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Health and environmental impacts of pesticides: A responsibility principle and two novel systems for hazard classification and external cost determination

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Abstract

Environmental policies built on the principles of 'Extended Producer Responsibility' (EPR) have spread to cover multiple categories of products and their containers or packages. Although pesticides are genuinely hazardous to human health and the environment, their negative impacts/externalities have not been targeted by these policies. In this manuscript, the author proposes an overarching *'toxi-economic'* principle called the *'Extended Pesticide Producer and User Responsibility' (EPPUR)* that justifiably assigns responsibility to the imposer(s) of health and environmental impacts of pesticides throughout their life cycles. The producer, sometimes the importer, should solely bear the upstream responsibility (toxicological, physical, informative, financial, legal, etc.) of the negative impacts of pesticides from the time of their production till their end-of-life. However, the downstream (post-consumption phase) responsibility should be distributed between the producer and the consumer/user. Because it is mostly related to toxicological impacts, the producer rather than the user responsibility is hard to be economically assessed. In an attempt to monetize the toxicological impacts of *'individual'* pesticides on human health and the environment, the author establishes a novel *'Pesticide Negative Externality Assessment'* (PNEA) system which customizes the *'undifferentiated'* baseline cost to an *'individual'* cost using the environmental impact quotient (EIQ). This system establishes Euro 0.303 to be the standard external cost for each EIQ unit. By knowing the EIQ value of any pesticide, one can easily calculate its external cost and use it to levy the producer for the health and environmental externality caused by any amount of this pesticide. Finally the author proposes a novel EIQ-based hazard classification and color-coding system to possibly replace or complement the WHO/FAO system which is limitedly based on the mammalian acute toxicity.

Keywords: Pesticide hazard classification, negative impacts of pesticides, negative externality, external or social cost, pesticide taxation, pareto efficiency, producer pays principle, extended producer responsibility, end-of-life management, pesticide environmental accounting (PEA), pesticide negative externality assessment (PNEA), environmental impact quotient, environmental policies, environmental tax

Background

Thousands of agricultural and non-agricultural pest species (insects, mites, fungi, bacteria, nematodes, rodents, weeds, etc.) compete with humans for food; reduce the quality of agricultural products; cause diseases to humans as well as domestic and wild animals. Therefore, humans control pests since the time they started living and farming. Although the first record of pesticide use dated back to 2500 BC, it is only in the last century that pesticide chemicals have been used extensively worldwide [1]. Pesticides have steadily become indispensably the most frequently used means of pest control/management for several reasons: they are mostly cost-effective; they have high return on investment [2]; they have high structural, toxicological and functional diversity; they offer multipurpose management options; they have wide-spectrum efficacy; and they allow high flexibility and better timing.

Despite all their benefits and contribution to maintain a stable supply of affordable agricultural products, pesticides are commonly known to damage human health and the environment. The adverse side effects of pesticides impact the society in general and those who are directly and unjustifiably exposed to their residues, in particular. Toxicologists consider pesticides to have become a necessary evil and like many discoveries or developments, people have been quick to reap their benefits, but extra slow to comprehend and deal with their negative reversible, sometimes irreversible, impacts on human health and the environment. The adverse impacts of used pesticides are unavoidable for at least two reasons: (1) over 90% of applied pesticides reach different environmental destination other than the target pests [3], and (2) all pesticides are toxicologically and/or structurally designed to affect/kill some form(s) of life [4] and are then expected to affect human and non-human health in many different ways. The seemingly unavoidable negative impacts of pesticides imply that their producers and users impose external costs on others for which the imposers are not properly charged. It is ethically and socio-economically legitimate to set a policy that shifts the responsibility of pesticides' negative externalities from the general public, or local government to producers and users.

Hundreds of environmental policies that dealt with the negative externality of a multitude of products, except pesticides, were developed along with their internalization instruments [5]. Therefore, the author of this manuscript conceptualized a stewardship policy principle to properly assign the responsibility of pesticides' negative impacts and their associated externalities to producers and users. This principle implies that external costs of controlling and cleaning up pollution of pesticides; of preventing, curbing or abating their environmental damaging potential and of avoiding, minimizing, or remedying their adverse effects on human health must be paid by those who are benefiting from their production and use. To help translate the proposed principle into an implementable policy, the author innovates two systems; one for assessing and monetizing the negative externality of individual pesticides, and the other for their hazard classification.

