate, mediated largely by diverse metabolic mechanisms [91]. According to Velki et al. [93] and Pham and Bui [92], diazinon is moderately toxic to early life stages of zebrafish. Hodaifa et al. [94] stated that *Daphnia lumholtzi* neonate species were highly sensitive to this compound than the temperate *Daphnia magna*. On 2002, the Environmental Protection Agency suggested removing diazinon because of its possible toxicity to the environment [95,96]. However, in Algeria, this compound is always available, in regular use in farms, and not yet removed from the markets.

3. CONCLUSION

Concerns about pesticide's negative repercussions on the environment and human health increase due to an inappropriate usage by farmers. However, pesticide risk indicators can give a quick aid to evaluate the potential environmental dangers from pesticide use. Therefore, limited data availability and resources encourage using these applicable indicators with low cost, which could help the authorities and the regulatory agencies to control the use of chemical products and review the current Algerian law and regulation. It could facilitate farmers' choice of pesticides, which presents the least risk for the environment and human health. In general, pesticides could have a potential risk to the humans, environment, and terrestrial and aquatic organisms if they are used improperly. The environmental risks could be worsened by the perception and attitude of farmers, the lack of education, and the poor knowledge and understanding of safe practices in pesticide use, including handling, storage, and disposal. Finally, the concerted efforts are required to create awareness and changes in attitude among Algerian farmers to follow hygiene practices such as respect the application technique and the recommended dose. Besides, monitoring and regular surveillance at the retail and farm level are needed to guarantee safer pesticide use.

CONFLICT OF INTEREST

Authors declared that there is no conflicts of interest.

FUNDING STATEMENT

The authors received no specific funding for this work.

REFERENCES

1. Allache F, Bouta Y, Demnati F. Population development of the tomato moth *Tuta absoluta* (Lepidoptera: Gelechiidae) in greenhouse tomato in Biskra, Algeria. J Crop Prot 2015;4(4):509–17.
2. Bencheikh A, Nourani A, Chabaca MN. Sustainability evaluation of agricultural greenhouse structures in southern of Algeria using AHP, case of study: Biskra province. Agric Eng Int CIGR J 2017;19(1):56–64.

