

Research Article

Prioritization of Applied Pesticides in Ethiopia for Routine Chemical Surveillance Based on Environmental Mobility, Usage Quantity, and Non-Communicable Diseases Effect

Tassew Arega Faris^{1,*} , Abel Weldtinsae², Mesay Getachew¹, Melaku Gizaw¹, Daniel Abera¹, Samson Mideksa¹

¹Non-Communicable Disease Research Division, Ethiopian Public Health Institute, Addis Ababa, Ethiopia

²Environmental and Climate Change Research Division, Ethiopian Public Health Institute, Addis Ababa, Ethiopia

Abstract

Ethiopia is one of the largest users of pesticides in East Africa for agricultural and other purposes. Pesticides provide benefits such as protecting crops from losses, maximizing yields, and controlling vectors. However, if not properly managed or controlled, pesticides can create environmental and public health risks like ocular, dermal, cardiovascular, gastrointestinal, carcinogenic, endocrine-disrupting (hormonal), developmental (reproductive), neurological (mental), mutagenic (genetic mutation), and respiratory effects. The aim of the study was to identify and prioritize pesticides for routine public health surveillance in Ethiopia using a multi-index approach. This ranking technique is based on current pesticide use (Quantity Index or QI), mobility in the environment (Environmental Exposure Potential or EEP), and acute and chronic health risks (Toxicity Potential or TP, and Hazard Potential or HP). Pesticide use and data on physicochemical and toxicity were used to prioritize pesticides for human health risk. Four indices were used for prioritization. The Quantity Index (QI) ranked pesticides by their use quantity. The Toxicity Potential Index (TP) ranked pesticides based on scores from five health effects: endocrine disruption, carcinogenicity, teratogenicity, mutagenicity, and neurotoxicity. The Hazard Potential Index (HP) was calculated by multiplying the TP by an environmental exposure potential score determined by the GUS index for each pesticide. The Weighted Hazard Potential (WHP) multiplied the HP by the ratio of a pesticide's use to the total use of all pesticides in the country. The highest scoring numbers for each effect—cancer, mutagenicity, endocrine disruption, teratogenicity, and neurotoxicity—were used for prioritization. The quantity of 2, 4-D pesticide was very high across all QI, TP, HP, and WHP, whereas permethrin was the only pesticide with a higher TP value and a high risk to human beings for carcinogenicity, endocrine-disrupting chemicals, teratogenicity, and neurotoxicity or mental effects. Folpet pesticide was the highest risk for human beings from Mutagenicity or Genetic mutation effect. Endosulfan and Flutriafol pesticides had the highest GUS values, which mean the highest mobility potential and risk to groundwater. This prioritization can be useful to inform the level of pesticides, develop monitoring programs, identify priority areas for management interventions, investigate optimal mitigation strategies, and estimate the human and environmental risks at a national level.

Keywords

Pesticide, Risks, Prioritizing, Environment, Teratogenicity, Mutagenicity, Carcinogenicity, Neurotoxicity, Ethiopia

*Corresponding author: seidarega33@gmail.com (Tassew Arega)

Received: 18 December 2025; Accepted: 6 January 2026; Published: 26 January 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Pesticides are one of the agricultural sectors, to increase productivity and alleviate food insecurity. Pesticides are applied in large-scale greenhouses and small-scale irrigation farms. The application of pesticides is not limited to agriculture only; since the 1940s, Ethiopia has been utilizing pesticides for disease control and prevention programs. For the control of malaria, DDT and Malathion have been used ubiquitously. For this reason, Ethiopia is a signatory to important international conventions, such as the Stockholm Convention and Basel Convention, which are primarily designed for the control and/or eradication of hazardous pesticides.

If not properly managed or controlled, pesticides can potentially create environmental and public health risks [19]. These risks could be high, particularly for those occupationally exposed [12]. Occupational pesticide exposure can occur directly during mixing and pesticide application and indirectly while performing re-entry tasks in pesticide-treated crops or by take-home exposure. Pesticide exposure can occur through the skin (dermal uptake), via the respiratory system (inhalation), or the mouth (ingestion). It may result in health effects like ocular, dermal, cardiovascular, gastrointestinal, carcinogenic, endocrine disruption, developmental, neurological, and respiratory effects [5, 14]. Pesticides can also contaminate water, soil, and vegetation. For instance, the consumption of agricultural produce that has pesticide residue or drinking from water sources that are contaminated with pesticides.

The potential chronic human health effects resulting from exposure to pesticides are well-known and include chronic neurotoxicity, endocrine disruption, immune impacts, genotoxicity, mutagenicity, and carcinogenicity [10].

The combination of potential health risks and environmental exposure is of particular concern in a country like Ethiopia, where, whilst great progress has been made in improving water, sanitation, and supply, many poor and rural Ethiopians do not have access to treated, piped water and often make use of water collected directly from surface and groundwater resources [16].

