Heliyon 6 (2020) e05524

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Suggested policy and legislation reforms to reduce deleterious effect of pesticides in Lebanon

Mohamad I. Abou Zeid [a,b], Adla M. Jammoul [b], Khalil C. Melki [c], Yusuf Abou Jawdah [d], Mireille Kallassy Awad [a,*]

[a] Faculty of Sciences, Biotechnology Laboratory, UR EGP, Saint- Joseph University, B.P. 11-514 Riad El Solh, Beirut, 1107 2050, Lebanon
[b] Kfarchima Laboratory, Ministry of Agriculture, Kfarchima, Lebanon
[c] Unifert s.a.l., P.O. Box 11-6937, Beirut Riad El Solh, 1107 2230, Lebanon
[d] Department of Agriculture, Faculty of Agricultural & Food Sciences, American University of Beirut, Bliss Street, P.O. Box 11-0236, Riad El-Solh, 1107-2020, Beirut, Lebanon

ARTICLE INFO

Keywords:
Policy
Legislations
Reforms
Pesticides
Prescription
Developing countries
Risk reduction
Agricultural policy
Crop protection
Chemical pest control
Environmental assessment
Legislation

ABSTRACT

Countrywide pesticide management activities are resource draining, even for developed countries, which sometimes fall short in achieving the optimum protection against pesticides deleterious effects on humans and environment. Additionally, in Lebanon, basic flaws exist at different levels of pesticide management cycle. In this study, through an extensive review of relevant literature regarding the pesticides impact on humans and environment in Lebanon and adopted policies in existing legislation, several gaps have been identified. Accordingly, recommendations to reduce pesticide risk through a combination of reforms at the policy level and its tools, particularly legislation, are proposed. In our opinion, the starting point is to adopt a minimum list of lower risk pesticides supported by a combination of: "prescriptions" based on a comprehensive registration and an effective implementation systems, a suitable IPM/ICM government-supported credit system, traceability systems of agricultural commodities and pesticides containers, Pesticide stock management system to reduce the quantity of obsolete pesticides, and containers recycling system. For a global sustainability of pesticides risk reduction, a binding global intervention fostered by the UN, based on human rights for safe food, is called upon to ban hazardous pesticides-except those of WHO class IV- trafficking in developing countries scoring low in an international official assessment of their pesticides lifecycle management. At the same time, global funds should support pesticides alternatives and the enhancement of the developing countries capacities for pesticides lifecycle management, which is a part of a larger global matrix in risk reduction.

1. Introduction

Many agricultural experts strongly believe that currently, pesticides represent a technology without which it would be difficult to feed an increasing world population, and famines would prevail. It is estimated that, by the year 2050, when the world's population reaches about 9 billion (Alexandratos and Bruinsma, 2012; Cox and Surgan, 2006), there won't be enough agricultural land and resources to produce food with today's technologies. What would the picture look like if we knew that up to 50% of crops' yield worldwide is lost due to pest infestations at the different stages of crop production and marketing (Oerke, 2006)? Hence, emerges the omnipresent importance of pesticides. On the other hand, other scientists believe (Horgan, 2017; van den Berg, 2004) the essentiality of pesticides for food security is only a "myth" aggressively promoted for by the agrochemical companies that have invested lots of money to influence policymakers and contest scientific evidence (The Lancet, 2017). Safe alternatives, such as agroecology, to intensified agricultural production systems that rely heavily on pesticides exist and is capable of feeding 9 billion now without violating human rights for safe and healthy food (UN/Human Rights Council, 2017). Between these two extremes, some consider that only the highly hazardous and hazardous pesticides categories constitute the core of the problem of human and environmental health and need to be substituted (Jepson et al., 2020a) along with the introduction of new plant production and protection technologies. Scientists around the world, along with giant chemical pesticide companies through acquisition or partnership with

* Corresponding author.
E-mail address: Mireille.kallassy@usj.edu.lb (M.K. Awad).

https://doi.org/10.1016/j.heliyon.2020.e05524
Received 22 April 2020; Received in revised form 2 October 2020; Accepted 12 November 2020

other specialized companies, like Bayer crop science/Monsanto, Syngenta/Chemchina, BASF, Dupont-DowAgroSciences/Corteva, and Sumitomo (Olson, 2015), are developing alternatives, such as microbial pesticides, genetic engineering tools, biomolecules and safer/reduced risk molecules to replace or reduce the use of conventional pesticides in the intent of reducing hazard to people and environment, decreasing cost of production, protecting workers, and appeasing a cautious public (Borel, 2017). It is estimated that the return of a 1 $ investment in ecologically friendly practices to control pests is 30–300 $, which is far more than the 4 $ return achieved by chemical pesticides (Culliney, 2014). Likewise, Pretty and Bharucha (2015a, b) have estimated the external costs of pesticides by $4–$19 (€3–15) per kg of active ingredient applied, suggesting that IPM approaches that result in lower pesticide use will benefit not only farmers but also wider environments and human health (Pretty and Bharucha, 2015a). Practically, it is hard to deny, at least for the time being, the fact that pesticides, even the synthetic ones, can still play a certain role in crop productivity and profitability if they are used judiciously and within the context of an integrated pest management program (Lechenet et al., 2017). Unfortunately, the synthetic chemical pesticides represent a technology that does not come without a price. In fact, pesticides have their own advantages and disadvantages, and registration authorities do conduct benefit/risk analysis. Pesticides have proven to be fast, easy to use, and an effective tool to pest control with visible results to produce an abundance of unblemished agricultural commodities (Damalas and Eleftherohorinos, 2011). On the other hand, pesticides have been incriminated and held responsible for having a deleterious effect on biodiversity and natural balance, causing resurgence of pest resistance, leaving residues in food, posing risks to human health if used improperly, increasing the risk for direct poisoning of applicators, and contaminating soil and ground water (Bonvoisin et al., 2020; Jepson et al., 2020b; Karunarathne et al., 2020; Pimentel and Burgess, 2005; Zhang et al., 2015).

Accordingly, to benefit from pesticides merits and avoid the negative implications of their use on human health and environment, governments around the world have created a legislative tool, known as registration of pesticides. Registration, according to the international code of conduct on Pesticide Management, means "the process whereby the responsible national government or regional authority approves the sale and use of a pesticide, following the evaluation of comprehensive scientific data demonstrating that the product is effective for the intended purposes and does not pose an unacceptable risk to human or animal health or the environment under the conditions of use in the country or region." (FAO, 2014). Accordingly, pesticide registration is not supposed to be the privilege of only the rich and developed countries. Resource poor countries, such as Lebanon, are not supposed to minimize the measures that mitigate the pesticides hazards because of a shortage of resources needed to conduct studies or, at least, to assess them as well as to conduct monitoring and surveillance to take corrective measures. Developing countries that want to authorize for use the same pesticides in number and quality, especially the newer and the safer active ingredients, in their combat against pests, should wisely invest their limited resources to fulfill only the essential requirements of pesticides registration and post-registration, unlike the advanced countries that are capable of fulfilling all the requirements. Developing countries need not repeat many of the active ingredients' studies made public on many official sites. The "Agence nationale de la sécurité sanitaire, de l'alimentation, de l'environnement et du travail" (ANSES)-France had a budget of 135 million euros in 2017 to conduct the work (SENAT FRANCAIS, 2017), which represents the budget of one rapporteur country of the 37 countries of the OECD. Likewise, the Environmental Protection Agency's-EPA-total budget is about 6.146 billion dollars, 161.6 million of which is for ensuring the safety of pesticides and chemicals in the marketplace (EPA, 2019). In addition, both agencies charge registration fees (EPA, 2015a). Nevertheless, the public of advanced countries is still dissatisfied with registration schemes adopted by these countries, and his concerns are not appeased. Many articles reveal the public concerns that the pesticide registration system is not satisfactory, and there is a demand for a more stringent pesticide regulatory framework (InfoCuria and Case-law, 2019; Storck et al., 2017). For example, the EPA was claimed to be "arbitrary and capricious" when it refused to revoke the registration of chlorpyrifos in response to a petition, claiming that its tolerances constitute a human health threat (Centner, 2018). Jepson et al. (2020a, b) claimed that currently accepted criteria for defining highly hazardous pesticides do not adequately protect human bystanders, aquatic life, terrestrial wildlife, and pollinators (Jepson et al., 2020b).

One can wonder about the success and effectiveness of the Lebanese pesticides policy and consequently the legislation and regulations fostering registration and other aspects of the lifecycle management in protecting human health and the environment. An obvious problem is within the registration process as registration in Lebanon follows registration in the reference countries (EU, USA, Japan, UK, …) without conducting local trials on pesticides residues. Other problems reside somewhere else at post-registration level in the life cycle management. Youssef et al. (2015) concluded from a study on ground and surface water in South Lebanon with a recommendation for setting and enforcing regulations to reduce pesticides' impact on environment and human health (Youssef et al., 2015). Obviously, this calls for a reassessment. It is believed that the current registration/legislation should be updated, and post-registration control should be reinforced. However, in this article, the focus will be on pinpointing reforms suitable for Lebanon and other developing countries that share relatively the same concerns and limitations. Such reforms are to take place at the level of the government policy and its tools, particularly legislation, without getting into the task of formulating one.

2. Methodology

A literature search was conducted using Elsevier, Science direct, Google scholar, and Google to assess all available data on the health and environmental impact of pesticides in Lebanon. The same method was followed by Loha et al. (2018) (Loha et al., 2018). In addition, the sites of FAO, EPA, and OECD were consulted in the quest of guidelines to make a comparative study of pesticides policies and legislation to highlight gaps and extract recommendations for improvement. Access to all legislation undertaken by the ministries concerning pesticides was secured from Faolex, ministries websites, and the Official Gazette. Pesticides Import statistics were gathered from the Lebanese Customs official website. Major keywords searched: Lebanon, pesticide poisoning, import, impact on health and environment, policies, regulations, and registration.

3. Results

3.1. Impact of pesticides on humans and environment in Lebanon

Recently, tests conducted on different agricultural commodities in Lebanon have revealed that many samples contained not only high levels of pesticides residues above the maximum residue limits (MRLs) of the Codex Alimentarius but also residues of pesticides that have either been banned for many years or that had never been registered (El Hawari et al., 2019). Many times, over the past few years, the media have been inflamed after the publications of some pesticides residues tests that have shown residues above the MRLs (Kfoury et al., 2002; Hattam, 2009). The public panicked for a while and stopped consuming commodities, such as strawberries or squash, that showed high residues (Hattam, 2009). Prices of agricultural commodities plummeted, and farmers suffered (Habboush, 2017). The floor then was opened for accusations (Assaf, 2002) and blames (The Daily Star, 2009) until the public would forget the incidence or another study show that contrary to the other studies, it was safe to consume those commodities because residues were below the MRLs (Nasreddine et al., 2016) or because processing could decrease pesticides residues. Further studies on the effect of pesticides used in