3. Rekibi F. Analyse compétitive de la filière tomate sous serre: cas de la Wilaya de Biskra. (Doctoral dissertation). Université de Mohamed Khider, Biskra, Algérie, 2015:189.
4. Belhadi A, Mehenni M, Reguieg L, Yakhlef H. Risques potentiels pour la santé humaine et l'environnement des pratiques phytosanitaires des serristes maraîchers d'une région du Bas-Sahara algérien. Environnement, Risques Santé 2016;15(3):219–27.
5. Direction des services agricoles (DSA). Rapport des services statistiques de l'agriculture de la wilaya de Biskra, Algérie. Direction des services agricoles (Biskra, Algérie) 2019:1–31.
6. Akay Demir AE, Dilek FB, Yetis U. A new screening index for pesticides leachability to groundwater. J Environ Manage 2019;231:1193–202.
7. National Research Council (NRC). Committee on Long-Range Soil and Water Conservation Soil and Water Quality: An Agenda for Agriculture. National Academy Press, Cop., Washington, DC, 1993:542.
8. Food and Agriculture Organisation (FAO). Chapter 4. Water quality concerns in drainage water management. Available from http://www.fao.org/3/y4263e/y4263e07.htm (Accessed December 3, 2019)
9. Aftresearch.org. American Farmland Trust: Center for Agriculture in the Environment - Integrated Pest Management (AFT). Available via http://www.aftresearch.org/ipm/risk (Accessed 20 February 2019)
10. Feola G, Rahn E, Binder CR. Suitability of pesticide risk indicators for less developed countries: a comparison. Agric Ecosyst Environ 2011;142(3–4):238–45.
11. Le Bellec F, Vélu A, Fournier P, Le Squin S, Michels T, Tendero A, et al. Helping farmers to reduce herbicide environmental impacts. Ecol Indic 2015;54:207–16.
12. Pérez-Lucas G, Vela N, El Aatik A, Navarro S. Environmental risk of groundwater pollution by pesticide leaching through the soil profile. Pesticides – use and misuse and their impact in the environment. In Pesticides, anthropogenic activities and the health of our environment. IntechOpen, London, UK, 2019:1–27.
13. Schmolke A, Thorbek P, Chapman P, Grimm V. Ecological models and pesticide risk assessment: current modeling practice. Environ Toxicol Chem 2010;29(4):1006–12.
14. Toumi K, Vleminckx C, van Loco J, Schiffers B. Pesticide residues on three cut flower species and potential exposure of florists in Belgium. Int J Environ Res Public Health 2016;13(10):943.
15. Boesten JJ. Conceptual considerations on exposure assessment goals for aquatic pesticide risks at EU level. Pest Manag Sci 2017;74(2):264–74.
16. Mfarrej MFB, Rara FM. Competitive, sustainable natural pesticides. Acta Ecologica Sinica 2019;39(2):145–51.
17. Mahmood I, Imadi SR, Shazadi K, Gul A, Hakeem KR. Effects of pesticides on environment. In: Plant, soil and microbes. Springer, Cham, Switzerland, pp 253–69, 2016.
18. Kohler H-R, Triebskorn R. Wildlife ecotoxicology of pesticides: can we track effects to the population level and beyond? Science 2013;341(6147):759–65.
19. Forbes VE, Brain R, Edwards D, Galic N, Hall T, Honegger J, et al. Assessing pesticide risks to threatened and endangered species using population models: findings and recommendations from a CropLife America Science Forum. Integr Environ Assess Manag 2015;11(3):348–54.
20. Crenna E, Sala S, Polce C, Collina E. Pollinators in life cycle assessment: towards a framework for impact assessment. J Clean Prod 2017;140:525–36.
21. Schäfer RB, Liess M, Altenburger R, Filser J, Hollert H, Roß-Nickoll M, et al. Future pesticide risk assessment: narrowing the gap between intention and reality. Environ Sci Eur 2019;31(1):1–5.
22. Altman J. Pesticide interactions in crop production: beneficial and deleterious effects. CRC Press, Boca Raton, FL, 2017:591.
23. Ugya AY, Ahmad A, Adamu H, Giwa S, Imam T. Phytoextraction of heavy metals and risk associated with vegetables grown from soil irrigated with refinery wastewater. J Appl Biol Biotechnol 2019;7(2):14–9.
24. Rosell G, Quero C, Coll J, Guerrero A. Biorational insecticides in pest management. J Pestic Sci 2008;33(2):103–21.
25. Collier R, Jukes A, Daniel C, Hommes M. Ecological selectivity of pesticides and application methods. IOBC-WPRS Bull 2016;118: 94–8.
26. Bueno A de F, Carvalho GA, Santos AC dos, Sosa-Gómez DR, Silva DM da. Pesticide selectivity to natural enemies: challenges and constraints for research and field recommendation. Ciência Rural 2017;47(6):e20160829.
27. Carriger JF, Rand GM, Gardinali PR, Perry WB, Tompkins MS, Fernandez AM. Pesticides of potential ecological concern in sediment from South Florida canals: an ecological risk prioritization for aquatic arthropods. Soil Sediment Contam 2006;15(1):21–45.
28. Levitan L. An overview of pesticide impact assessment systems (aka" Pesticide Risk Indicators") based on indexing or ranking pesticides by environmental impact. Background paper presented at the Organisation of Economic Cooperation and Development (OECD). In: Workshop on pesticide risk indicators, Copenhagen, Denmark, 21-23 April 1997. Available via http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.3449&rep=rep1&type=pdf
29. Levitan L. "How to" and "why": assessing the environ-social impacts of pesticides. Crop Prot 2000;19(8–10):629-36.
30. Reus J, Leendertse P, Bockstaller C, Fomsgaard I, Gutsche V, Lewis K, et al. Comparison and evaluation of eight pesticide environmental risk indicators developed in Europe and recommendations for future use. Agric Ecosyst Environ 2002;90(2):177–87.
31. Macharia IN, Mithöfer M, Waibel H. Potential environmental impacts of pesticides use in the vegetable sub-sector in Kenya. Afr J Hortic Sci 2009;2:138–51.
32. Finizio A, Villa S. Environmental risk assessment for pesticides. Environ Impact Assess Rev 2002;22(3):235–48.
33. Handal AJ, Hund L, Páez M, Bear S, Greenberg C, Fenske RA, et al. Characterization of pesticide exposure in a sample of pregnant women in Ecuador. Arch Environ Contam Toxicol 2015;70(4):627–39.
34. Muhammetoglu A, Durmaz S, Uslu B. Evaluation of the environmental impact of pesticides by application of three risk indicators. Environ Forensics 2010;11(1–2):179–86.
35. Elbashir AA, Aboul-Enein HY. Application of gas and liquid chromatography coupled to time-of-flight mass spectrometry in pesticides: Multiresidue analysis. Biomed Chromatogr 2017;32(2):e4038.
36. Samsidar A, Siddiquee S, Shaarani SM. A review of extraction, analytical and advanced methods for determination of pesticides in environment and foodstuffs. Trends Food Sci Technol 2018;71:188–201.
37. Damalas CA, Eleftherohorinos IG. Pesticide exposure, safety issues, and risk assessment indicators. Int J Environ Res Public Health 2011;8(5):1402–19.
38. van den Dries MA, Pronk A, Guxens M, Spaan S, Voortman T, Jaddoe VW, et al. Determinants of organophosphate pesticide exposure in pregnant women: a population-based cohort study in the Netherlands. Int J Hyg Environ Health 2018;221(3):489–501.
39. Ahrens A, Traas TP. Environmental exposure scenarios: development, challenges and possible solutions. J Expo Sci Environ Epidemiol 2007;17(S1):S7–15.
40. Cramer D, Howitt DL. The SAGE dictionary of statistics: a practical resource for students in social sciences. London, UK: SAGE Publications Ltd, 2004.
41. Reus J, Leendertsee P, Bockstaller C, Fomsgaard, Inge S, Gutsche V, Lewis K, Nilsson C, Pussemier L, Trevisan M, Van der Werf H, Alfarroba F, Blümel S, Isart J, McGrath D, Seppälä T. Comparing Environmental Risk Indicators for Pesticides: results of the European CAPER Project. Centre for Agriculture and Environment, Clm 426-1999, Utrecht, Netherlands 1999:184–84.