The essence and origin of negative externality

This section overviews some general principles of externality and internalization, and how they are used by the author to address and quantify *'specifically'* pesticide negative externality. Henry Sidgwick and Arthur C. Pigou are two pioneering British economists who have been credited with initiating the formal study of externalities [6]. One of the simplest definitions of negative externality (also called external cost or social cost) is: *"an economic activity that imposes a negative effect on an unrelated third party. It can arise either during the production or the consumption of a good or service"* [6]. Almost a century ago, Arthur C. Pigou proposed compensation of the society for any social or public burden or damage in the form of taxation [7]. Although Pigou's ideas on externality and internalization were reconsidered and framed in modern economy by Ronald Coase [8], William Baumol [9] and others, they have never been taken seriously for pesticides except in few countries including the Scandinavian and Nordic countries [10] and Mexico [11]. To illustrate one dimension of negative externality let's think about the use of a pesticide on paddy rice in fields of standing water. Residues of this pesticide will remain in the water when it is drained from the paddy field. People, domestic animals, honey bees, fish and wildlife located downstream may be exposed and negatively affected by polluted water. Under these circumstances, recipients of the pesticide's adverse effects have no way of charging the upstream rice farmers for polluting their water and negatively affecting their health and belongings. The cost in this case is called *'external cost'* as it is not borne by those who genuinely benefit from the production and use of the pesticide [12]. In this case, not internalizing the negative external costs of pesticide pollution into the rice production costs of upstream farms causes social injustice and market inefficiency. Internalization of pesticide negative externality in the form of taxation would buffer against pesticide overuse and bring pesticide market to the Pareto efficiency [13]. According to Wikipedia [14], *"Pareto efficiency is a state of allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off."* Investigating pesticide externality in the US agricultural sector indicates that full internalization substantially reduces application rates of pesticides on corn and soybean as climate changes [15]. Besides, experiences from many Scandinavian countries have indicated that eco-taxes can be quite effective in their environmental impact not only for pesticides but also for fertilizers [10].

Externality and responsibility principles

Issues related to environmental protection and sustainable development were discussed in US and European scientific and regulatory/policy circles in the early 1970's. Since then many environmentally-friendly principles and policies have been gradually adopted to protect human health and the environment. In particular, 'Polluter Pays Principle' (PPP) was first introduced by the OECD on May 26th, 1972 [16], and later reaffirmed in its recommendations of November 14th 1974 [17] and July 7th 1989 [18]. It implied that the environmental responsibility of dealing with the waste(s) of any product must be shifted from local government to the producer of this product. Another environmental principle that seems to be operational and practical is the Extended Producer Responsibility (EPR). This principle was introduced to the Swedish Ministry of the Environment as a conceptual framework for designing environmental policies [19,20]. EPR aims at improving the end-of-life (EOL) management or treatment of waste or discarded products. Interestingly, EPR was introduced at a time when several European and Scandinavian countries implemented some PPP-related policies [21]. Since its first introduction, the original EPR concept had spread around the world like a virus and its definition [22] and name [23] were modified. The OECD definition of EPR [22] is concise,

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straightforward and reads: "*an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle.*" There has been cumulative adoption of EPR- or EPR-like policies since the eighties. The adoption rate increased significantly in the last decade [24] to reach over 384 implemented policies in 28 EU states; covering a variety of products in a very heterogeneous manner [25]. In British Columbia (BC), alone, at least 23 different EPR programs exist and seem to be both economically and environmentally beneficial [26].

Strategies and policies that internalize the cost of managing the products' end-of-life are also implemented in non EU countries such as Canada, the US, Japan [27], the State of New South Wales in Australia [28], and many Asian countries including Korea [29], China [30], Thailand [31], to count just a few. Recently, in the Alameda County (California) and the King County (Washington), EPR-ordinances for pharmaceuticals have been upheld allowing any local US government to set policies that make the producers pay for the management systems/costs of all products not just pharmaceuticals [32]. The Institute for European Environmental Policy provided a comprehensive report on environmental tax reform (ETR) to the Netherlands Ministry of Infrastructure and the Environment and suggested marine litter and pesticides to be focal targets [33]. Furthermore, Sanz and others [34] are leading a campaign of redesigning EPR policies to embody continuous responsibility throughout the product's entire life cycle, not just its end-of-life.

Five critical observations can be extracted from the above Background sections. (1) Most European EPR policies focus only on the end-of-life, i.e., once the product has become a waste. Thus, had these policies been applied to pesticides, they would only cover the minor, physical component of their negative impacts. (2) In many EPR systems, the costs connected to waste collecting, recycling, and/or disposing, are not fully or reasonably reflected in the price of the products. (3) The policy instruments are not efficient enough to steer any transition towards circular economy. (4) EPR- or EPR-like policies are not broad enough to target pesticides despite their serious toxicological and physical impacts to human health and the environment. (5) A new extended responsibility principle and related policies that target the toxicological and physical impacts of pesticides throughout their life cycles are critically due at this moment.