Lebanon on human health, particularly on agricultural workers, demonstrated that some of them have limited skills regarding safe pesticides application that was associated with low precautionary measures to reduce the risk of pesticides contamination (Salameh et al., 2004). In another comparative study, it was suggested that among Lebanese agricultural workers, there was a higher prevalence of multiple symptoms of subacute intoxications that might be due to pesticides but did not need hospitalization (Salameh and Abi Saleh, 2004). On the other hand, workers, exposed to pesticides because of their profession, bare a 4-time higher risk of having life-threatening acute intoxications than other workers. In another published study, it was shown that asthma in Lebanese adult patients in Lebanon was highly correlated with professional and non-professional exposure to pesticides (Salameh et al., 2006). Moreover, a study by Al-Alam et al. (2015) in North Lebanon has detected the use of some pesticides with known blood hemolytic potential, such as zineb, though banned, on tomatoes and lemons, metalxyl on lemons and trifluraline on strawberries. Nevertheless, hemolytic effect of those pesticides was not observed at the detected residues concentration levels in the sampled commodities (Al-Alam et al., 2015). In a recent study on 120 samples of breast milk in a Syrian refugee camp in North Lebanon, pesticides residues of lufeneron were detected in 4 samples, methamidophos in one sample, and chloropyrifos with a concentration of 12.32 μg/L in one sample (Smadi and Darra, 2019). Though present at concentration excluding a health risk, organochlorines pesticides residues were detected in blood serum samples taken in another cross-sectorial study during 2013–2014 (Harmouche-Karaki et al., 2018). In a study by Al-Alam et al. (2017) on apiaries in North Lebanon, 10 pesticides were detected with a total level up to 1753.92 (ng g-1) in collected honey samples among which long time banned organochlorines, penconazole, pyraclostrobin, and diflufenican, the latter was never registered for use in Lebanon (Al Alam et al., 2017). Furthermore, soil tests in Aakkar regions revealed the presence of organochlorines pesticides, though banned years ago (Helou et al., 2019), in addition to heavy metals, mainly Nickel and a moderate pollution with Cadmium (Chaza et al., 2018a b). In another study conducted later that year, tests on groundwater samples in Aakkar revealed the presence of organochlorines, with levels reaching up to 58.9 μg/L, exceeding the limits set by the European Union, in addition to other organophosphates, mainly methyl-parathion, with levels ranging from 18.2 μg/L to 98.29 μg/L (Chaza et al., 2018b a). This last study, also demonstrated a recent use of dicofol (2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol), in which DDT was only an impurity, by, calculation of (DDD + DDE)/DDT ratios that were lower than 0.5 and 2,4′-DDT/4,4′-DDT ratios that ranged from 0.81 to 2.31, and by comparing levels with a 2 years older study (El-Osmani et al., 2014). DDD (dichloro diphenyl dichloroethane) and DDE (dichloro diphenyl dichloroethylene) are 2 metabolites of DDT. Surface water tests in river Ibrahim, river Hasbani, and Quaroun Lake revealed what appears to be a significant problem since the (PRISW-1: Short- Term Pesticide Risk Index for Surface Water System) calculated for the 45 detected pesticides, constitutes a high-risk threat for *Daphnia magna* and fish species (Aisha et al., 2017). The PRISW-1 scores calculated, ranged from 46 for Ibrahim River, 49 for Hasbani River and Qaroun Lake (>40), and the major contributors were chlorpyriphos, DDE-pp, diazinon and fenpropathrin (Aisha et al., 2017). In South Lebanon, ground and surface water tests on samples taken during 2012 showed low levels of organochlorines and organophosphates, except for a high level of pirimiphos-methyl that reached up to 300.87 ng L−1 in a ground water sample meant for drinking (Youssef et al., 2015).

3.2. Pesticides management in Lebanon

3.2.1. Statistics

By December 2019, the total number of licensed agricultural pesticides importers had been 53. Only two local formulators have been licensed. The number of registered active ingredients of chemical pesticides was 106, while the number of formulations totaled 128, and the total number of trade names was about 687. The number of biorational formulations registered was about 26, 19 of which are pheromones, while only 3 belong to the microbial category biopesticides. One fact indicating a registration problem is that no beneficial macro-organism has yet been registered. A list of the active ingredients and their formulations currently registered in Lebanon is presented in Table 1, while banned active ingredients are listed in Table 2.

According to the Lebanese Customs Website (Lebanese Customs, 2019a,b), Lebanon's imports of all types of pesticides, including public health pesticides and rodenticides, are about 6,641 tons/year (Figure 1).

Some quantities of the imported pesticides could not be sold within their validity period and stockpile as outdated or obsolete in the warehouses of the importers or the retailers. Sometimes, the reason is simply a market issue having to do with the availability of cheaper or more effective pesticide alternatives. Other times, obsolete pesticides stockpile occur as a result of confiscation of banned pesticides that are kept either at the merchants 'warehouses or those of the ministry. In 2010, a confiscated stock of 9 tons of obsolete pesticides was still kept at the ministry of agriculture warehouse at Kfarchima, waiting to be disposed of, in addition to an undefined amount found hither and thither at the retailers' shops.

3.2.2. Policy and legislation in Lebanon

3.2.2.1. Policy and strategy. Unfortunately, there is no one document that specifies the Lebanese governmental policy on pesticide use. The governmental approach is disclosed through mainly legislation and regulations issued at different levels, be it parliamentary laws, decrees, or ministerial decisions, issued primarily in the objective of pesticides management. One can realize that other policy tools, besides legislation, are being used hither and thither. The government is also using taxation reduction on pesticides and fertilizers imports, in addition to an exemption from VAT based on customs law decree 4461 dated 15/12/2000 (Lebanese Customs, 2019a,b) and its amendment by the Decree No 5497 (Imposition of some procedures in order to protect national products) (Ministry of Economics, 2019). Also, the Decree No. 167 of 2017 (to determine the details for the implementation of article 20 of the Law on Environmental Protection No.444 of 2002), aims at establishing the percentage of tax reduction for a number of activities directed towards protecting the environment, among which is the reduction of custom tariffs on environmentally friendly goods.

Extension agents of the Ministry of Agriculture and several NGOs are organizing seminars to raise farmers' awareness and build their capacities in integrated pest management. However, these seminars are not being conducted regularly to declare that Lebanese farmers are well trained and committed to producing safe food and preserving the environment. Many NGO's, like Mouawad foundation, Fares foundation, Safadi, and Indevco, which benefit from projects financed by external agencies, are doing some extension in the North of Lebanon. The Ministry of Agriculture is also aiding the farmers by providing them with small amounts of pesticides alternatives, such as pheromones, traps, biopesticides, etc… However, this is not done in a planned and programmed manner within the context of a formulated policy where all the resources in the government arsenal are used in a coordinated manner and do not serve contradictory objectives. There are no policy indicators that are being evaluated and monitored and no corrective actions taken.

The Ministry of Agriculture has a strategy of its own, tailored to answer its needs for the years 2015–2019 (Lebanese Ministry of Agriculture, 2015). This strategy has helped the ministry to meet some of its goals related to agriculture, but it can't be described as a strategy for the whole agricultural sector even though many of the stakeholders involved have participated in the SWOT (Strengths, weaknesses, Opportunities, threats) analysis and assessment of needs. Among the needs was an urgency to intervene at the level of pesticide management. Accordingly, the strategy includes 8 courses of action, 2 of which pertain to: (#1) the

Table 1. Currently registered active ingredients and formulations.

Common name	% AI (active ingredient)	Code	Formulation
2,4-D Amine Salt	72	SL	Soluble liquid
2,4-D + MCPA	36 + 31.5	SL	Soluble liquid
6-Benzyladenin + Giberellins	1.9 + 1.9	SL	Soluble liquid
Abamectin	1.8	EC	Emulsifiable concentrate
Abamectin + Thiametoxam	3.3 + 15.2	SC	Suspension concentrate
Abamectin + Chlorantraniliprole	1.8 + 4.5	SC	Suspension concentrate
Acequinocyl	15	SC	Suspension concentrate
Acetamiprid	20	SP	Soluble powder
Acrinathrin	76.6	EW	Emulsion
Alpha-Cypermethrin	10	EC	Emulsifiable concentrate
Aluminium phosphide	56	TB	Tablets
Azadirachtin A	1	EC	Emulsifiable concentrate
Azoxystrobin	25	SC	Suspension concentrate
Azoxystrobin + Difenoconazol	20 + 12.5	SC	Suspension concentrate
Azoxystrobin + Metalaxyl-M	32.2 + 12.4	SE	Suspo-emulsion
Bifenazate	24	SC	Suspension concentrate
Boscalid + Pyraclostrobin	25.2 + 12.8	WG	Water dispersible granule
Bromadiolone	0.005	Pellets	Pellets
Buprofezin	25	WP	wettable powder
Captan	80	WDG	water dispersible granule
Chlorantraniliprole	20	SC	Suspension concentrate
Chlorantraniliprole + thiamethoxam	10 + 20	SC	Suspension concentrate
Chlorothalonil	75	WP	wettable powder
Chlorothalonil + Azoxystrobin	40 + 8	SC	Suspension concentrate
Chlorpropham	50	HN	Hot fogging concentrate
Chlorpyrifos	48%	EC	Emulsifiable concentrate
Chlorpyrifos + Cypermethrin	50 + 5	EC	Emulsifiable concentrate
Chlorpyrifos + Dimethoate	27.8 + 22.2	EC	Emulsifiable concentrate
Chlorpyrifos + Gamma Cyalothrin	30 + 1	EC	Emulsifiable concentrate
Chromafenozide	5	SC	Suspension concentrate
Clodinafop-propagyl + Pinoxaden	2.25 + 2.25	EC	Emulsifiable concentrate
Copper hydroxide	53.8	WG	Water dispersible granule
Copper Oxychloride	50	WP	wettable powder
Cycloxydim	10	EC	Emulsifiable concentrate
Cyflufenamid + difenoconazole	3 + 6	DC	Dispersible concentrate
Cyflumetofen	20	SC	Suspension concentrate
Cymoxanil + Chlorothalonil	5 + 37.5	SC	Suspension concentrate
Cymoxanil + Famoxadone	30 + 22	WG	Water dispersible granule
Cymoxanil + Mancozeb	8 + 64	WP	Wettable powder
Cyproconazole	10	SL	Soluble liquid
Cyprodinil	50	WG	Water dispersible granule
Cyprodinil + Fludioxonil	37.5 + 25	WG	Water dispersible granule
Cyromazine	75	WP	Wettable powder
Deltamethrin	2.5	EC	Emulsifiable concentrate
Diafenthiuron	25	SC	Suspension concentrate
Diazinon	50	EC	Emulsifiable concentrate
Difenoconazole	25	EC	Emulsifiable concentrate
Diflubenzuron	25	WP	Wettable Granule
Dimethomorph	50	WG	Wettable Granule
Diquat Dibromide	20	SL	Soluble liquid
Emamectin Benzoate	2.3	EC	Emulsifiable concentrate
Esfenvalerate	5	EC	Emulsifiable concentrate
Ethephon	48	SL	Soluble liquid
Etoxazole	10	SC	Suspension concentrate
Fenazaquin	20	SC	Suspension concentrate
Fenbutatin oxide	50	WP	Wettable powder
Fenhexamid	50	SC	Suspension concentrate
Fenpyrazamin	50	WG	Wettable Granule

(*continued on next page*)

Table 1 (*continued*)