Taking into consideration the potential human health effects associated with exposure to agro-chemicals and their intensive use, alongside the challenges posed by the questionable supply and quality of drinking water in poor communities, it becomes essential to address the interconnected issues of pesticide exposure, water quality, and health risks. The combination of these factors can lead to significant public health concerns, particularly in rural areas where access to safe and clean drinking water is limited. This study aims to highlight the importance of monitoring and managing the risks associated with pesticides to safeguard human health and ensure the availability of high-quality water resources.

It is important to identify and prioritize: 1) Those pesticides that are likely to move into water resources and pose potential risks to human health, and 2) Areas where communities may

be exposed to priority chemicals. Irrespective of the biological entity of concern (e.g., aquatic, terrestrial, or human), pesticide prioritization procedures generally integrate pesticide use, physicochemical properties (or environmental fate models), and toxicity data to indicate potential risk [2, 11, 17].

Other international studies used carcinogenicity as a more relevant toxicity endpoint for non-occupational exposure and also included environmental characteristics (i.e., half-life) as an additional indicator of various environmental exposure potential [8, 13, 18].

For all studies, pesticide sales data were used as a proxy for pesticide use. Whilst these methods provide a national overview of priority pesticides, they do not provide a spatial picture of where priority pesticides are applied and which communities may be at risk of exposure. Linking pesticide use to specific crop types is a useful means of providing a more detailed first level of spatial assessment [1]. This study forms part of a larger integrated project examining the risks of current agricultural pesticide use to human and animal health [20].

Taking the potential negative effect into consideration and creating an implementation mechanism for the signed convention, Ethiopia has promulgated several regulations for the safe management of pesticides or chemicals. Concerning pesticide management, Ethiopia has endorsed a regulation for the registration and control of pesticides (Proclamation number 674/2010) in 2010. Since then, under the leadership of the Ministry of Agriculture, a registry of imported and produced pesticides has been underway. As of 2021, around 781 different concentration mixtures of pesticides of various classes have been registered.

2. Methods

2.1. Overview

Pesticide prioritization was carried out according to the method established by the study [4, 6, 18]. The approach followed two distinct phases. The first phase involves identifying all active ingredients used for agricultural activity in Ethiopia. The list of all active ingredients was collected from the Ministry of Agriculture and Natural Resources and the Plant Health regulatory directorate. The first prioritization was based on usage (quantity applied on agricultural fields) and their toxicity property. The main output from the first phase was eliminating less important pesticides, those with low usage and low toxicity. For the screening, a minimum use threshold was established to ensure that only pesticides with significant presence in the market were considered. This threshold was determined based on economic and logistical considerations, such as the availability of data and the resources required for monitoring numerous compounds. Additionally, toxicological criteria were also taken into account to

pre-emptively identify those compounds that could pose a greater risk, ensuring that our focus remained on those with the highest potential impact.

During the second phase, pesticides were ranked or prioritized according to their relative risk to human health and the environment. The health risk was estimated based on the potential pesticides to cause acute toxicity, endocrine disruption, carcinogenicity, teratogenicity, mutagenic, and neurotoxic effects. Hitherto, the toxicity score was generated and multiplied by the mobility score (a factor of groundwater ubiquity score). The mobility indicates the potential environmental hazard of each pesticide. Finally, the weighted hazard score for each pesticide was developed.

2.2. Pesticide Use Data of Ethiopia

The list of all active ingredients was collected from the Ministry of Agriculture and Natural Resources, Plant Health Regulatory Directorate. Furthermore, additional pertinent information, which is not available to the ministry, was collected from local importers. The distribution of active ingredients might not be available from the ministry; you can find them from the regional state office. Thus, data from a total of 64 local importers were collected. In addition, pesticide use data from the regional agricultural bureau were collected to understand the spatial distribution. Data from the regional bureau considers where they apply, the typical pesticides.

2.3. Pesticide Use Screening

The screening process involves identifying all pesticides imported and sold in Ethiopia. In such a way, the quantity of use was the first approach to prioritize, since pesticides used in large quantities have a larger effect. Thus, all the pertinent information was collected and collated from the Ministry of Agriculture. Based on the acquired information, the minimum cut-off point was decided so that any use below the assigned amount was considered low enough not to be of national importance. All pesticides were ranked by volume of usage (kg).

2.4. Toxicity Screening

Information on endpoints such as endocrine disruption potential, carcinogenicity, mutagenicity, teratogenicity, and neurotoxicity for each active ingredient was collected from [7]. In case the required information is not available for pesticides, the study team tries to review epidemiological and toxicity testing reports to identify the aforementioned endpoints in human health.

2.5. Pesticide Prioritization Criteria

To prioritize pesticides, the following major indicators were used.