42. Greitens TJ, Day E. An alternative way to evaluate the environmental effects of integrated pest management: pesticide risk indicators. Renew Agric Food Syst 2007;22(3):213–22.
43. Labite H, Cummins E. A quantitative approach for ranking human health risks from pesticides in Irish groundwater. Hum Ecol Risk Assess Int J 2012;18(6):1156–85.
44. Stoytcheva M. Pesticides : formulations, effects, fate. Intech, Rijeka, Croatia, 2011.
45. Ochoa V, Maestroni B. Pesticides in water, soil, and sediments. Integrated Analytical Approaches for Pesticide Management 2018; 133–147; doi:10.1016/b978-0-12-816155- 5.00009-9
46. Ngom S, Seydou T, Thiam MB, Anastasie M. Contamination des produits agricoles et de la nappe phréatique par les pesticides dans la zone des Niayes au Sénégal. Synthèse: Revue des Sciences et de la Technologie 2012;25(1):119–30.
47. Hashemi SM, Rostami R, Hashemi MK, Damalas CA. Pesticide use and risk perceptions among farmers in Southwest Iran. Hum Ecol Risk Assess Int J 2012;18(2):456–70.
48. Adjrah Y, Dovlo A, Karou SD, Eklu-Gadegbeku K, Agbonon A, De Souza C, et al. Survey of pesticide application on vegetables in the Littoral area of Togo. Ann Agric Environ Med 2013;20(4):715–20.
49. Lekei EE, Ngowi AV, London L. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health 2014;14(1):389.
50. Afari Sefa V, Asare-Bediako E, Kenyon L, Micah J. Pesticide use practices and perceptions of vegetable farmers in the cocoa belts of the ashanti and western regions of Ghana. Adv Crop Sci Technol 2015;03(03):1–10.
51. Jallow M, Awadh D, Albaho M, Devi V, Thomas B. Pesticide knowledge and safety practices among farm workers in kuwait: results of a survey. Int J Environ Res Public Health 2017;14(4):340.
52. Son D, Somda I, Legreve A, Schiffers B. Pratiques phytosanitaires des producteurs de tomates du Burkina Faso et risques pour la santé et l'environnement. Cah Agric 2017;26(2):25005.
53. Toumi K, Joly L, Tarchoun N, Souabni L, Bouaziz M, Vleminckx C, et al. Risk assessment of Tunisian consumers and farm workers exposed to residues after pesticide application in chili peppers and tomatoes. Tunisian J Plant Prot 2018;3(1):127–43.
54. Nguyen TM, Le NTT, Havukainen J, Hannaway DB. Pesticide use in vegetable production: a survey of Vietnamese farmers' knowledge. Plant Prot Sci 2018;54(4):203–14.
55. Boukhalfa H, Dhorban A, Abrougui K, Belhamra M. Characterization of greenhouse spray. Commun Agric Appl Biol Sci 2018;83(2):349–54.
56. Mubushar M, Aldosari FO, Baig MB, Alotaibi BM, Khan AQ. Assessment of farmers on their knowledge regarding pesticide usage and biosafety. Saudi J Biol Sci 2019;26(7):1903–10.
57. Jones E, Mabota A, Larson DW. Farmers' knowledge of health risks and protective gear associated with pesticide use on cotton in mozambique. J Dev Areas 2008;42(2):267–82.
58. Slimani S, Boulakoud MS Abdennour C. Pesticide exposure and reproductive biomarkers among male farmers from North-East Algeria. Ann Biol Res 2011;2:290-7.
59. Berroukche A, Bendahmane-Salmi M, Kandouci BA. Inappropriateness of prostate cancer screening by PSA in young Algerian farmers. Open J Immunol 2013;03(03):119–22.
60. Madani FZ, Hafida M, Merzouk SA, Loukidi B, Taouli K, Narce M. Hemostatic, inflammatory, and oxidative markers in pesticide user farmers. Biomarkers 2015;21(2):138–45.
61. Nabti D, Achou M, Soltani N. DECIS 25 EC toxicity to Algerian honeybees. J Entomol Zool Stud 2015;3(6):285–8.
62. Allal Benfekih L, Bellache M, Aoudia B, Mahmoudi A. Impact of insecticides on pollinator populations: role of phytosanitary performance indicators in tomato crops. AGROFOR Int J 2018;3(2):5–13.
