Environmental risk assessment of pesticide use in Algerian agriculture

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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
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 α = 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:

\[ ERS = (GUS \times Kh + (B + W + D + A + S)/5 \times Kow/10 \] (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:

$$\text{Final Indicator of ER} = \frac{E_{RS} \times (\text{Actual Application Rate} / \text{Standard Application Rate})}{\text{Standard Application Rate}}$$  \hspace{1cm} (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 Muhammadetoglu 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].
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),

| Table 1: Pesticide use patterns and farmers’ practices. |
|--------------------------------------------------------|
| Pesticide application                                    | Frequency n (%) |
|--------------------------------------------------------|
| How do you choose your phytosanitary products?           |                |
| Experience                                             | 16(34%)        |
| Neighbors recommendations                               | 11(23%)        |
| Retailer recommendations                                 | 20(43%)        |
| Do you read, understand and follow pesticide labels?    |                |
| Yes                                                    | 22(47%)        |
| No                                                     | 25(53%)        |
| Do you respect the recommended dose?                    |                |
| Always                                                 | 41(87%)        |
| Sometimes                                              | 6(13%)         |
| Farmers’ practices on storage and disposal of pesticides| Frequency n (%)|
| Where do you store pesticides?                         |                |
| Buy and mix only needed pesticides                      | 28(60%)        |
| Non-landscaped building                                 | 9(19%)         |
| Open shed                                              | 10(21%)        |
| What do you do with the unused leftover pesticides?     |                |
| Dispose in the field                                    | 23(49%)        |
| Finished until the last drop                            | 21(45%)        |
| Reuse for the next application                          | 3(6%)          |
| What do you do with empty pesticide containers?         |                |
| Discard on-farm                                         | 25(53%)        |
| Buried on-farm                                          | 7(15%)         |
| Burned on-farm                                          | 15(32%)        |
| 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%)          |
| No                                                      | 27(57%)        |
| Not really                                              | 17(36%)        |
| Do you think pesticides are hazardous?                  |                |
| Yes                                                     | 37(79%)        |
| No                                                      | 10(21%)        |
| Why do we use pesticides in agriculture?                |                |
| It is very important to protect the crops               | 24(51%)        |
| Lack of alternatives                                    | 12(26%)        |
| All                                                     | 11(23%)        |
| Do you think that pesticides affect human health and/or the environment? | Frequency n (%) |
| Human health                                            | 17(36%)        |
| Environment                                             | 2(4%)          |
| Human health and environment                            | 17(36%)        |
| Nothing to report                                       | 11(23%)        |
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, fluzifop-p-butyl, mancozeb, indoxacarb, 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.

Kb (Henry’s law constant) describes the concentration of pesticide in air (vapor pressure) divided by the concentration in water (solubility) [69]. The higher the Kb, 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, W score, D score, and E 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 thiacloprid), 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 (Phyto sanitary 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 activitya | DT50b | Kocc | GUSd | Kowf (Pa m²/mol) | LC50g Bees (mg/bee) | LC50g Worms (mg/kg) | LC50h Daphnia (mg/L) | EC50h Algae (mg/L) | CLP 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              |
| Chlorantranil- 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 × 10-2     | >0.11               | >105                | 0.47                | >0.40              | H400, H410         |
| Hexymexazol    | F 30                | –     | 2.63 | 0.30 | 1.40 × 10-4     | >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, H410         |
| Metribuzin     | H 7                 | 37.90 | 2.06 | 1.75 | 0.25 × 10-4     | >0.08               | 427                 | 49                  | 0.02               | H400, H410         |
| Thiacylpron     | 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         |

1. *I* = Insecticide, including acaricide; *F* = Fungicide; *H* = Herbicide.
2. DT50 = Half-life in soil (day).
3. Koc = Soil sorption coefficient.
4. GUS = Groundwater ubiquity score.
5. KC = Kh constant.
6. *Kh* = Henry’s constant.
7. LC50 = Lethal concentration value.
8. 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 | Khcore | Kow score | Bscore | Wscore | Dcore | Ascore |
|-------------------|-----|-----------|--------|-----------|--------|--------|-------|--------|
| Thiacylpron        | 1.28 | 1         | 1      | 1         | 1      | 5      | 2     | 2      |
| Mancozeb          | 1.40 | 1         | 1      | 1         | 1      | 5      | 1     | 5      |
| Acetamiprid       | 2.33 | 2         | 2      | 1         | 1      | 5      | 4     | 2      |
| Hexythiazox       | 2.38 | 2         | 2      | 1         | 1      | 4      | 2     | 5      |
| 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      |
| Hexymexazol       | 4.25 | 4         | 1      | 1        | 4      | 2     | 2     | 2      |
| Metribuzin        | 4.35 | 4         | 1      | 1        | 5      | 2     | 2     | 2      |
| Diazinon          | 5.00 | 3         | 1      | 5         | 5      | 3     | 5     | 3      |
| Imidacloprid      | 5.30 | 5         | 1      | 1        | 5      | 3     | 2     | 2      |
| Chlorantranil-prole | 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.
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].

**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   |
| Abamectin (AB)          | Bioc 1.8 Ec, Limactine, Transact 18Ec, Metry | 2.64     | 2.64   |
| Abamectin (AB)          | Baucimec                                | 5.71     | 5.71   |
| Abamectin (AB)          | Aceplan 20 SP, Mopistop, Morsuplan 20 SP, Rustilan | 11.18    | 9.32   |
| Abamectin (AB)          | Cetam 20% SL                            | 5.59     | 4.66   |
| Acetamiprid (AC)        | Picador 20% SL                          | 2.80     | 2.33   |
| Acetamiprid (AC)        | Ghazal 20 SP                            | 4.66     | 3.87   |
| Acetamiprid (AC)        | 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  |
| 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  |
| Hexythiazox (HX)        | Acarol 10 Wp                            | 23.80    | 19.04  |
| Hymexazol (HY)          | Tachigazole, Tachigaren 30 SL           | 12.75    | 4.25   |
| Imidacloprid (IM)       | Confidor Supra, Fidor Super 70          | 21.20    | 17.65  |
| Indoxacarb (IN)         | Zinad 15 SC                             | 40.00    | 80.00  |
| Linuron (LI)            | Etalon                                  | 0.04     | 0.08   |
| Mancozeb (MA)           | Dithane M 45, Manco 80 Riva, Mancophyt  | 1.75     | 1.75   |
| Metribuzin (ME)         | Manco 80 Wp                             | 1.40     | 1.40   |
| Metribuzin (ME)         | Turbo, Ribuzine                         | 3.73     | 6.21   |
| Thiacloprid (TH)        | Metribuzell 70 WP                       | 2.87     | 4.83   |
| Triadimenol (TR)        | Calypso                                 | 2.12     | 2.12   |
| Triadimenol (TR)        | Trifidan 25                             | 30.65    | 61.30  |
| Trifloxystrobin (TF)    | Vidan 25                                | 6.13     | 10.18  |
| Trifloxystrobin (TF)    | Flint 50 XG                             | 26.30    | 105.20 |
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 injuries 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
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