- 1) Quantity of use (Index) (QI)
- 2) Toxicity potential (TP)

- 3) Environmental exposure potential (EEP)
- 4) Hazard potential (HP)

2.5.1. Quantity Index (QI)

As of 2021, the Ministry of Agriculture has already registered 781 pesticides. However, the amount being used is not known. Therefore, the study team identified the amount being distributed by local vendors. When such data is not available, a registry of FAO was used to differentiate the amount of chemicals used in each crop-specific agricultural field.

How many active ingredients were found at the country level, for each pesticide ingredient record the quantity of volume /weight and indicate the year of the data that was collected and also identify the fungicide, or insecticide in percent for another type of pesticide type like Fungicides, herbicides, and insecticides accounted for 28%, 32.14% and 33.8% of the total use, respectively.

2.5.2. Toxicity Potential (TP)

Pesticides can have a wide range of toxicological properties. As far as epidemiological studies are concerned, they can cause lethal death, endocrine disruption, carcinogenicity, teratogenicity, and neurotoxic. The toxicological property of all pesticides was collected from the pesticide properties database, [7]. Once their toxicological property was identified, each toxic effect was classified into one of four different endpoint categories, namely "Yes" (there is definitive evidence that the pesticide can cause the toxic effect), "Possible" (there is evidence that the chemical may result toxic effect), No data (No studies have been performed to confirm whether the pesticide does or does not cause the toxic effect), No (there is definitive evidence that the chemicals do not cause the toxic effect). Once this category was created, a scoring method as described by [18] was used to weigh the effect of pesticides.

Table 1. The scoring system used to rank pesticides for five human health effects.

Toxic effect	Classification	Value*
Endocrine disruption	Yes	8
	Possible	6
	No data	3
	No	0
Carcinogenicity	Yes	8
	Possible	6
	No data	3
	No	0
Mutagenicity	Yes	6
	Possible	4

Toxic effect	Classification	Value*
Teratogenicity	No data	2
	No	0
	Yes	4
	Possible	2
	No data	1
	No	0
Neurotoxicity	Yes	4
	Possible	2
	No data	1
	No	0

The scores for carcinogenicity, mutagenicity, and teratogenicity were weighted according to their relative importance for cancer study (i.e. carcinogenicity > mutagenicity > teratogenicity).

The scores for endocrine disruption and neurotoxicity were weighted equally to carcinogenicity and teratogenicity, respectively. The system scores possible evidence of a higher-ranked effect equally to the highest score for a lower-ranked impact. Therefore, assume that a strong potential for a less important effect is at the same level as a weak potential for a more important impact. Effects for which no data were available (i.e., “No Data”) were given a higher value than for a definitive absence of effect (i.e., “No”) as a precautionary measure that essentially accounts for uncertainty. The score was lower than that given for a possible impact, as it is assumed that there is a higher probability that more serious effects would have been identified. For all endpoints, a value of 0 was attributed when the literature reported a proven absence of impacts.

The toxicity potential (TP) was obtained by summing the scores attributed to each of the five toxic effects for each active ingredient. Similar scoring and weighting approaches have been adopted in other prioritization studies [8].

2.5.3. Environmental Exposure Potential (EEP)

It was established that pesticides can translocate either through spray drift, leaching, or runoff. The spray drift is a function of the amount of pesticide being applied, which is, in other words, represented through the QI. The ability of a pesticide to run and leach depends on the physicochemical properties of the pesticide.

Thus, in this prioritization project, a scoring technique called the Groundwater Ubiquity Score or GUS index [9] was used. GUS is a logarithmic scale, where compounds higher than 2.8 are classified as highly mobile and those with a value

less than 1.8 are classified as non-leachers. The GUS index was used as a measure of environmental exposure potential (Table 2) as it has been widely used as an indicator of pesticide mobility in other studies [3, 15] and pesticide property databases [7].

Table 2. scoring system to rank pesticides in terms of their potential exposure risk to water resources based on their groundwater ubiquity score (GUS).

Environmental exposure potential	GUS score	Value
High	GUS>2.8	4
Medium	2.8>GUS>1.8	2
Low	GUS<1.8	1
No data	No Koc or DT50 value	1.5

2.5.4. Hazard Potential (HP)

The hazard potential (HP) indicates the potential for exposure to highly toxic pesticides and is calculated as follows:

$$HP = TP * EEP \quad (1)$$

Where TP is the toxicity potential score of the pesticide, and EEP is the environmental exposure potential.

2.5.5. Weighted Hazard Potential (WHP)

Weighted Hazard potential is the result of HP multiplied by the proportion of the usage of the pesticide relative to the total usage of all pesticides.

$$WHP = HP * QI/Q_{tot} \quad (2)$$

Where HP is the hazard potential of the pesticide, QI is the total quantity of usage (kg) of the pesticide nationally and Q_{tot} is the sum of the quantity of usage (kg) of all the pesticides.