63. Aktar W, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. Interdiscip Toxicol 2009;2(1):1–12.
64. Dalton RL, Pick FR, Boutin C, Saleem A. Atrazine contamination at the watershed scale and environmental factors affecting sampling rates of the polar organic chemical integrative sampler (POCIS). Environ Pollut 2014;189:134–42.
65. McKnight US, Rasmussen JJ, Kronvang B, Binning PJ, Bjerg PL. Sources, occurrence and predicted aquatic impact of legacy and contemporary pesticides in streams. Environ Pollut 2015;200:64–76.
66. Carazo-Rojas E, Pérez-Rojas G, Pérez-Villanueva M, Chinchilla-Soto C, Chin-Pampillo JS, Aguilar-Mora P, et al. Pesticide monitoring and ecotoxicological risk assessment in surface water bodies and sediments of a tropical agro-ecosystem. Environ Pollut 2018;241:800–9.
67. Sabatier P, Poulenard J, Fanget B, Reyss JL, Develle AL, Wilhelm B, et al. Long-term relationships among pesticide applications, mobility, and soil erosion in a vineyard watershed. Proc Natl Acad Sci 2014;111(44):15647–52.
68. Pereira VJ, Cunha JPAR da, Morais TP de, Oliveira JPR de, Morais JB de. Physical-chemical properties of pesticides: concepts, applications, and interactions with the environment. Biosci J 2016;32(3):627–41.
69. Kerle EA, Jenkins JJ, Vogue PA, Oregon State University. Extension Service. Understanding pesticide persistence and mobility for groundwater and surface water protection. Oregon State University Extension Service, Corvallis, OR, 1994.
70. Jenkins JJ, Thomson PA. OSU extension pesticide properties database. Oregon State University Extension Service, Corvallis, OR, 1999. Available via http://extension.oregonstate.edu/catalog/pdf/em/em8709.pdf
71. Pretty JN. The pesticide detox : towards a more sustainable agriculture. Earthscan, London, UK, 2005.
72. Arias-Estévez M, López-Periago E, Martínez-Carballo E, Simal-Gándara J, Mejuto JC, García-Río L. The mobility and degradation of pesticides in soils and the pollution of groundwater resources. Agric Ecosyst Environ 2008;123(4):247–60.
73. Da Silva J. Aqueous photochemistry of pesticides triadimefon and triadimenol. J Photochem Photobiol A Chem 2003;154(2–3):293–8.
74. Mackay D, Shiu WY, Kc M, Sc L. Handbook of physical-chemical properties and environmental fate for organic chemicals. In Introduction and hydrocarbons. volume 1, Crc Press, Boca Raton, FL, 2006.
75. Cabrera A, Trigo C, Cox L, Celis R, Cornejo J. A comparative study of the use of organoclay-based formulations and organic amendment to reduce the leaching of the herbicide MCPA in soil. Clean 2008;36(12):990–5.
76. Minguela JV, Cunha JPAR. Manual de aplicação de produtos fitossanitários. Aprenda Fácil, Viçosa, Brazil, p 588, 2010.
77. Saganuwan S. Toxicity studies of drugs and chemicals in animals: an overview. Bulg J Vet Med 2017;20(4):291–318.
78. Sanchez-Bayo F, Goka K. Impacts of pesticides on honey bees. In: Beekeeping and bee conservation - advances in research, InTech, London, UK, pp 77–97, 2016; doi:10.5772/62487
79. Pelosi C, Barot S, Capowiez Y, Hedde M, Vandenbulcke F. Pesticides and earthworms. A review. Agron Sustain Dev 2013;34(1):199–228.
80. Rajini A, Revathy K, Chitrikha T. Toxicity and reproductive effect of combination pesticide to daphnia magna. Indian J Sci Technol 2016;9(3):1–5.
81. Staley ZR, Harwood VJ, Rohr JR. A synthesis of the effects of pesticides on microbial persistence in aquatic ecosystems. Crit Rev Toxicol 2015;45(10):813–36.
82. Hyvönen T, Salonen J. Weed species diversity and community composition in cropping practices at two intensity levels a six-year experiment. Plant Ecol 2002;159(1):73–81.