Common name	% AI (active ingredient)	Code	Formulation
Fenyproximate	5	SC	Suspension concentrate
Fluazifop-p-butyl	12.5	EC	Emulsifiable concentrate
Fluazinam	50	SC	Suspension concentrate
Flubendiamide	48	SC	Suspension concentrate
Fludioxonil	10	FS	Flowable concentrate
Flutriafol	12.5	SC	Suspension concentrate
Fosethyl-Aluminium	80	WP	Wettable powder
Gamma Cyalothrin	6	CS	Capsule Suspension
Gibberellic Acid	90	TB	Tablets
Glufosinate-Ammonium	20	SL	Soluble liquid
Glyphosate	36	SL	Soluble liquid
Hexythiazox	10	WP	Wettable powder
Hexythiazox	10	WP	Wettable powder
Hymexazol	30	SL	Soluble liquid
Hymexazol	30	SL	Soluble liquid
Imicyafos	1.5	G	Granular
Imicyafos	30	SL	Soluble liquid
Imidacloprid	20	SL	Soluble liquid
Indoxacarb	15	EC	Emulsifiable concentrate
Iprodione	25	SC	Suspension concentrate
Isopyrazam + Difenoconazole	4 + 10	SC	Suspension concentrate
Kasugamycin + Copper Oxychloride	5 + 75.6	WP	Wettable powder
Lambda-Cyhalothrin	5	EC	Emulsifiable concentrate
Lufenuron	5	EC	Emulsifiable concentrate
Mandipropamide	25	SC	Suspension concentrate
Mandipropamide + difenoconazole	25 + 25	SC	Suspension concentrate
Mefenoxam	2.5	GR	Granular
Metaflumizone	24	SC	Suspension concentrate
Metalaxyl	25	WP	Wettable powder
Metalaxyl-M + Chlorothalonil	3.75 + 50	SC	Suspension concentrate
Metaldehyde	6	GR	Granular Bait
Metaldehyde	4.9	GB	Granular Bait
Metaldehyde	5	GB	Granular bait
Metaldehyde	80	WP	Wettable powder
Metaldehyde	6	GR	Granular
Methyl Anthranilate	27.4	SC	Suspension concentrate
Metribuzin	70	WP	Wettable powder
Mineral oil	97	EC	Emulsifiable concentrate
Myclobutanil	12	EC	Emulsifiable concentrate
Oxamyl	10	GR	Granular
Parrafinic Oil	99.1	EC	Emulsifiable concentrate
Penconazole	10	EC	Emulsifiable concentrate
Pendimethaline	33	EC	Emulsifiable concentrate
Propamocarb Hydrochloride	72.2	SL	Soluble liquid
Propiconazole	25	EC	Emulsifiable concentrate
Propineb	70	WP	Wettable powder
Propyzamide	50	WP	Wettable powder
Proquinazid	20	EC	Emulsifiable concentrate
Pymetrozine	50	WG	Wettable dispersible granules
Pyridaben	20	WP	Wettable powder
Pyrimethanil	40	SC	Suspension concentrate
Pyroxsulam + Cloquintocet-mexyl	4.5 + 9	OD	Oil dispersion
Rimsulfuron	25	WG	water dispersible granule
S-Abscissic acid	20	SG	Water soluble granule
Spinetoram	11.7	SC	Suspension concentrate
Spinosad	0.24	Bait	Bait
Spirodiclofen	24	SC	Suspension concentrate
Spirotetramat	10	SC	Suspension concentrate
Sulfoxaflor	24	SC	Suspension concentrate

(*continued on next page*)

Table 1 (*continued*)

Common name	% AI (active ingredient)	Code	Formulation
Sulfur	80	WDG	Water dispersible granule
Tebuconazole	25	EW	Emulsion
Tetraconazole	10	EC	Emulsifiable concentrate
Thiamethoxam	25	WG	Water dispersible granule
Thiamethoxam + Lambda Cyhalothrin	14.1 + 10.6	SC	Suspension concentrate
Thiophanate Methyl	70	WP	Wettable powder
Tolfenpyrad	15	EC	Emulsifiable concentrate
Tribasic Copper Sulfate	34.5	SC	Suspension concentrate
Tribenuron Methyl	75	WDG	Water dispersible granule
Trifloxystrobin	50	WG	Water dispersible granule
Triflumizole	30	WP	Wettable powder

improvement of food safety and quality of locally produced agricultural commodities, (#2) the improvement of the value chains, and the increase of the value-added for products of plant origin. Under the first course of action, the relevant areas of intervention were identified as (#1.1.1) development of the legislative and operational framework of inspectors and health juridical control and (#1.1.4) development of a system for contaminants monitoring programs. Under the second course of action, there are also 2 areas of interventions: (#2.1.1) strengthening the management of agricultural inputs and (#2.1.4) promoting Good Agricultural Practices. Another course of action of direct relevance is the one pertaining to (#4) the improvement of extension services, which will supposedly aid in raising awareness and building the capacity of the farmers, especially when it comes to the safe use of pesticides. Also, the third course of action related to improving the good governance and sustainable use of natural resources intervention (#3.1.3) Protection from risks and pests that threaten forests, forests integrated pest management was proposed.

However, despite good intentions, yearly work plans are not being followed accurately, and reports on indicators' assessment do not show real achievements. Probably, it is because of the shortage of funding as the strategy relied on both internal and external funding of about 366 million dollars over a period of 5 years, while the total yearly budget of the Ministry of Agriculture doesn't go beyond 40 million dollars/year.

3.2.2.2. Legislation for pesticide management

3.2.2.2.1. International legal instrument. Lebanon ratified a number of binding international treaties, mainly The Rotterdam Convention on the Prior Informed Consent (PIC) in 2006 (Rotterdam Convention Text, 2019), Stockholm convention on Persistent organic pollutants (POPs) in 2003 (Stockholm Convention Text on persistent pollutants (POPs), 2019), Montreal Protocol in 1993 (MULTILATERAL Montreal Protocol on Substances that Deplete the Ozone Layer (with annex). Concluded at Montreal on 16 Sep tember 1987, n.d.), and a few of the international labor organizations conventions on workers' safety, mainly the C170 (ILO, 1990) and the C152(ILO, 1979). In addition, within the category of the non-binding or soft international laws, Lebanon has been a founder member of FAO since 1945 and relies on its codes and guidelines, mainly the Code of Conduct on Pesticide Management (FAO and WHO, 2014), Codex Alimentarius (FAO-WHO, 2019a), Joint Meeting on Pesticide Specifications (JMPS) (FAO/WHO, 2019b), and Joint Meeting on Pesticide residues (JMPR) (FAO/WHO, 2019c).

3.2.2.2.2. National legislation. At this level, pesticides management is not treated in a holistic approach. Pesticides Management jurisdiction is distributed depending on the pesticide's type among ministries, mainly agriculture, public health, and others like environment.

The following table (Table 3) summarizes the main active legislation and regulations of pesticides.

3.2.2.2.2.1. Pesticides registration

3.2.2.2.2.1.1. Plant protection products registration

The regulations pertaining to the registration of plant protection products have come a long way since the ministerial decision # 29/1 issued in 1995. This decision was supposed to regulate the decree #5039/1982 based on the law #6/68. Article 4 of the decree 5039/82 also specifies the formation of a technical committee to manage all aspects of agricultural pesticides, including registration. Registration was as simple as filling in an application form, with the minimum information required. Importing companies could register a product and name it by its common name as a trade name or register more than one trade name for the same product to be able to commercialize it in different regions of Lebanon as if it was a different product. They even could market a product without declaring its content in terms of active ingredient(s). In 2003, a new decision for pesticides registration was issued under the #396/1, amending the decision #29/1 within a period of 6 months. This decision took into consideration some of the recommendations proposed by FAO; nevertheless, it has never been implemented. The same occurred for another decision that was issued in 2004 under the #348/1, in compliance with the provisions of the unified bilateral treaty on pesticides between Lebanon and Syria on the Unified Form for the importation, circulation and control of agricultural pesticides (Unified Bilateral Treaty on Agricultural Pesticides, 2002). This decision gave the registration right for only basic producers of pesticides. Again, this decree has never been implemented, as another decision was issued in 2004, under the #280/1 and was amended to give right for registration for formulators. The legislation kept on changing until the decision 59/1 was issued in 26/2/2005. Though this decision has never been implemented until the end of 2006, it was the only decision to survive the continuous pressure of the private sector.

It was not until 2009 that a special decision numbered 280/1 dated 13/6/2009, which deals with bio-pesticides, was issued. Perhaps, what instigated such a decision was the need of the Ministry of Agriculture to concretize its approach of integrated pest management (IPM) and to open the door for alternatives better than chemical control, which was the culprit behind the increased pesticides residues in agricultural commodities. This decree has been inspired by the OECD guidelines (OECD, 2004), yet no bio-pesticides had been registered for a whole year. Some claimed that the decision 280/1 was so stringent in such a way that the suppliers could not fulfill its requirements. But probably there was not enough demand by farmers for this type of pesticides to encourage pesticides companies to willingly carry the burden of their registration. This is still applicable today not only at the level of the Lebanese registration but also worldwide, specifically at the level of the European Union in comparison to other countries (Damalas and Koutroubas, 2018). Accordingly, in 2010, the pesticides committee decided to further

Table 2. Banned active ingredients in Lebanon.

Active ingredient	Decision	Date
1,2 Dibromo - Ethane	94/1	20-5-1998
2,3,4,5- Bis (2-butylene) tetrahydro-2-furaldehide [*Repellent-11*]	94/1	20-5-1998
2,4,5- Trichlorophenoxyacetic acid (2,4,5-T)	94/1	20-5-1998
Acrolein	94/1	20-5-1998
Acrylonitrile	94/1	20-5-1998
Aldicarb	94/1	20-5-1998
Aldrin	94/1	20-5-1998
All compounds containing Arsenic salts	94/1	20-5-1998
Aminocarb	94/1	20-5-1998
Aramite	94/1	20-5-1998
Arsenious oxide	94/1	20-5-1998
BHC Technical (not Gamma HCH-Lindane)	94/1	20-5-1998
Binapacryl	94/1	20-5-1998
Butocarboxim	94/1	20-5-1998
Butoxycarboxim	94/1	20-5-1998
Cadminate	94/1	20-5-1998
Cadmium Calcium Copper Zinc Chromate Complex	94/1	20-5-1998
Cadmium compounds	94/1	20-5-1998
Calcium Arsenate	94/1	20-5-1998
Calcium Arsenite	94/1	20-5-1998
Calcium cyanide	94/1	20-5-1998
Captafol	94/1	20-5-1998
Carbon tetrachloride	94/1	20-5-1998
Carbophenothion	94/1	20-5-1998
Chloranil	94/1	20-5-1998
Chlordane	94/1	20-5-1998
Chlordecone	94/1	20-5-1998
Chlordimefon	94/1	20-5-1998
Chlorinated camphene [*Toxaphene*]	94/1	20-5-1998
Chlormephos	94/1	20-5-1998
Chloromethoxypropylmercuric Acetate (CMPA)	94/1	20-5-1998
Chlorthiophos	94/1	20-5-1998
Copper Acetoarsenite	94/1	20-5-1998
Copper Arsenate	94/1	20-5-1998
Copper Arsenite	94/1	20-5-1998
Crimidine	94/1	20-5-1998
Crotoxyphos	94/1	20-5-1998
Cyanothoate	94/1	20-5-1998
Cycloheximide	94/1	20-5-1998
DBCP (Dibromo chloropropane)	94/1	20-5-1998
DDT	94/1	20-5-1998
Decachlorooctahydro - 1,3,4 - methoxy - 2H - cyclobuta (cd) pentalen-2-one *Chlordecone*	94/1	20-5-1998
Dechlorane	94/1	20-5-1998
Demephion-O	94/1	20-5-1998
Demephion-S	94/1	20-5-1998
Diamidafos	94/1	20-5-1998
Dibromochloropropane	94/1	20-5-1998
Dicrotophos	94/1	20-5-1998
Dieldrin	94/1	20-5-1998
Dimefox	94/1	20-5-1998
Dimetilan	94/1	20-5-1998
Dinoterb salts	94/1	20-5-1998
Dinoseb salts	94/1	20-5-1998
Dioxathion	94/1	20-5-1998

(*continued on next page*)

Table 2 (*continued*)