3. Results and Discussion

In this analysis, 173 active pesticide ingredients were identified at a country level. For those pesticides, the quantity of use, the environmental health risk, and human health risk data were generated based on the pesticide prioritization index. The total quantity of the 25 top-ranked pesticides in each index was (29465106.3, 24022482, 22829290, and 29106636.5) Kg for the QI, TP, HP, and WHP, respectively.

Table 3. The calculated quantity of top 25 ranked pesticides for (QI — quantity index, TP — toxicity potential, HP — hazard potential, WHP — weighted hazard potential) prioritization indices values.

S.no.	Active Ingre- dient	QI(Kg)	Active Ingredi- ent	TP(Kg)	Active Ingredi- ent	HP(Kg)	Active Ingre- dient	WHP (Kg)
1	2,4-D	21792372.9	Permethrin	113.5	2,4-D	21792373	2,4-D	21792372.9
2	Glyphosate	2154281	Thiacloprid	210842	Endosulfan	46850	Glyphosate	2154281
3	Dimethoate	518055.2	2,4-D	21792373	Propoxur	17235	Atrazine	422307.5
4	Mancozeb	481229.6	Deltamethrin	160882.3	Cyproconazole	20600	Dimethoate	518055.2
5	Aluminium phosphide	460587.58	piperonyl butoxide	50	Methoxyfenozide	112506	Mancozeb	481229.6
6	Atrazine	422307.5	Acephate	1484	Topramezone	156	S-metolachlor	357704.5
7	S-metolachlor	357704.5	Bifenthrin	1940.5	Clothianidin	300	Fipronil	184250
8	Bifenazate	322367	Bromoxynil octanoate	4702.6	Sulfosulfuron	500	Methoxyfenozide	112506
9	Triadimefon	295092	Carbaryl	667	Carbaryl	667	Triadimefon	295092
10	Chlorothalonil	273279.1	Chlorothalonil	273279.1	Epoxiconazole	15	Chlorothalonil	273279.1
11	Carbosulfan	257181	Epoxiconazole	15	Flubendiamide	36011	Deltamethrin	160882.3
12	Clofentezine	251745	Triadimefon	295092	Flutriafol	1180	Mecoprop	200543.14
13	Thiacloprid	210842.001	Benomyl	346	Metribuzin	98	Thiacloprid	210842.001
14	Mecoprop	200543.14	Acetochlor	10.7	Nicosulfuron	20200	Aluminium phosphide	460587.58
15	Fipronil	184250	α -cypermethrin	40000	Permethrin	113.5	Tebuconazole	150105.5
16	Dimethomorph	176870.2	Atrazine	422307.5	Atrazine	422307.5	Bifenazate	322367
17	Deltamethrin	160882.3	Diazinon	15640	Fipronil	184250	Pyroxsulam	115229
18	Tebuconazole	150105.5	Fipronil	184250	Imidacloprid	340	Endosulfan	46850
19	Profenfos	147063	Iprodione	9046	Deltamethrin	160882.3	Malathion	117159.38
20	Malathion	117159.38	Malathion	117159.4	piperonyl butoxide	50	Clofentezine	251745
21	Pyroxsulam	115229	Mancozeb	481229.6	Carbendazim	4256	Dimethomorph	176870.2
22	Methoxyfenozide	112506	Pendimethalin	1600	Diuron	1530	Flubendiamide	36011
23	Metalaxyl-M	103791.8	Thiram	78	Metolachlor	226.5	Clomazone	98703.6
24	Trifloxystrobin	100084	Bioallethrin	20.24	Bifenthrin	1940.5	Profenfos	147063
25	Fenoxaprop-p-ethyl	99577.6	Dicofol	9354	Bromoxynil octanoate	4702.6	Cyproconazole	20600
	Total	29465106.3	Total	24022482	Total	22829290	Total	29106636.5
		Q _{tot} (total 173 pest)	30882378.93 kg					

The quantity of 2, 4-D pesticide values for all QI, TP, HP, and WHP were very high values, whereas Permethrin pesticide was the only higher TP value as compared with other pesticides. The quantity use of 2, 4-D and Permethrin pesticides

was very high and very low, whereas the toxicity potential of 2, 4-D and Permethrin pesticides was low and very high, respectively. On the other hand, the hazardous potential of 2, 4-D was very high compared with other pesticides. Due to these

reasons, the WHP values of 2, 4-D were very high. 2, 4-D pesticide was very high at the national level by health risk and the quantity usage (Table 4).

Table 4. The calculated (QI — quantity index, TP — toxicity potential — hazard potential; WHP — weighted hazard potential) prioritization indices values of the top 25 ranked pesticides.