83. Goulson D, Nicholls E, Botias C, Rotheray EL. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 2015;347(6229):1255957.
84. Johnson RM, Dahlgren L, Siegfried BD, Ellis MD. Acaricide, fungicide and drug interactions in honeybees (Apis mellifera). PLoS One 2013;8(1):e54092.
85. European Food Safety Authority (EFSA), Arena M, Auteri D, Barmaz S, Bellisai G, Brancato A, et al. Peer review of the pesticide risk assessment of the active substance Trifloxystrobin. EFSA J 2017;15(10):e04989.
86. Cao M, Li S, Wang Q, Wei P, Liu Y, Zhu G, et al. Track of fate and primary metabolism of trifloxystrobin in rice paddy ecosystem. Sci Total Environ 2015;518–519:417–23.
87. Paranjape K, Gowariker V, Krishnamurthy VN, Gowariker S. The pesticide encyclopedia. CAB International, Oxfordshire, UK, 2014.
88. Zhu L, Wang H, Liu H, Li W. Effect of trifloxystrobin on hatching, survival, and gene expression of endocrine biomarkers in early life stages of medaka (Oryzias latipes). Environ Toxicol 2013;30(6):648–55.
89. Li H, Cao F, Zhao F, et al. Developmental toxicity, oxidative stress and immunotoxicity induced by three strobilurins (pyraclostrobin, trifloxystrobin and picoxystrobin) in zebrafish embryos. Chemosphere 2018;207:781–90.
90. Jang Y, Lee AY, Chang S-H, Jeong SH, Park KH, Paik MK, et al. Trifloxystrobin induces tumor necrosis factor-related apoptosis-inducing ligand (TRAIL)-mediated apoptosis in HaCaT, human keratinocyte cells. Drug Chem Toxicol 2016;40(1):67–73.
91. Larkin DJ, Tjeerdema RS. Fate and effects of Diazinon. Rev Environ Contam Toxicol 2000;166:49–82.
92. Pham T-L, Bui HM. Comparison of Diazinon Toxicity to Temperate and Tropical Freshwater Daphnia Species. J Chem 2018;2018:1–5.
93. Velki M, Di Paolo C, Nelles J, Seiler T-B, Hollert H. Diuron and diazinon alter the behavior of zebrafish embryos and larvae in the absence of acute toxicity. Chemosphere 2017;180:65–76.
94. Hodaifa G, Moya López AJ, Paraskeva C. Chemical management and treatment of agriculture and food industries wastes. J Chem 2019;2019:4089175.
95. Debski B, Kania BF, Kuryl T. Transformations of diazinon, an organophosphate compound in the environment and poisoning by this compound. Ecol Bratislava 2007;26(1):68.
96. Garber K, Steege T. Problem formulation for the environmental fate and ecological risk, endangered species and drinking water assessments in support of the registration review of diazinon. Office of Prevention, Pesticides, and Toxic Substances, US EPA, Washington, DC, 2008. Available via https://www3.epa.gov/pesticides/chem_search/cleared_reviews/csr_PC-057801_26-Mar-08_a.pdf (Accessed 10 April 2019).

How to cite this article:
Soudani N, Belhamra M, Ugya AY, Patel N, Carretta L, Cardinali A, Toumi K. Environmental risk assessment of pesticide use in Algerian agriculture. J Appl Biol Biotech 2020;8(05):036–047. DOI: 10.7324/JABB.2020.80505