Active ingredient	Decision	Date
Edifenphos	94/1	20-5-1998
Endothion	94/1	20-5-1998
Endrin	94/1	20-5-1998
EPN (Ethyl (p-nitrophenyl) thio benzene phosphonate)	94/1	20-5-1998
Erbon	94/1	20-5-1998
Ethylan	94/1	20-5-1998
Ethyl Parathion	94/1	20-5-1998
Ethylene Dibromide (EDB)	94/1	20-5-1998
Ethylene oxide	94/1	20-5-1998
Fensulfothion	94/1	20-5-1998
Fluoroacetamide	94/1	20-5-1998
Fosthietan	94/1	20-5-1998
HCH containing less than 99.0% of gamma isomer	94/1	20-5-1998
Heptachlore	94/1	20-5-1998
IFSP = Aphidan	94/1	20-5-1998
Isazophos	94/1	20-5-1998
Isobenzane	94/1	20-5-1998
Isodrin	94/1	20-5-1998
Isothioate	94/1	20-5-1998
Isoxathion	94/1	20-5-1998
Kepon	94/1	20-5-1998
Lead arsenate	94/1	20-5-1998
Leptophos	94/1	20-5-1998
Maleic Hydrazin and its salts	94/1	20-5-1998
Medinoterb acetate	94/1	20-5-1998
Mercuric chloride	94/1	20-5-1998
Mercuric Compounds (Organic and inorganic)	94/1	20-5-1998
Mirex	94/1	20-5-1998
Nitrofen	94/1	20-5-1998
OMPA [*Schradan*]	94/1	20-5-1998
Oxydeprofos	94/1	20-5-1998
Parathion ethyl	94/1	20-5-1998
Phenazine	94/1	20-5-1998
Phenylmercuric oleate (PMO)	94/1	20-5-1998
Phenylmercury acetate (PMA)	94/1	20-5-1998
Phospholan	94/1	20-5-1998
Potassium 2,3,5 - trichlorophenate (2,4,5,-TCP)	94/1	20-5-1998
Pyriminil [*Vacor*]	94/1	20-5-1998
Repellent -11	94/1	20-5-1998
Safrole	94/1	20-5-1998
Salithion	94/1	20-5-1998
Schradan	94/1	20-5-1998
Silvex	94/1	20-5-1998
Sodium arsenate	94/1	20-5-1998
Sodium arsenite	94/1	20-5-1998
Sodium Cyanide	94/1	20-5-1998
Sodium fluoroacetate	94/1	20-5-1998
Sodium pentachloro-phenoxide (Sodium pentachlorophenate)	94/1	20-5-1998
Strobane	94/1	20-5-1998
TDE (1,1-Dichloro-2,2-bis (p-chlorophenyl) Ethane	94/1	20-5-1998
TEPP (Tetra ethyl diphosphate or Tetra ethyl pyrophosphate or Ethyl pyrophosphate)	94/1	20-5-1998
Terpene polychlorinates [*Strobane*]	94/1	20-5-1998
Thallium sulfate	94/1	20-5-1998
Thionazin	94/1	20-5-1998

(*continued on next page*)

Table 2 (*continued*)

Active ingredient	Decision	Date
Toxaphene	94/1	20-5-1998
Triamiphos	94/1	20-5-1998
Trichloronate	94/1	20-5-1998
Trysben	94/1	20-5-1998
Vacor	94/1	20-5-1998
Vinyl chloride	94/1	20-5-1998
Wipeout	94/1	20-5-1998
Monocrotophos	262/1	26-9-2001
Methyl Parathion	262/1	26-9-2001
Lindane	262/1	26-9-2001
Chlorobenzilate	570/1	24-12-2008
Dinitro-ortho-cresol (DNOC)	570/1	24-12-2008
Hexachlorobenzene	570/1	24-12-2008
Combination of: Benomyl at above 7%, Carbofuran at above 10%, Thiram at above 15%	570/1	24-12-2008
Methamidophos	570/1	24-12-2008
Phosphamidon	570/1	24-12-2008
Methamidophos	79/1 & 868/1	13-2-2010 14-12-2010
Acephate	79/1 & 868/1	13-2-2010 14-12-2010
Endosulfan	79/1 & 868/1	13-2-2010 14-12-2010
Paraquat	79/1 & 868/1	13-2-2010 14-12-2010
Zineb	79/1 & 868/1	13-2-2010 14-12-2010
Methidathion	309/1	24-6-2010
Methyl Parathion	309/1	24-6-2010
Cyhexatin	309/1	24-6-2010
Simazine	309/1	24-6-2010
Atrazine	309/1	24-6-2010
Abamectin Dark color	674/1	29-10-2010
N-Phenyl Phthalamic acid	294/1	19-3-2011
Naphtylacetic acid hydrazide (NAA)	294/1	19-3-2011
Naphtyl oxyacetic acid (NOA)	294/1	19-3-2011
4-Chlorophenoxyacetic acid (4-CPA)	294/1	19-3-2011
β-Naphtyl oxyacetic acid (β NOA)	294/1	19-3-2011
Propargite	403/1	8-5-2012
Hexaconazole	850/1	12-9-2012
Cypermethrin	143/1	7/2/2014
Carbofuran	534/1	6/20/2016
Carbosulfan	534/1	6/20/2016
Amitraz	1053/1	12/13/2011
Methomyl	849–1	9/12/2012
Benomyl	159/1	3/7/2019
Carbaryl	159/1	3/7/2019
Chlorfenapyr	159/1	3/7/2019
Fenvalerate	159/1	3/7/2019
Haloxyfop-methyl	159/1	3/7/2019
Permethrin	159/1	3/7/2019
Phosphamidon	159/1	3/7/2019
Procymidone	159/1	3/7/2019
Fipronil	159/1	3/7/2019
Hydrogen cyanamide	159/1	3/7/2019
Piperonyl butoxide	159/1	3/7/2019
Trifluralin	159/1	3/7/2019
Linuron	159/1	3/7/2019
Iprodione	159/1	3/7/2019
Diurone	159/1	3/7/2019

(*continued on next page*)

Table 2 (*continued*)

Active ingredient	Decision	Date
Ziram	159/1	3/7/2019
Triadimenol	159/1	3/7/2019
Thiram	159/1	3/7/2019
Phosmet	159/1	3/7/2019
Methomyl	159/1	3/7/2019
Mancozeb	159/1	3/7/2019
Folpet	159/1	3/7/2019
Dimethoate	159/1	3/7/2019
Cypermethrin	159/1	3/7/2019
Dichlorvos DDVP	pesticide committee 14/2011	2/21/2011
Nonylphenol ethoxylate	3005/3	5/17/2017
1,3-Dichloropropene	285/1	5/4/2016
Carbendazim	pesticide committee 18/2011	6/7/2011

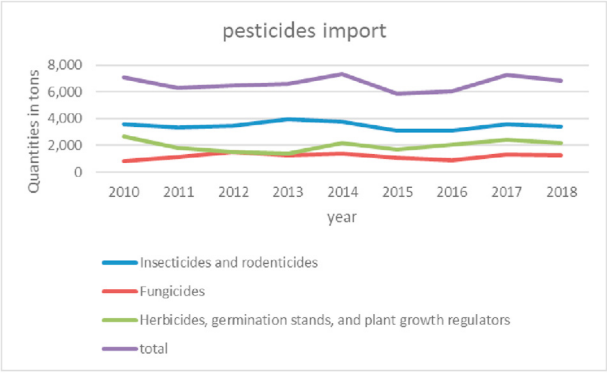

Figure 1. Pesticides types/quantities imported to Lebanon (2010–2018).

simplify the procedure of bio-pesticides registration, which resulted in the birth of the current decision numbered 307/1 dated 24/6/2010. On the same date of the year 2010, the chemical pesticides registration decree 59/1 was slightly amended and resulted in the decision 310/1 dated 24/6/2010, which conserved the same spirit as its preceding one but with fine-tuning. Accordingly, pesticides manufactured by a basic producer or an ISO (9001: scope formulation) holder formulator are entitled to be registered in Lebanon. Plant protection products with active ingredients and co-formulants allowed for use in reference countries can be registered in Lebanon. In fulfillment of the decree 311/1 dated 26/9/2010, pesticides consignments are inspected at the port of entries, and representative samples of each imported batch are analyzed at the Ministry of Agriculture Lab For active ingredient content as well as for impurities of toxicological concerns as per FAO specifications.

3.2.2.2.2.1.2. Veterinary pesticides registration

The registration of veterinary pesticide follows only the ministerial decision numbered 121/1, which was issued by the minister of agriculture in 27/1/2011 and is still in vigor. It deals with the organization of the registration, import, manufacture, and use of veterinary medicines, disinfectants, raw veterinary materials, and non-medicinal feed additives. This decision deals with each of the categories of the veterinary products separately, with veterinary pesticides being a part of category 1 under point-b dealing with veterinary medicinal products used in control of ecto- and endo-parasites. At that time, the registration part of this decision was inspired by the accumulated experience in the registration of agricultural pesticides with some differences. Nevertheless, the national committee for veterinary products that included representatives of the veterinary doctors' syndicate, World Organization for Animal Health (OIE), and the ministry of Public health, approved the current registration decision. Unfortunately, this committee has stopped convening since 2014.

3.2.2.2.2.1.3. Public health pesticides registration

Public health pesticides registration followed article 1 and 5 of chapter 1 of the law # 11/78 dated 24/4/1978 (regulation of the import and licensing of sale, filling, packing, formulation, manufacturing, and use of household insecticides and rodenticides). It stipulated that a prior consent from the Ministry of Public Health be acquired for each pesticide intended for use in Lebanon, be it imported or locally manufactured, and on every imported shipment of that pesticide. Accordingly, a request to the sanitary engineering service together with a copy of the license to import, a certified analysis, 3 samples, and a certified copy of the authorization permit for use in the country of origin, should be submitted. The consent is given by the general director of public health upon the recommendation of the sanitary engineering service. In 12/4/1982, the decree numbered 5100/82 was issued to determine the technical and special specifications pertaining to the licensing for import, sale, filling, packing, formulation, manufacturing, and use of household insecticides and rodenticides, but this decree has nothing to do with registration.

The registration of both agricultural and public health pesticides has continued in separate schemes within the framework of separate legislation until mid-2016 when jurisdictions overlapped, and entanglement began. The minister of health and the minister of agriculture issued two joint decisions, numbered 1048/1 dated 13/6/2016, and 1202/1, dated 27/6/2016 (repealing the decree 1048/1) to ban the registration and import of 36 pesticides active ingredients, breakdown products, solvents and impurities. The last 2 decisions disrupted the entire process of registration as they created the need to review the registration of not only pesticides whose active ingredients' formulations are still in use in reference countries but also the breakdown products, solvents, synergists and impurities of all the other registered pesticides. Meanwhile, the Ministry of Public Health issued a decision numbered 764/1 dated 5/5/2017 for the regulation of imports of insecticides and rodenticides, repealing the 2 previous decisions 1048/1 and 1202/1. It was the first time that the Ministry of Health paces in the direction of adopting and reviewing lists of registered active ingredients in reference countries and the ECHA (European Chemicals Agency), similar to what the Ministry of Agriculture does with agricultural pesticide registration. However, this decree still carries the same disadvantages of the law 11/78, revealed mainly by the absence of a technical committee to review registration dossier, inspection and testing at the port of entry, and inspection and compliance at the level of sale and use. Under the pressure of the media, as well as the allegations that the Ministry of Agriculture and the Ministry of Health are supporting the registration of carcinogenic pesticides, the Ministry of Agriculture issued a new decision numbered 73/1 dated 29/1/2018, re-suspending the registration of active ingredients that had been

Table 3. Active pesticides legislation and regulations in Lebanon.