S.no.	Active ingredients	QI	Active ingredients	TP	Active ingredients	HP	Active ingredients	WHP
1	2,4-D	21792372.9	Permethrin	26	2,4-D	88	2,4-D	62.09783
2	Glyphosate	2154281	Thiacloprid	24	Endosulfan	64	Glyphosate	1.255637
3	Dimethoate	518055.2	2,4-D	22	Propoxur	64	Atrazine	0.492289
4	Mancozeb	481229.6	Deltamethrin	22	Cyproconazole	56	Dimethoate	0.469703
5	Aluminium phosphide	460587.58	piperonyl butoxide	22	Methoxyfenozide	56	Mancozeb	0.420732
6	Atrazine	422307.5	Acephate	21	Topramezone	56	S-metolachlor	0.301153
7	S-metolachlor	357704.5	Bifenthrin	20	Clothianidin	48	Fipronil	0.214783
8	Bifenazate	322367	Bromoxynil octanoate	20	Sulfosulfuron	44	Methoxyfenozide	0.204011
9	Triadimefon	295092	Carbaryl	20	Carbaryl	40	Triadimefon	0.191107
10	Chlorothalonil	273279.1	Chlorothalonil	20	Epoxiconazole	40	Chlorothalonil	0.176981
11	Carbosulfan	257181	Epoxiconazole	20	Flubendiamide	40	Deltamethrin	0.171914
12	Clofentezine	251745	Triadimefon	20	Flutriafol	40	Mecoprop	0.168838
13	Thiacloprid	210842.001	Benomyl	19	Metribuzin	40	Thiacloprid	0.163854
14	Mecoprop	200543.14	Acetochlor	18	Nicosulfuron	40	Aluminium phosphide	0.149143
15	Fipronil	184250	Alpha-cypermethrin	18	Permethrin	39	Tebuconazole	0.126374
16	Dimethomorph	176870.2	Atrazine	18	Atrazine	36	Bifenazate	0.114824
17	Deltamethrin	160882.3	Diazinon	18	Fipronil	36	Pyroxsulam	0.104474
18	Tebuconazole	150105.5	Fipronil	18	Imidacloprid	36	Endosulfan	0.097091
19	Profenfos	147063	Iprodione	18	Deltamethrin	33	Malathion	0.068287
20	Malathion	117159.38	Malathion	18	piperonyl butoxide	33	Clofentezine	0.065214
21	Pyroxsulam	115229	Mancozeb	18	Carbendazim	32	Dimethomorph	0.057272
22	Methoxyfenozide	112506	Pendimethalin	18	Diuron	32	Flubendiamide	0.046643
23	Metalaxyl-M	103791.8	Thiram	18	Metolachlor	32	Clomazone	0.044746
24	Trifloxystrobin	100084	Bioallethrin	17	Bifenthrin	30	Profenfos	0.042858
25	Fenoxaprop-p-ethyl	99577.6	Dicofol	17	Bromoxynil octanoate	30	Cyproconazole	0.037355
	Total	29465106.3	Total	490	Total	1085	Total	67.28312

From the 173 total national pesticides, 16.19% (high), 15.03% (medium), 20.23% (no data), and 48.56% (low) environmental exposure potential risk to water based on groundwater ubiquity score (GUS). From this (i.e., 48.56%), most pesticides had lower environmental exposure potential.

Endosulfan (GUS index= 5.28), and Flutriafol (GUS index= 5.18) pesticides had the highest GUS values, which means the highest mobility potential and risk to groundwater.

Table 5. The calculated Environmental Exposure Potential.

S.no.	Active ingredients	GGUS index US index	EEP (mobility)	S.no.	Active ingredients	GGUS index US index	EEP (mobility)
1	Endosulfan	5.28	High	15	Chlorantraniliprole	3.51	High
2	Flutriafol	5.18	High	16	Nicosulfuron	3.44	High
3	Amicarbazone	4.89	High	17	Metsulfuron-methyl	3.28	High
4	Hexazinone	4.43	High	18	Fluopyram	3.23	High
5	Flumetsulam	4.22	High	19	Azoxystrobin	3.1	High
6	Sulfosulfuron	4.09	High	20	Cyproconazole	3.04	High
7	Flubendiamide	3.98	High	21	Clopyralid	3.02	High
8	Tricyclazole	3.89	High	22	Methoxyfenozide	3	High
9	Mesosulfuron -methyl	3.85	High	23	MCPA	2.98	High
10	2,4-D	3.82	High	24	Metribuzin	2.96	High
11	Clothianidin	3.74	High	25	Flucarbazone-sodium	2.94	High
12	Imidacloprid	3.69	High	26	Topramezone	2.88	High
13	Propoxur	3.65	High	27	Chlorimuron-ethyl	2.86	High
14	Thiamethoxam	3.58	High	28	Pyroxsulam	2.84	High

The pesticides were very high risk to human beings from carcinogenicity or Cancer effects (Permethrin, Chlorothalonil, Epoxiconazole, and Diuron which were the scoring system for human impact (score of 8) respectively.

Table 6. Pesticides that have the highest Cancer Effect.

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	Name of Pesticides
1	Permethrin	25	Isoxaflutole	49	Metolachlor
2	Chlorothalonil	26	Ethoprophos	50	Cyproconazole
3	Epoxiconazole	27	Propoxur	51	Tribenuron methyl
4	Diuron	28	Tetramethrin	52	Bupirimate
5	Thiacloprid	29	Mecoprop	53	Picoxystrobin
6	2,4-D	30	Fosetyl	54	Dimethenamid-P
7	Deltamethrin	31	Benomyl	55	Sulfosulfuron
8	piperonyl butoxide	32	Topramezone	56	Diclofop-methyl
9	Bifenthrin	33	S-metolachlor	57	Fludioxonil
10	Fipronil	34	Thiophanate-methyl	58	Dithianon
11	Malathion	35	Propiconazole	59	Paraquat
12	Diazinon	36	Terbutylazine	60	Boscalid
13	Acephate	37	Tembotrione	61	Clofentezine
14	Dicofol	38	Tebufenpyrad	62	Difenoconazole

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	Name of Pesticides
15	Carbaryl	39	Allethrin	63	Bioallethrin
16	Triadimefon	40	Bromoxynil octanoate	64	Hexaconazole
17	Alpha-cypermethrin	41	Mancozeb	65	Folpet
18	Atrazine	42	Iprodione	66	Nicosulfuron
19	Thiram	43	Pendimethalin	67	Methoxyfenozide
20	Cypermethrin	44	Acetochlor	68	Glyphosate
21	Dicamba	45	Carbendazim	69	Penoxsulam
22	Mepiquat chloride	46	Tebuconazole	70	Kresoxim-methyl
23	Dimethoate	47	Alachlor	71	Carfentrazone-ethyl
24	Clodinafop- Propargyl	48	Chlorfenapyr	72	Glyphosate, isopropylamine salt

Folpet, which was the scoring system for human impact (score of 6). Dimethoate and Oxydemeton-methyl pesticides were at the highest risk for human beings from Mutagenicity or Genetic mutation effect, next to Folpet.

Table 7. Pesticides that have the highest Mutagenicity effect.

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	Name of Pesticides
1	Folpet	29	Acetochlor	57	Mesosulfuron -methyl
2	Dimethoate	30	Alachlor	58	Zinc phosphide
3	Oxydemeton-methyl	31	Chlorfenapyr	59	Bixafen
4	Permethrin	32	Metolachlor	60	Diafenthiuron
5	Chlorothalonil	33	Picoxystrobin	61	oxymatrine/ martin
6	Epoxiconazole	34	Dimethenamid-P	62	Tricyclazole
7	Thiacloprid	35	Paraquat	63	Prallethrin
8	2,4-D	36	Boscalid	64	Fatty alcohol ethoxylate
9	Deltamethrin	37	Bioallethrin	65	Halauxifen-methyl
10	piperonyl butoxide	38	Hexaconazole	66	Trifloxystrobin
11	Acephate	39	Methoxyfenozide	67	Pyraclostrobin
12	Triadimefon	40	Glyphosate, isopropylamine salt	68	Chlorimuron-ethyl
13	Atrazine	41	Flocoumafen	69	Saflufenacil
14	Thiram	42	Ametrine	70	Hexazinone
15	Dicamba	43	Rape seed oil	71	MCPA
16	Propoxur	44	Endosulfan	72	Copper (II) hydroxide
17	Tetramethrin	45	Amitraz	73	Spinosad
18	Mecoprop	46	Indoxacarb	74	Flumetsulam
19	Fosetyl	47	Flucythrinate	75	Diclosulam
20	Benomyl	48	Cyfluthrin	76	Acetamiprid
21	S-metolachlor	49	Fluroxypyr	77	Sulfur
22	Thiophanate-methyl	50	Profenfos	78	Amicarbazone

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	
23	Propiconazole	51	iodosulfuron-methyl-sodium	79	Novaluron
24	Allethrin	52	Bifenazate	80	Flucarbazone-sodium
25	Bromoxynil octanoate	53	Emamectin Benzoate	81	Polyoxin AL
26	Mancozeb	54	Prometryn	82	Brodifacoum
27	Iprodione	55	Fenthion		
28	Pendimethalin	56	Thidiazuron		

The pesticides were very high risk to human beings from endocrine disrupting chemicals or EDCs (Permethrin, Thiacloprid, and Deltamethrin, which were the scoring system for human effect (score of 8).

Table 8. Pesticides that have the highest Endocrine disruptor effect.