Agricultural pesticides/Plant protection products			
Type	#	Date	scope
Law	6/68	8/1/1968	Organization of the trade of fertilizers, agricultural pesticides, and feedstuff
Decree	5039	26/3/1982	Regulatory provisions for trade of phytosanitary products
Decision	92/1	20/5/1998	Pesticides label specifications
Decision	94/1	20/5/1998	Import prohibition of some pesticides listed in supplementary data S2
Decision	262/1	26/9/2001	Prohibition of issuance of import permits of some pesticides: monocrotophos, methyl parathion, lindane
Decision	79/1	13/2/2010	Withdrawal of authorizations and import prohibition of some pesticides; methamidophos, acephate, endosulfan, paraquat, zineb.
Decision	307/1	24/6/2010	Regulation of the import and registration of bio-pesticides in Lebanon
Decision	310/1	24/6/2010	Regulations of import, registration, and use of Phytosanitary products in Lebanon
Decision	311/1	24/6/2010	Organization of pesticides import
Decision	309/1	24/6/2010	Prohibition of registration and import of some pesticides mainly methidathion, cyhexatin, simazine, atrazine, all formulations of methyl-parathion
Decision	674/1	29/10/2010	Prohibition of import of overcooked formulas of abamectin
Decision	403/1	8/5/2012	Prohibition of registration and import of propargite
Decision	850/1	12/9/2012	Prohibition of registration of a plant protection product: hexaconazole
Decision	1048/1	13/6/2016	Prohibition of registration, import of 36 deleterious agricultural pesticides
Decision	1202/1	27/6/2016	Repealing of the decision 1048/1
Decision	790/1	30/10/2017	Repealing of the decision 1048/1
Decision	73/1	29/1/2018	Repealing of the decision 790/1
Veterinary pesticides			
Decision	121/1	27/1/2011	The organization of the registration, import, manufacture, use of veterinary medicinal, disinfectants, raw veterinary materials, and non-medicinal feed additives
Public health pesticides			
Law	11/78	24/4/1978	Regulation of the import and licensing of sale, filling, packing, formulation, manufacturing, and use of household insecticides and rodenticides
Decree	5100/82	12/4/1982	Technical and special specifications pertaining to the import, sale, filling, packing, formulation, manufacturing, and use of household insecticides and rodenticides
Decision	764/1	5/5/2017	Regulation of imports of insecticides and rodenticides
Decision	126/1	22/1/2018	Suspension of art. 9 of the decision 764/1 (regulation of imports of insecticides and rodenticides
Environmental regulations pertaining to pesticides			
Law	64	1988	Pertaining to hazardous waste
Law	444	2002	On environmental protection
Law	432	2003	Regulates the production and utilization of persistent organic pollutants (POPs)

banned in the decree 1048/1, waiting for a reassessment from an independent committee of experts. So did the Ministry of Public Health in issuing the decision 126/1 dated 22/1/2018 (Suspension of art. 9 of the decision 764/1 (regulation of imports of insecticides and rodenticides). This dilemma of the give and take stresses the need for clear procedures based on scientific grounds, with such strong legislation that does not allow easily for changes unless it is for all stakeholders' sake.

4. Discussion and recommendations

4.1. Policy and legislation reforms

Policy and legislation are practically inseparable. Though legislation is one tool of a policy, a policy cannot be concretized effectively without legislation. At the same time, reforms at the level of legislation are also reforms at the level of the policy. But for our own purpose, we will categorize the reforms at the level of the intent as policy, while at the level of practice as legislation reforms.

4.1.1. Policy

The driving forces of a pesticide's policy are the same in all responsible countries in the world. They all need to manage this paradox of the need to use pesticides and at the same time mitigate their deleterious effects on humans and environment (Viero et al., 2016). However, these countries differ relatively in the level of their people's awareness (Sharafi et al., 2018), enforcement, compliance mentality (Yan et al., 2017), and most importantly, their governmental resources and how much of these are invested in the management of the pesticides life cycle (Damalas and Eleftherohorinos, 2011; Mengistie et al., 2015). It is a fact that no developing country will ever possess the resources needed to maintain comprehensive control over all the components of pesticides lifecycles. In a study conducted by Van den Berg et al. (2020) on gaps in the pesticide lifecycle management in agriculture and public health in both developed and developing countries, it was shown that global shortcomings exist but are more aggravated in the developing countries (Van den Berg et al., 2020). It is also a fact that no country in the world, even the wealthiest one, will ever have the ultimate lifecycle management performing at 100% certainty (Centner, 2018; Stehle and Schulz, 2015; Storck et al., 2017). If we are talking about risk (Skevas et al., 2013), all that can be done is to build a policy based on reducing the uncertainty or mitigating risk to an acceptable level. Accordingly, pesticides are not the privilege of the developed countries only; the developing countries can have their share of the play but with acceptable limitations. The main question here is how? The following represents an opinion that could reinforce not only Lebanon's policy but also the other developing countries that share the same problems, limitations, and concerns (Damalas and Eleftherohorinos, 2011; Mengistie et al., 2017; Onwona Kwakye et al., 2018). Surely, the solution to the problem will be achieved only within the context of a recipe of policy tools put together (Skevas et al., 2013). A logical approach would be to build on what one country has and borrow from the more fortunate countries what it can use, discarding the wrong and the unsuitable under its own working conditions (Manuweera, 2007). Based on this approach, "Prevention" would be the best curing proposition. Countries which score less than 50% on their pesticide lifecycle management in an international assessment fostered by a UN global initiative, similar to the one proposed by Van den Berg et al. (2020), should completely refrain or even be compulsory prevented from using any pesticides on their territories, except those of WHO class VI. This should be globally supported by a common fund to develop safe agro-ecological alternatives and legislation adequate to run safely a pesticide lifecycle. For those countries, using pesticides of other classes no matter what the direct benefit is of severe consequences, like handing a loaded gun to a child. Similarly, countries scoring between 50% and 95% on the same assessment are to use pesticides only from a minimum list of safe pesticides and work on enhancing their lifecycle to the full 100% to guarantee a safe use on humans and environment. This proposition is expected to be challenged by the same debate on the necessity of some specific pesticides for enough productivity and profitability (Lechenet et al., 2017). In any case, inspired by Aven and Renn (2018) in their paper on the eight principles for improving policy on risk reduction (Aven and Renn, 2018), the government should have a clear pesticides policy, give up the" Action on Impact" mentality and turn into a more planned response. Some of the basic principles that should be adopted by government decision makers to improve the pesticides policy in Lebanon and ultimately the legislation relevant to their management, without specific ordering, are mainly: decision making based on evidence, using cautionary/pre-cautionary/discursive management strategies to lower risk to humans and environment, balancing different concerns through proportionality and consistency, allocation of responsibility for managing risks to those best placed to control them, openness and transparency, and involvement (Aven and Renn, 2018). Based on these principles and others brought forth in UNEP Global Chemicals Outlook II: summary for policymakers Report 2019 (UNEP/EA.4/21/Global Chemcial Outlooks II, 2019), following are some of the suggested reforms at the level of the policy. The government should:

i. Make information and studies pertaining to pesticides risk available to the public through specialized sites as mandated in the EU by article 52 (obligation to keep information available) of the REGULATION (EC) No 1107/2009 (European Parliament, 2009) and the United States of America-EPA (United States Environmental Protection Agency, 2018) based on the FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT whereby decision-makers and the public will dialogue on pesticide registration decisions. This brings a better understanding of potential risks, benefits, and meaningful protective measures.
ii. Adopt one lifecycle management strategy for all types of pesticides: agricultural, public, and industrial. This will save human and financial resources (FAO, 2014). Inter-ministerial cooperation is required to unify the view and the claim for the sake of effective management and to avoid unnecessary disputes over jurisdictions.
iii. Reduce the reliance on pesticides by improving Integrated Pest Management (IPM) and adopting Integrated Vector Management (IVM) techniques (FAO, 2014; 2010; Pretty and Bharucha, 2015b).
iv. Promote education and invest in compulsory training for all stakeholders handling pesticides. Going by the principle of "Better knowledge of pesticides will bring better safety performance" (Damalas Christos and Koutroubas, 2017) that promotes education, especially at the level of decision makers. The mandate of the ministry of agriculture-official agricultural schools need to be changed into professional training centers (Hillocks, 2012) and their curricula amended to serve the purpose of graduating certified pesticides prescribers, certified applicators, and IPM certified producers. At the same time, abandon the official farmers' extension approach and support chambers of agriculture extension service similar to what has been done in more developed countries years ago. Another approach for knowledge dissemination and extension is the promotion of the Farmers Field Schools concept that has proven to be an effective tool in some developing countries to not only consistently reduce pesticides use but also in achieving increased crop yield (Pretty and Bharucha, 2015b; van den Berg, 2004). An additional approach is to promote "University-decision makers close relation" and "University-community partnerships" which have proven to be an effective tool to address environmental health concerns associated with pesticides exposure (Quandt et al., 2011), especially that Lebanese agriculture also relies on foreign hand labors similar to the case of California and the Mexican workers.
v. Ensure the involvement and consequently the commitment of all the stakeholders and have them all on board in the quest of

pesticides risk reduction; the public-private partnership seems an important approach that has shown its effectiveness in many parts of the world (Mengistie et al., 2015; Schreinemachers et al., 2017)

vi. Seek the establishment of a new suitable farmers' credit system to replace the current one in Lebanon. At present, farmers get credits from merchants in their region on debt terms until the end of the season. In the same way, the merchants are accredited from the importing companies. The present system can be blamed for "debt dilemma", primarily participating in the pesticides abuse. The dangerous thing about this system is that it is putting the producers under the mercy of the merchants who ultimately dictate the types and amount of pesticides that are lucrative for them. The producers, out of fear of not being either accredited or able to return their debt due to crop loss (Wilson and Tisdell, 2001), abide by the merchants' suggestions. This results in more pesticides use than actually needed. Another destructive outcome of this vicious circle is that the whole chain of production is compromised when the price of the produce goes down, and the producer will not be able to pay back the merchant. The latter will not be able to pay back the importing company. Therefore, governments could intervene with an incentive-based policy depicted by providing a credit system that could be used as a tool for fulfilling its pesticide' policy goals. For example, credits are facilitated with low interest rates for the congregation of producers who are implementing IPM/Integrated Crop Management (ICM)/GAP.

vii. Use the market-based instruments of the pesticides policy judiciously and coherently to serve the objective of risk reduction. In collaboration with the customs, governments should consider differential taxation rate on import, value added taxes, fees of registration, and fees of registration' maintenance tools that can promote the use of safer pesticides and non-chemical alternatives (FAO, 2010) and make the use of high risk pesticides unattractive as they will be more costly. To be effective, the tax should be high enough to increase the costs of unsafe pesticides (Böcker and Finger, 2016; Finger et al., 2017) yet not to the extent of making illegal trafficking a more lucrative trade.

viii. Establish twinning projects with an advanced country for cooperation in pesticides management and training.

ix. In addition to all what has been proposed, there is no way to go about without using the most essential tool of a policy, "the command and control", revealed by comprehensive laws, bans and restrictions (Skevas et al., 2013; Stavins and Kennedy, 2003).

4.1.2. Legislation

4.1.2.1. Holistic pesticides law. To avoid exhaustion of resources due to managing a multitude of pesticides lifecycles depending on pesticides types, a modern holistic national pesticides law needs to be issued. This law with its scopes, objectives, and updated definitions (FAO/WHO, 2015a) should be coherent with the concepts of good agricultural practices (GAP), integrated pest management (IPM) and integrated vector management (IVM) to reduce reliance on pesticides. Such a law, which is in line with the Ministry of Agriculture strategy (Lebanese Ministry of Agriculture, 2015, p. 32) will result eventually not only in the production of agricultural commodities with pesticides residues below the maximum levels allowed for safe consumption but also in the reduction of hazards pesticides use places on humans and environment (Vapnek et al., 2007). Unlike other governmental stakeholders, the Ministry of Agriculture has a functional pesticide committee and a secretariat for agricultural pesticides registration. Thus, equipped with experience and some of the tools, the ministry of agriculture would be the perfect candidate to administer this proposed law as a competent primary authority (FAO/WHO, 2015a) through the creation of a pesticide board which can be an upgrade of the existing pesticide committee. A technical committee of scientists and "implementation committees" in each concerned ministry are to be attached to this board. Structurally, the pesticides board should include representatives from several ministries and institutions/agencies: Agriculture, Public health, Environment, Labor, Industry, Justice, Customs, the designated focal points of all the binding international instruments, like Rotterdam, Basel, and Stockholm (Vapnek et al., 2007, p. 38), in addition to representatives from the different businesses with advisory roles only. Functionally, the pesticides board controls the lifecycle of all types of pesticides from import, manufacturing, registration, transport, packaging, labeling, storage, sale, use, and disposal by its compelling decisions for all the stakeholders involved. The technical committee (FAO, 2015a, b), composed of independent and highly qualified experts in the fields of pesticides, human health, toxicology, environment, and other relevant disciplines, will serve as the European Food Safety Authority (EFSA) towards the European Commission (EC) in terms of handling the scenarios of pesticides assessment as a whole, i.e assessing not just the active ingredients but all of the ingredients of the formulation (Storck et al., 2017) as well as cost-benefit studies and proposition of recommendations, including management and mitigation measures. Practically, each ministry, within its jurisdiction, oversees fulfilling the board' decisions on all the activities within the pesticides lifecycle, including inspection, monitoring, and surveillance, through "implementation committees" formed in each ministry. Accordingly, a review of all the pertaining legislation and regulations should be conducted to reach holistic governance with coordinated responses (Manuweera, 2007). Pesticides registration should be unified, while control and inspection, monitoring and surveillance could be done by the different relevant ministries.

4.1.2.2. Registration. The government should:

i. Stick to the approach of the registration by analogy (FAO/Pesticide Registration Toolkit, 2018) with reference countries, as a general guideline, aiming at a more comprehensive registration system. Registration authorities need to follow up carefully on the changes in pesticides registration in Europe and the world and follow cautiously (using the precautionary principle and the burden of proof) so as not to miss out on technological advancements (The Science Communication Unit, 2017). This approach will save on the resources (UNEP/EA.4/21/Global Chemcial Outlooks II, 2019) needed for conducting costly assessment studies already published, help in allocating the necessary resources to perform the local studies that differ per country-such as adaptation to the critical good agricultural practices that suit the country's condition, performance of local residues trials (FAO, 2016),sustainability and continuity of quality control systems (FAO & WHO, 2011), and concentrate the resources into cost-benefit-analysis, managing the risks, monitoring and surveillance, and compliance and enforcement. Nevertheless, registration by analogy is not capable by itself of reducing the risks of pesticides on human and environmental health in developing countries. First, some pesticides may be registered in reference countries because these latter fulfill certain mitigation measures the developing countries are not apt to achieve, the least of these are protective clothing (Davis et al., 2020; UN/Human Rights Council, 2017). Second, there might be cases when some pesticides managed to get registered in the developed countries because they satisfied the current requirements at that time only to be revoked later on for having deleterious effects that were not detected or accounted for in the risk assessment studies especially on non-target organisms (Mancini et al., 2019). Therefore, it would be safer for developing countries with weak regulations and enforcement to adopt a "modified registration by analogy" only from a minimum list of lower risk pesticides, compatible with IPM, built by applying the global guidelines for pesticides classification proposed by Jepson et al. (2020a; 2020b).

ii. Introduce the concept of "restricted use" pesticides (United States Environmental Protection Agency, 2011) that can be used only by professional certified applicators and are outside the minimum low risk pesticides list proposed previously. This measure is only reverted to in extreme cases and through controlled steps - from the decision taking of use through import until disposal of empty containers. In this way, it will not deprive agriculture producers of pesticides of those categories that might be occasionally needed for one reason or another (Lechenet et al., 2017; Pelfrène and Vettorazzi, 1987).

iii. Make available alternatives to chemical pesticides by facilitating registration of biopesticides and natural enemies (Damalas and Koutroubas, 2018). Also, publish a list of registered pesticides as a result of a comparative assessment fulfilling the substitution principle similar to what it is required in REGULATION (EC) No 1107/2009 (placing of plant protection products on the market) (European Parliament, 2009).

iv. Set clear provisions for registration of equivalent pesticides formulations. Developing countries need to register generics or equivalent formulations, due to economic reasons related to decreasing the cost of production and to illegal trafficking of smuggled and counterfeit pesticides (OECD, 1996) when the supply of officially authorized pesticides is short or high in price. However, at the same time, "Market liberation without effective regulations and adequate market-based incentives may lower the costs of supplying pesticides, but can increase the tendency for ineffective, inefficient, and non-sustainable crop protection" (Popp et al., 2013). Therefore, legislation should be made to accommodate for a specialized track for registration of experimentally proven equivalent formulations with elaborated provisions, such as those present in the article 52 of the regulation EC 1107/2009 (European Parliament, 2009) with clear requirements for assessment (WHO, 2016) (FAO/Pesticide Registration Toolkit, 2018), especially that the formulated product might carry impurities and isomers of the active ingredient, safeners, synergists, or co-formulants, which are much more hazardous than the active (Cox and Surgan, 2006; FAO & WHO, 2011; Nagy et al., 2020).

v. Introduce regulations and procedures for the registration of "minor use" in line with article 51 of the regulation (placing of plant protection products on the market) (European Parliament, 2009) ((EC) No 1107/2009, 2009) and the guidelines of the OECD (Guidance Document on Regulatory Incentives for the Registration of Pesticide Minor Uses) (OECD, 2011).

vi. Modify the decision 310/1 dated 24/6/2010 (Regulations/ Legislation of import, registration, and use of Phytosanitary products in Lebanon) to accommodate for the registration of the post-harvest pesticides category.

vii. Amend the decision 92/1 dated 20/5/1998 (Pesticides label specifications) so that the label includes additional details about critical good agricultural practices (cGAP), such as the maximum number of pesticide applications/season, the pesticides mode of action codes set by the Insecticides Resistance Action Committee (IRAC) and Fungicides Resistance Action Committee (FRAC) in order to help in management of pest resistance to pesticides, and practical ways for disposal of empty containers (FAO/WHO, 2015b). Furthermore, provisions to accommodate the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) should be accounted for (Handford et al., 2015; UNEP/EA.4/21/Global Chemcial Outlooks II, 2019).

4.1.2.3. Traceability. The main objective of traceability is to identify the risk resulting from malpractice at the different food chain node levels. While traceability has become a global concern in food safety and a legal obligation in many advanced countries, like USA, EU, Japan, and others (Charlebois et al., 2014), most of the Lebanese farmers still pack their agricultural produce for the wholesale market in unlabeled plastic crates, making the identification of their origin and the agricultural activities made for their production an impossible task. Likewise, most of the imported agricultural commodities sold at the small retailers' shops do not have any labeling. Thus, Lebanon urgently needs to set 2 functional systems of traceability, mainly:

4.1.2.3.1. Farm-to-fork traceability system. Many countries have established technologically advanced systems of agricultural product traceability (Aiello et al., 2015; Cheng et al., 2013), involving digitalized bar codes, Radio frequency identification (RFID) tags, mobile applications, and information disclosure programs to unveil information about food production and distribution processes (Sugahara, 2009). Farm-to-fork traceability system (Singh et al., 2017) would start by a mandatory farm registration with a requirement to maintain a farm register and associated with a monitoring system of pesticides residues achieved in full collaboration with municipalities and the Ministry of Economics, being the parties with jurisdictions over markets. Establishment of the traceability system will assist in identifying the origin of the incompliant agricultural produce along with the types of residues that should be linked with pesticides use. This, in turn, will allow corrective measures to be taken, such as visits by the extension officers to the incompliant farmer, mandatory training, and even fines and penalties.

4.1.2.3.2. Pesticide containers management traceability system.- Monitoring pesticides containers from the day they are imported or even before until they are collected back and disposed of safely within the context of a realistic disposal system will have a positive impact in decreasing risk on human health and environment. Gathered Information from containers barcodes or RFID tags technology analyzed with information generated from import permits, prescriptions and other systems of pesticides residues monitoring will expose illegal trafficking and misuse of pesticides, making room for legal actions to be taken against perpetrators. The "Pesticide Stock Management System (PSMS)" ("PSMS - Pesticide Stock Management System," 2019) offered by FAO can be modified to serve as a start in pesticides container tracking. Other systems from private suppliers are available worldwide. Still, to achieve results, government incentives for farmers to return empty containers, cooperation of public and private stakeholders, and training are needed.

4.1.2.4. Prescriptions. If, at the end of the day, the deleterious effect of pesticides on humans and environment is promulgated by their misuse by farmers who often don't possess the proper knowledge, putting the decision of using hazardous chemical pesticides in capable hands seems very logical. The panacea, the "solve it all" proposition in such a case would be "prescriptions" (Eddleston et al., 2002). Accordingly, highly hazardous and hazardous pesticides won't be available for sale by merchants without prescriptions. Only certified agricultural engineers, who have been trained with a definite curriculum and passed the official examination, will be allowed to prescribe pesticides of those categories to trained pesticide applicators or qualified farmers. Only pesticides from a safe list of pesticides will be available over the counter for the public. For traceability reasons, prescriptions are to be made on 5 copies. One copy remains with the prescriber; the other copies are provided for each of the farmer, the merchant, the ministry of agriculture, and the order of agricultural engineers. In a country such as Lebanon, prescriptions will not only define responsibilities in pesticides misuse, but will also restrict illegal trafficking with counterfeit and smuggled pesticides.

4.1.2.5. Application equipment. Uncalibrated equipment or wrong spraying equipment leads to an overdosing or under-dosing of the pesticide liberated in the environment (Hillocks, 2012). The Lebanese market is full of all kinds of sprayers ranging from classical knapsack to electrostatic sprayers, including locally made and assembled tractor driven sprayers sold without any quality control. Therefore, it is recommended to include some legislative clauses based on the published

FAO guidelines on minimum requirements and standards for agricultural pesticide application equipment among other guidelines (FAO, 2001).

4.1.2.6. Cost of pesticide management activities. Provisions within the law should be made to charge the pesticides industry/business for services of registration, lab tests, disposal of obsolete pesticides and inspections.… (EPA, 2015b) to generate enough resources to cover the cost of the other activities within the pesticides lifecycle management, from the needed risk assessment studies until the monitoring and surveillance of issues related to pesticides impact on health and environment, which is in line with the guidelines of the FAO code of conduct (FAO/WHO, 2015a; FAO & WHO, 2011). Mainstreaming, industry involvement (promoted extended producer responsibility and internalization of costs by industry), and dedicated external financing, along with new and innovative financing (e.g. through cost recovery and engagement of the financial sector) could also be accounted for (UNEP/EA.4/21/Global Chemcial Outlooks II, 2019).