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	
1	Permethrin	22	Benomyl	43	Cypermethrin
2	Thiacloprid	23	Propiconazole	44	Carbendazim
3	Deltamethrin	24	Allethrin	45	Cyproconazole
4	piperonyl butoxide	25	Mancozeb	46	Tribenuron methyl
5	Acephate	26	Iprodione	47	Bupirimate
6	Bromoxynil octanoate	27	Pendimethalin	48	Glyphosate
7	Bioallethrin	28	Acetochlor	49	Penoxsulam
8	Prometryn	29	Alachlor	50	Bromadiolone
9	Bifenthrin	30	Chlorfenapyr	51	Chlorpyrifos
10	Carbaryl	31	Metolachlor	52	Chlorpyrifos ethyl
11	Flufenoxuron	32	Hexaconazole	53	Clothianidin
12	Flubendiamide	33	Methoxyfenozide	54	Bendiocarb
13	Fenitrothion	34	Endosulfan	55	Propamocarb hydrochloride
14	Chlorothalonil	35	Amitraz	56	Copper oxychloride
15	Epoxiconazole	36	Indoxacarb	57	Penconazole
16	2,4-D	37	Diuron	58	Flutriafol
17	Triadimefon	38	Fipronil	59	Metribuzin
18	Atrazine	39	Malathion	60	Pyriproxyfen
19	Thiram	40	Diazinon	61	Myclobutanil
20	Propoxur	41	Dicofol	62	Beta-cypermethrin
21	Tetramethrin	42	Alpha-cypermethrin	62	Beta-cypermethrin

The pesticides were very high risk to human beings from Teratogenicity or reproduction /development effects were Permethrin, Thiacloprid, and Bromoxynil octanoate, which were the scoring system for human effects (score of 4), respectively.

Table 9. Pesticides that have the highest Teratogenicity effect.

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	Name of Pesticides
1	Permethrin	16	Carbendazim	31	Cymoxanil
2	Thiacloprid	17	Bromadiolone	32	Thiencarbazone-methyl
3	Bromoxynil octanoate	18	Chlorpyrifos	33	Dodemorph acetate
4	Carbaryl	19	Chlorpyrifos ethyl	34	Fenbutatin oxide
5	Chlorothalonil	20	Penconazole	35	Oxydemeton-methyl
6	Epoxiconazole	21	Flutriafol	36	S-metolachlor
7	2,4-D	22	Metribuzin	37	Thiophanate-methyl
8	Triadimefon	23	Bifenazate	38	Trifloxystrobin
9	Benomyl	24	Zinc phosphide	39	Pyraclostrobin
10	Mancozeb	25	Bixafen	40	Abamectin
11	Iprodione	26	Halauxifen-methyl	41	Glufosinate-ammonium
12	Pendimethalin	27	Topramezone	42	Prothioconazole
13	Acetochlor	28	Tebuconazole	43	Spinetoram
14	Endosulfan	29	Imidacloprid		
15	Alpha-cypermethrin	30	Clomazone		

The Permethrin, Thiacloprid, and 2, 4-D pesticides were very high risk to a human being from Neurotoxicity or mental effects, which were the scoring system for human effect (score of 4).

Table 10. Pesticides that have the highest Neurotoxicity effect.

S.no.	Name of Pesticides	S.no.	Name of Pesticides	S.no.	Name of Pesticides
1	Permethrin	11	piperonyl butoxide	21	Cyfluthrin
2	Thiacloprid	12	Bifenthrin	22	Fluroxypyr
3	2,4-D	13	Amitraz	23	Acephate
4	Endosulfan	14	Indoxacarb	24	Dicofol
5	Chlorpyrifos	15	Fipronil	25	Profenfos
6	Chlorpyrifos ethyl	16	Malathion	26	iodosulfuron-methyl-sodium
7	Oxydemeton-methyl	17	Diazinon	27	Mesotrione
8	Abamectin	18	Clothianidin	28	Carbaryl
9	Glufosinate-ammonium	19	Bendiocarb		
10	Deltamethrin	20	Flucythrinate		

4. Conclusion

The prioritization approach is used to inform the level of pesticides, develop monitoring programs, identify priority areas for

management interventions, and investigate optimal mitigation strategies. The reliability of sales data as a proxy for pesticide use data has high associated uncertainty, but it is currently the most effective and widely used means of performing such assessments. The importance of this methodology is to prioritize the list of pes-

ticides based on four indices, ensuring the highly toxic and mobile pesticides, as well as high-use pesticides, are included. Generally, the pesticide prioritization process is used to estimate the human and environmental risks at a national level, because pesticide data is often only available as the total quantity of a pesticide sold (or used).

5. Recommendation

This study is the first assessment at the national level. Addressing and prioritizing applied pesticides has recently emerged as a global priority, and hence, it is very necessary to identify pesticides with high mobility, large volume of use, together with significant potential health impacts, for further investigation or mitigation strategies. By carefully considering the findings of this study, further research, risk assessment, and potential regulations with a multi-faceted approach are required.