5. Conclusions

Unquestionably, there is an urgent need to upgrade the existing pesticides legislation and regulations within the context of a clear policy built on judicial and coordinated use of its tools to amend many of the revealed strategic flaws. Few of these flaws just cannot be disregarded as they could have many negative implications on the country's population's health and environment. The main issue here is to be able to deal with pesticides safely and holistically to include all types of pesticides and all aspects of their lifecycle management. Interministerial cooperation in the quest of a unified policy and a national pesticides law should be secured to ensure involvement and adoption by all stakeholders and to eliminate the parties' fear of jurisdictions and power loss. In addition, all the governmental agencies involved in the pesticide lifecycle management, non-governmental agencies, pesticides industry, research institutes and universities should collaborate to achieve good governance over an acceptable pesticides risk mitigation. The process of reforms can be started by any of the concerned ministries as a proposal to the government to include human health and environment protection within its vision and pesticides risk reduction within its mission. The proposed amendments cannot be done all at once; the administration has to move forward by upgrading the regulations on a step by step approach, starting with the national law and initiation of the pesticides board and its affiliated technical and implementation committees. Some amendments should be done at a parliamentary level; others are to be done at the level of the cabinet, and some need only ministerial decisions to suit the country's need in the best way possible. In a transitional phase, policy makers in developing countries, which have weak regulations and enforcement and are incapable of having a good governance over the pesticides lifecycle, should adopt the prevention approach to preserve human and environmental health. Accordingly, banning the use of highly hazardous and hazardous pesticides categories and encouraging safe alternatives should be set as a priority for spending the limited resources their countries possess. To achieve good governance over an acceptable pesticides risk control it is necessary to have a combination of a comprehensive pesticides registration, monitoring and implementation systems supported by a “prescription” systems, a suitable IPM/ICM government-supported credit system, a traceability system of agricultural commodities and pesticides containers, a Pesticide stock management system to reduce the quantity of obsolete pesticides, and empty containers recycling system. Finally, national pesticides risk management is to be looked at as a part of a global matrix to sustain planetary health and resources for the generations to come. Hence, a global intervention fostered by the United Nations is called upon to enhance and update the already existing mechanisms of Basel, Stockholm, Rotterdam conventions to ban the trafficking of highly hazardous and hazardous pesticides into and on developing countries' territories with proven weak pesticides lifecycle management. Global fund should be secured to support those developing countries in producing the necessary legislation for an effective pesticides' lifecycle management, in addition to concretizing safe alternatives.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data included in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors are thankful to Mrs. Nisrine Awarke Abou Zeid for English editing the manuscript.

References

Aiello, G., Enea, M., Muriana, C., 2015. The expected value of the traceability information. Eur. J. Oper. Res. 244, 176–186.

Aisha, A.A., Hneine, W., Mokh, S., Devier, M.H., Budzinski, H., Jaber, F., 2017. Monitoring of 45 pesticides in Lebanese surface water using polar organic chemical integrative sampler (POCIS). Ocean Sci. J. 52, 455–466.

Al-Alam, J., Millet, M., Chbani, A., Fajloun, Z., 2015. Contribution to the food products' analysis: a research and evaluation on the hemolytic effect of some pesticides used in Lebanon. J. Environ. Sci. Health Part B Pestic. Food Contam. Agric. Wastes 50, 788–796.

Al Alam, J., Fajloun, Z., Chabni, A., Millet, M., 2017. The use of honey as environmental biomonitor of pesticides contamination in northern Lebanon. Euro-Med. J. Environ. Integr. 2.

Alexandratos, N., Bruinsma, J., 2012. World Agriculture towards 2030/2050: the 2012 Revision. WORLD AGRICULTURE.

Assaf, N., 2002. Produce Poisoned by Pesticides | News, Lebanon News | the DAILY STAR [WWW Document]. http://www.dailystar.com.lb/News/Lebanon-News/2002/Jan-19/36232-produce-poisoned-by-pesticides.ashx (accessed 10.27.19).

Aven, T., Renn, O., 2018. Improving government policy on risk: eight key principles. Reliab. Eng. Syst. Saf. 176, 230–241.

Böcker, T., Finger, R., 2016. European pesticide tax schemes in comparison: an analysis of experiences and developments. Sustain. Times 8, 378.

Bonvoisin, T., Utyasheva, L., Knipe, D., Gunnell, D., Eddleston, M., 2020. Suicide by pesticide poisoning in India: a review of pesticide regulations and their impact on suicide trends. BMC Publ. Health 20.

Borel, B., 2017. When the pesticides run out. Nature 543, 302–304.

Centner, T.J., 2018. Cancelling pesticide registrations and revoking tolerances: the case of chlorpyrifos. Environ. Toxicol. Pharmacol 57, 53–61.

Charlebois, S., Sterling, B., Haratifar, S., Naing, S.K., 2014. Comparison of global food traceability regulations and requirements. Compr. Rev. Food Sci. Food Saf. 13, 1104–1123.

Chaza, C., Rayane, S., Sopheak, N., Moomen, B., Baghdad, O., 2018a. Distribution of organochlorine pesticides and heavy metals in Lebanese agricultural soil: case study—plain of akkar. Int. J. Environ. Res. 12, 631–649.
Chaza, C., Sopheak, N., Mariam, H., David, D., Baghdad, O., Moomen, B., 2018b. Assessment of pesticide contamination in Akkar groundwater, northern Lebanon. Environ. Sci. Pollut. Res. 25, 14302–14312.
Cheng, C., Jiang, P., Liu, J., 2013. A common traceability method for agricultural products based on data center. Sens. Lett. 11, 1269–1273.
Cox, C., Surgan, M., 2006. Unidentified inert ingredients in pesticides: implications for human and environmental health. Environ. Health Perspect. 114, 1803–1806.
Culliney, T.W., 2014. Crop losses to arthropods. In: Integrated Pest Management: Pesticide Problems, 3, pp. 201–225.
Damalas, C.A., Eleftherohorinos, I.G., 2011. Pesticide exposure, safety issues, and risk assessment indicators. Int. J. Environ. Res. Publ. Health.
Damalas Christos, A., Koutroubas, S.D., 2017. Farmers' training on pesticide use is associated with elevated safety behavior. Toxics 5 (3), 1–10.
Damalas, Christos A., Koutroubas, S.D., 2018. Current status and recent developments in biopesticide use. Agric. For. 8, 1–6.
Davis, M., Gathorne-Hardy, A., Jaacks, L., 2020. Pesticides and increased food production–a response to Dunn & colleagues. Clin. Toxicol.
Eddleston, M., Karalliedde, L., Buckley, N., Fernando, R., Hutchinson, G., Isbister, G., Konradsen, F., Murray, D., Piola, J.C., Senanayake, N., Sheriff, R., Singh, S., Siwach, S.B., Smit, L., 2002. Pesticide poisoning in the developing world - a minimum pesticides list. Lancet 360, 1163–1167.
El-Osmani, R., Net, S., Dumoulin, D., Baroudi, M., Bakkour, H., Ouddane, B., 2014. Solid phase extraction of organochlorine pesticides residues in groundwater (Akkar Plain, North Lebanon). Int. J. Environ. Res. 8, 903–912.
El Hawari, K., Mokh, S., Al Iskandarani, M., Halloum, W., Jaber, F., 2019. Pesticide residues in Lebanese apples and health risk assessment. Food Addit. Contam. Part B Surveill. 12, 81–89.
EPA, 2019. . FY 2019 EPA Budget in Brief.
EPA, 2015a. PRIA3 Interpretations (9/11/2013) [costs Revised 7/17/15].
EPA, 2015b. PRIA3 Interpretations (9/11/2013) [costs Revised 7/17/15] FY 16/17.
European Parliament, 2009. REGULATION (EC) No 1107/2009 Concerning the Placing of Plant protection Products on the Market and Repealing Council Directives 79/117/EEC and 91/414/EEC THE, Official Journal of the European Union. https://doi.org/10.3000/17252555.L_2009.309.eng.
FAO-WHO, 2019a. Codex texts | CODEXALIMENTARIUS [WWW document]. Codex Aliment. Comm. http://www.fao.org/fao-who-codexalimentarius/codex-texts/en/ (accessed 11.10.19).
FAO/WHO, 2019b. Plant production and protection division: pesticide specifications and quality control standards page [WWW document]. JMPS. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmps/en/ (accessed 11.10.19).
FAO/Pesticide Registration Toolkit, 2018. Pesticide registration Toolkit | food and agriculture organization of the United Nations [WWW document]. http://www.fao.org/pesticide-registration-toolkit/registration-tools/registration-strategies/registration-by-analogy/en/ (accessed 11.20.19).
FAO/WHO, 2015a. International code of conduct on pesticide management guidelines on pesticide legislation.
FAO/WHO, 2015b. Guidelines on good labelling practice for pesticides (revised). Rome.
FAO/WHO, 2019c. Plant production and protection division: the joint FAO/WHO meeting on pesticide residues (JMPR) [WWW document]. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmpr/en/ (accessed 11.10.19).
FAO, 2016. Submission and evaluation of pesticide residues data for the estimation of maximum residue levels in food and feed. In: Third edit (Ed.), FOOD and AGRICULTURE ORGANIZATION of the UNITED NATIONS, Rome.
FAO, 2014. The International Code of Conduct on Pesticide Management. Rome.
FAO, 2010. Guidance on Pest and Pesticide Management Policy Development. FAO, Rome.
FAO, 2001. Guidelines on the Organization of Schemes for Testing and Certification of Agricultural Pesticide Sprayers in Use, International Code of Conduct on the Distribution and Use of Pesticides. Rome.
FAO, WHO, 2011. International Code of Conduct on the Distribution and Use of Pesticides. Guidelines for Quality Control of Pesticides. Rome.
FAO, WHO, 2014. The International Code of Conduct on Pesticide Management: Guidelines on Pesticide Advertising.
Finger, R., Möhring, N., Dalhaus, T., Böcker, T., 2017. Revisiting pesticide taxation schemes. Ecol. Econ. 134, 263–266.
Habboush, J., 2017. PressReader.com - your favorite newspapers and magazines. [WWW Document]. Leban. govt denies being Inf. UAE apple ban. https://www.pressreader.com/lebanon/the-daily-star-lebanon/20170428/281505046111984 (accessed 10.27.19).
Handford, C.E., Elliott, C.T., Campbell, K., 2015. A review of the global pesticide legislation and the scale of challenge in reaching the global harmonization of food safety standards. Integrated Environ. Assess. Manag. 11, 525–536.
Harmouche-Karaki, M., Matta, J., Helou, K., Mahfouz, Y., Fakhoury-Sayegh, N., Narbonne, J.F., 2018. Serum concentrations of selected organochlorine pesticides in a Lebanese population and their associations to sociodemographic, anthropometric and dietary factors: ENASB study. Environ. Sci. Pollut. Res. 25, 14350–14360.
Hattam, J., 2009. Pesticide scare drives organic purchases in Lebanon | TreeHugger [WWW document]. https://www.treehugger.com/green-food/pesticide-scare-drives-organic-purchases-in-lebanon.html (accessed 10.27.19).
Helou, K., Harmouche-Karaki, M., Karake, S., Narbonne, J.F., 2019. A review of organochlorine pesticides and polychlorinated biphenyls in Lebanon: environmental and human contaminants. Chemosphere.
Hillocks, R.J., 2012. Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. Crop Protect. 31, 85–93.
Horgan, F.G., 2017. Integrated pest management for sustainable rice cultivation: a holistic approach. In: Cambridge: Burleigh Dodds Science Publishing Limited. Burleigh Dodds Science Publishing Limited, Cambridge, pp. 309–342.
ILO, 1990. Convention C170-Chemicals Convention, 1990 (No. 170) [WWW Document]. https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE: C170 (accessed 11.10.19a).
ILO, 1979. Convention C152-Occupational safety and health (dock work) convention, 1979 (No. 152) [WWW Document]. https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE: C152 (accessed 11.10.19b).
InfoCuria, Case-law, 2019. Documents Relating to Carcinogenicity Studies Conducted in Connection with the Renewal of the Approval of the Active Substance Glyphosate [WWW Document]. Judgm. Gen. Court (Eighth Chamber). http://curia.europa.eu/juris/document/document_print.jsf;jsessionid=7A7C085F842A811DE5C79E8373F0CA89?docid=211426&text=&dir=&doclang=EN&part=1&occ=first&mode=DOC&pageIndex=0&cid=2356240 (accessed 3.30.20).
Jepson, P.C., Murray, K., Bach, O., Bonilla, M., Neumeister, L., 2020a. A global guideline for pesticide selection to reduce risks, and establish a minimum pesticides list. SSRN Electron. J.
Jepson, P.C., Murray, K., Bach, O., Bonilla, M.A., Neumeister, L., 2020b. Selection of pesticides to reduce human and environmental health risks: a global guideline and minimum pesticides list. Lancet Planet. Heal. 4, e56–e63.
Karunarathne, A., Gunnell, D., Konradsen, F., Eddleston, M., 2020. How many premature deaths from pesticide suicide have occurred since the agricultural Green Revolution? Clin. Toxicol.
Kfoury, L., Hilan, C., El-Amil, R., 2002. Residue analysis OF pesticides commonly used BY LEBANESE farmers ON strawberries. Leban. Sci. J.
Lebanese customs, 2019a. Trade Statistics [WWW Document]. Ten Yeards Comp. Stat. http://customs.gov.lb/Trade_Statistics/TenYears/TenYears.aspx (accessed 11.7.19).
Lebanese Customs, 2019b. Tariff Table [WWW Document]. http://customs.gov.lb/Tariff/Tariff_Table.aspx?CH=38 (accessed 11.9.19).
Lebanese Ministry of Agriculture, 2015. Ministry of Agriculture Strategy.
Lechenet, M., Dessaint, F., Py, G., Makowski, D., Munier-Jolain, N., 2017. Reducing pesticide use while preserving crop productivity and profitability on arable farms. Nat. Plants 3, 17008.
Loha, K.M., Lamoree, M., Weiss, J.M., de Boer, J., 2018. Import, disposal, and health impacts of pesticides in the East Africa Rift(EAR) zone: a review on management and policy analysis. Crop Protect.
Mancini, F., Woodcock, B.A., Isaac, N.J.B., 2019. Agrochemicals in the wild: identifying links between pesticide use and declines of nontarget organisms. Curr. Opin. Environ. Sci. Heal.
Manuweera, G., 2007. Alternative strategies of pesticide management. Outlooks Pest Manag.
Mengistie, B.T., Mol, A.P.J., Oosterveer, P., 2017. Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. Environ. Dev. Sustain. 19, 301–324.
Mengistie, B.T., Mol, A.P.J., Oosterveer, P., Simane, B., 2015. Information, motivation and resources: the missing elements in agricultural pesticide policy implementation in Ethiopia. Int. J. Agric. Sustain. 13, 240–256.
Ministry of Economics, 2019. Decree number 5497 (Imposition of some procedures in order to protect national products). Off. Gaz. 45, 3267–3272.
Multilateral Montreal Protocol on Substances that Deplete the Ozone Layer (with annex), 1987. Concluded at Montreal on 16 Sep Tember.
Nagy, K., Duca, R.C., Lovas, S., Creta, M., Scheepers, P.T.J., Godderis, L., Ádám, B., 2020. Systematic review of comparative studies assessing the toxicity of pesticide active ingredients and their product formulations. Environ. Res. 181.
Nasreddine, L., Rehaime, M., Kassaify, Z., Rechmany, R., Jaber, F., 2016. Dietary exposure to pesticide residues from foods of plant origin and drinks in Lebanon. Environ. Monit. Assess. 188 (21).
OECD, 2011. GUIDANCE DOCUMENT on REGULATORY INCENTIVES for the REGISTRATION of PESTICIDE MINOR USES Series on Pesticides No. 63 JT03304463. Paris.
OECD, 2004. OECD Guidance for Industry Data Submissions for Microbial Pest Control Products and Their Microbial Pest Control Agents (Dossier Guidance for Microbials) Guidelines and Criteria for Industry for the Preparation and Presentation of Complete Dossiers and of.
OECD, 1996. Report of the OECD-FAO Workshop on Pesticide Risk Reduction. Uppsala, Sweden.
Oerke, E.C., 2006. Crop losses to pests. J. Agric. Sci.
Olson, S., 2015. An analysis of the biopesticide market now and where it is going. Outlooks Pest Manag. 26, 203–206.
Onwona Kwakye, M., Mengistie, B., Ofosu-Anim, J., Nuer, A.T.K., van Den Brink, P.J., 2018. Pesticide registration, distribution and use practices in Ghana. Environ. Dev. Sustain. 1–25.
Pelfrène, A.F., Vettorazzi, G., 1987. Pesticide Use exposure and regulation in developed and developing countries. In: Toxicology of Pesticides. Springer Berlin Heidelberg, berlin, pp. 253–260.
Pimentel, D., Burgess, M., 2005. Environmental and economic costs of the application of pesticides primarily in the United States. Integr. Pest Manag. 47–71.
Popp, J., Pető, K., Nagy, J., 2013. Pesticide productivity and food security. A review. Agron. Sustain. Dev. 33, 243–255.
Pretty, J., Bharucha, Z.P., 2015a. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects 6, 152–182.
Pretty, J., Bharucha, Z.P., 2015b. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects 6, 152–182.

PSMS, 2019. Pesticide Stock Management System [WWW Document]. http://psms.fao.org/psms/login.htm (accessed 12.1.19).
Quandt, S.A., Arcury, T.A., Pell, A.I., 2011. A community and academic partnership to address farmworker pesticide exposure in North Carolina. Environ. Health Perspect. 109 (3), 435–441.
Rotterdam Convention Text [WWW Document], 2019. http://www.pic.int/TheConvention/Overview/TextoftheConvention/RotterdamConventionText/tabid/1160/language/en-US/Default.aspx (accessed 11.10.19).
Salameh, Pascale R., Abi Saleh, B., 2004. Symptoms and acute pesticide intoxication among agricultural workers in Lebanon. J. Med. Liban. 52, 64–70.
Salameh, P., Waked, M., Baldi, I., Brochard, P., Saleh, B.A., 2006. Respiratory diseases and pesticide exposure: a case-control study in Lebanon. J. Epidemiol. Community Health 60, 256–261.
Salameh, P.R., Baldi, I., Brochard, P., Abi Saleh, B., 2004. Pesticides in Lebanon: a knowledge, attitude, and practice study. Environ. Res. 94, 1–6.
Schreinemachers, P., Chen, H., pu Nguyen, T.T.L., Buntong, B., Bouapao, L., Gautam, S., Le, N.T., Pinn, T., Vilaysone, P., Srinivasan, R., 2017. Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. Sci. Total Environ. 593–594, 470–477.
SENAT FRANCAIS, 2017. Projet de loi de finances pour 2017 : Prévention des risques [WWW Document]. https://www.senat.fr/rap/a16-145-2/a16-145-22.html (accessed 10.25.19).
Sharafi, K., Pirsaheb, M., Maleki, S., Arfaeinia, H., Karimyan, K., Moradi, M., Safari, Y., 2018. Knowledge, attitude and practices of farmers about pesticide use, risks, and wastes; a cross-sectional study (Kermanshah, Iran). Sci. Total Environ. 645, 509–517.
Singh, D., Karthik, S., Nar, S., Piplani, D., 2017. Food traceability and safety: from farm to fork – a case study of pesticide traceability in grapes. J. Adv. Agric. Technol. 4, 40–47.
Skevas, T., Oude Lansink, A.G.J.M., Stefanou, S.E., 2013. Designing the emerging EU pesticide policy: a literature review. NJAS - Wageningen. J. Life Sci.
Smadi, Jammoul, Darra, El, 2019. Assessment of antibiotic and pesticides residues in breast milk of Syrian refugee lactating mothers. Toxics 7 (39).
Stavins, R.N., Kennedy, J.F., 2003. Experience with market-based environmental policy instruments. In: Handbook of Environmental Economics. Elsevier, Washington, DC, USA, pp. 355–435.
Stehle, S., Schulz, R., 2015. Pesticide authorization in the EU—environment unprotected? Environ. Sci. Pollut. Res. 22, 19632–19647.
Stockholm Convention Text on Persistent Pollutants (POPs) [WWW Document], 2019. http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx (accessed 11.10.19).
Storck, V., Karpouzas, D.G., Martin-Laurent, F., 2017. Towards a better pesticide policy for the. Eur. Union. Sci. Total Environ. 575, 1027–1033.
Sugahara, K., 2009. Traceability system for agricultural products based on RFID and mobile technology. In: IFIP Advances in Information and Communication Technology, pp. 2293–2301.
The Daily Star, 2009. MP Qabbani Urges State of Emergency over Poisoned Produce | News, Lebanon News | the DAILY STAR [WWW Document]. http://www.dailystar.com.lb/News/Lebanon-News/2009/Nov-09/54836-mp-qabbani-urges-state-of-emergency-over-poisoned-produce.ashx (accessed 10.27.19).
The Lancet, 2017. Phasing out harmful use of pesticides. Lancet.
The Science Communication Unit, U. of the W. of E, 2017. The precautionary principle: decision-making under uncertainty. Futur. Br. 1–24. September.
UN/Human Rights Council, 2017. Report of the Special Rapporteur on the Right to Food, A/HRC/34/48.
UNEP/EA.4/21/Global Chemcial Outlooks II, 2019. Programme of Work and Budget, and Other Administrative and Budgetary Issues Global Chemicals Outlook II: Summary for Policymakers Report of the Executive Director Summary. Nairobi.
Unified Bilateral Treaty on Agricultural Pesticides, 2002. Official Gazette. Official Gazette No. 5, 30 January 2002, p. 7.
United States Environmental Protection Agency, 2018. Public Participation Process for Registration Actions [WWW Document]. In: https://www.epa.gov/pesticide-registration/public-participation-process-registration-actions (accessed 11.18.19).
United States Environmental Protection Agency, 2011. Pesticides Classified for Restricted Use. U.S.C, USA.
van den Berg, H., 2004. IPM Farmer Field Schools: A Synthesis of 25 Impact Evaluations, FAO/Global IPM Facility. FAO Wageningen University, Wageningen, the Netherlands, Rome.
Van den Berg, H., Gu, B., Grenier, B., Kohlschmid, E., Al-Eryani, S., da Silva Bezerra, H.S., Nagpal, B.N., Chanda, E., Gasimov, E., Velayudhan, R., Yadav, R.S., 2020. Pesticide lifecycle management in agriculture and public health: where are the gaps? Sci. Total Environ. 742, 140598.
Vapnek, J., Pagotto, I., Kwoka, M., 2007. Designing National Pesticide Legislation (No. 97). Rome.
Viero, C.M., Camponogara, S., Cezar-Vaz, M.R., Costa, V.Z., da Beck, C.L.C., 2016. Risk society: the use of pesticides and implications for the health of rural workers. Esc. Anna Nery - Rev. Enferm. 20, 99–105.
WHO, 2016. DETERMINATION of EQUIVALENCE for PUBLIC HEALTH PESTICIDES and PESTICIDE PRODUCTS Report of a WHO Consultation. Geneva, Switzerland.
Wilson, C., Tisdell, C., 2001. Why farmers continue to use pesticides despite environmental, health and sustainability costs. Ecol. Econ. 39, 449–462.
Yan, H., van der Heijden, J., van Rooij, B., 2017. Symmetric and asymmetric motivations for compliance and violation: a crisp set qualitative comparative analysis of Chinese farmers. Regul. Gov. 11, 64–80.
Youssef, L., Younes, G., Kouzayha, A., Jaber, F., 2015. Occurrence and levels of pesticides in South Lebanon water. Chem. Speciat. Bioavailab.
Zhang, M., Zeiss, M.R., Geng, S., 2015. Agricultural pesticide use and food safety: California's model. J. Integr. Agric.