Abbreviations

QI	Quantity Index
TP	Toxicity Potential
HP	Hazard Potential
WHP	Weighted Hazard Potential
EEP	Environmental Exposure Potential
2,4-D	2,4-Dichlorophenoxyacetic Acid
MOA	Minister of Agriculture
FAO	Food and Agricultural Organization
GUS	Groundwater Ubiquity Score
C	Carcinogenicity/Cancer Effect
ED	Endocrine Disruptor /Body Hormone Effect
T	Teratogenicity /Reproduction/Development Effect
N	Neurotoxicity/Mental Effect
M	Mutagenicity/Genetic Mutation Effect

Conflicts of Interest

There is no conflict of interest.

References

- [1] Brown CD, Holmes C, Williams R, Beulke S, van Beinum W, Pemberton E, et al. How does crop type influence risk from pesticides to the aquatic environment? *Environ Toxicol Chem* 2007; 26(9): 1818-26.
- [2] Claeys S, Vagenende B, De Smet B, Lelieur L, Steurbaut W. The POCER indicator: a decision tool for non-agricultural pesticide use. *Pest Manag Sci* 2005; 6: 779-86.
- [3] Claver A, Ormad P, Rodríguez L, Ovelheiro JL. Study of pesticides in surface water in the Ebro River basin (Spain). *Chemosphere* 2006; 64: 1437-43.
- [4] Dalvie MA, Africa A, London L. Change in the quantity and acute toxicity of pesticides sold in South African crop sectors, 1994-1999. *Environ Int* 2009; 35(4): 683-7.
- [5] Damalas CA, Eleftherohorinos IG. (2011) Pesticide exposure, safety issues, and risk assessment indicators. *Int J Environ Res Public Health*; 8: 1402-19.
- [6] Dombrowski, S. U., Knittle, K., Avenell, A., Araújo-Soares, V., & Snihotta, F. F. (2014). Long term maintenance of weight loss with non-surgical interventions in obese adults: systematic review and meta-analyses of randomised controlled trials. *BMJ*, 348.
- [7] Footprint, the Footprint Pesticide Properties Database. Database collated by the University of Hertfordshire as part of the EU-funded Footprint project (FP6-SSP-022704), 2006. <http://www.eu-footprint.org/ppdb.html>
- [8] Gunier RB, Hamly ME, Reynolds P, Hertz A, and Von Behren J. Agricultural pesticide use in California: pesticide prioritization, use densities, and population distributions for a childhood cancer study. *Environ Health Perspect* 2001; 109(10): 1071-8.
- [9] Gustafson DI. Groundwater ubiquity score: a simple method for assessing pesticide leachability. *Environ Toxicol Chem* 1989; 8(4): 339-57.
- [10] Hallenbeck WH, Cunningham-Burns KM. Pesticides and human health. London: Springer; 2011 [166 pp.].
- [11] Kookana RS, Correll RL, Miller RB. Pesticide impact rating index — a pesticide risk indicator for water quality. *Water Air Soil Pollut* 2005; 5: 45-65.
- [12] McCauley LA, Anger WK, Keifer M et al. (2006) Studying health outcomes in farm workers population exposed to Pesticides. *Environ Health Perspect*; 114: 953-60.
- [13] Monge P, Partanen T, Wesseling C, Bravo V, Ruepert C, Burstyn I. Assessment of pesticide exposure in the agricultural population of Costa Rica. *Ann Occup Hyg* 2005; 49(5): 375-84.
- [14] Ntzani EE, Chondrogiorgi M, Ntritsos G et al. (2013) Literature review on epidemiological studies linking exposure to pesticides and health effects. European Food Safety Authority supporting publication. Available at: www.efsa.europa.eu/publications/497e.pdf Accessed 31 June 2015.
- [15] Papa E, Castiglioni S, Gramatica P, Nikolayenko V, Kayumov O, Calamari D. Screening the leaching tendency of pesticides applied in the Amu Darya Basin (Uzbekistan). *Water Res* 2004; 38: 3485-94.
- [16] STATSSA (Statistics South Africa). Census 2011: census in brief. Report no 03-01-41; 2012 [105 pp.].
- [17] Trevisan M, Di Guardo A, Balderacchi M. An environmental indicator to drive sustainable pesticide management practices. *Environ Model Software* 2009; 24(8): 994-1002.
- [18] Valcke M, Chaverri F, Monge P, Bravo V, Mergler D, Partanen T, et al. Pesticide prioritization for a case-control study on childhood leukemia in Costa Rica: a simple stepwise approach. *Environ Res* 2005; 97(3): 335-47.

- [19] Vergucht S, de Voghel S, Misson C et al. (2006) Health and environmental effects of pesticides and type 18 biocides (HEPEBI). Available at: <http://www.crphyto.be/pdf/heepebi.pdf> Accessed 10 October 2015.
- [20] WRC (Water Research Commission). Knowledge review 2010/2011. Pretoria, South Africa: Water Research Commission; 2011 [252 pp.].