Methods

The environmental impact quotient (EIQ) is central in the present study. EIQ can be defined as a summative measure of the potential impact of a pesticide's active ingredient on human health and the environment. This quotient was first developed by Kovach and others [35] at New York State Agricultural Experiment Station (NYSAES), Cornell University, Geneva, NY. The EIQ values used in the present study were mostly obtained from the New York State Integrated Pest Management Program [36]. Since some of the active ingredients were not included in the NYS-IPM database during the course of investigation, they were calculated by the author following Kovach's EIQ-equation [35], and using the physicochemical and ecotoxicological data that are currently available at the University of Hertfordshire's Pesticide Properties DataBase, PPDB [37]. When some measures were missing, the author used three proxy tables; one for each of the major pesticide groups (insecticides, herbicides and fungicides), that were kindly obtained as a courtesy from Dr. Joe Kovach [38], the founder of the EIQ equation. Each table contains the numbers that can be used to compensate for any of the missing EIQ measures. The EIQ equation will be briefly explained as follows:

$$EIQ=\{C*[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3$$

Where C=chronic toxicity which is the average impact of reproductive, teratogenic, mutagenic and oncogenic potential; DT=dermal toxicity; P=plant surface half-life; S= soil half-life; SY=systemicity; L=leaching potential; F=fish toxicity; R=runoff or surface loss potential; D=bird toxicity; Z=bee toxicity and B =beneficial arthropod toxicity. A scoring system (1-3-5, only 1 and 3 for SY) was used with the above-mentioned eleven parameters to quantify the magnitude of negative effects of any pesticide on seven human health and environmental components (applicator, picker, consumer, fish, birds, honey bee and natural enemies). Some authors inaccurately separate the ground water impact from the consumer impact; therefore, EIQ components become eight instead of seven. The numerical values (3 and 5 in the above equation) are impact multipliers or relative weights assigned to emphasize the likely exposure of individual EIQ components to the examined pesticide.

Results

This manuscript mainly contains three interrelated, value-added results that will be explained separately under the next sections. The main purpose of this study was to set an extended responsibility principle for the mammalian and eco-toxicological impacts of pesticides, as well their end-of-life physical impacts on the environment (the first result). In order to translate this principle into workable environmental policies, two novel systems were founded; one for assessing the negative externality of individual pesticides (the second result), and the other for classifying pesticide hazard based on the environmental impact quotient (the third result).

Extended pesticide producer and user responsibility (EPPUR)

Due to their multiple toxicological and physical impacts, pesticides could not be considered/targeted by the well-known principle of Extended Producer Responsibility and its related policies. This is why the author of this manuscript formulated a new principle of stewardship that justifiably distributes and assigns the responsibility of both the physical and toxicological impacts of pesticides throughout their life cycles mainly to their producers and users. The new principle is called *'Extended Pesticide Producer and User Responsibility' (EPPUR)* and can be defined as follows: *"EPPUR is an environmental principle under which the pesticide producer should bear the full responsibility for the adverse health and environmental impacts that are related to the nature and formulation of the active ingredient and may happen throughout the pesticide's life-cycle. When the pesticide is properly handled and applied according to its label instructions, the user may bear minor, sometimes subsidized, end-of-life responsibility for the clean-up of waste and disposal. The take-back of unused or expired pesticides remains the producer or importer responsibility."* The author coins a new adjective term for the EPPUR principle or its related policy; it is *'toxi-economic'* because it mainly depends on monetarily quantifying the negative toxicological impacts of pesticides. The EPPUR principle is considered new for at least two reasons: (1) it considers the responsibility throughout the pesticide's whole life cycle; not just its end-of-life; (2) it emphasizes both the toxicological and physical impacts of pesticides. In order to build an EPPUR management or regulatory policy, this policy should be structured into phases and levels as shown in **Figure 1**.

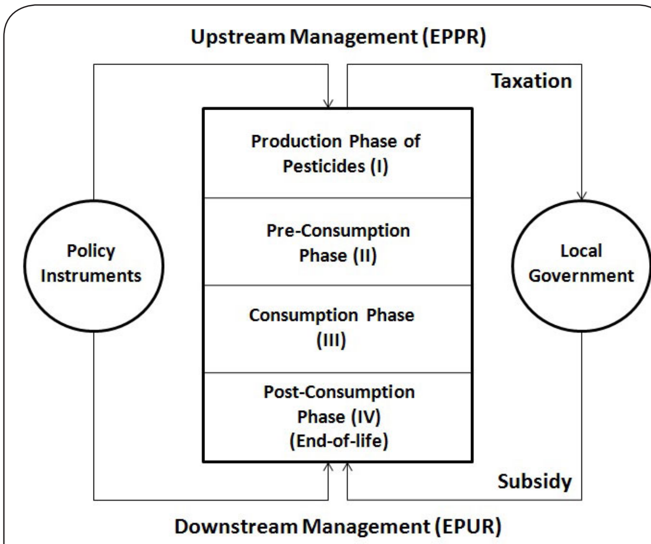

Figure 1. A schematic structure of an EPPUR-related policy showing the distribution of responsibility for the negative impacts of pesticides at two management levels and during four phases of the pesticides' life cycles.

As seen in **Figure 1**, the extended pesticide responsibility will be divided in two types: upstream and downstream. The upstream responsibility management is called *'Extended Pesticide Producer Responsibility' (EPPR)* which mostly covers the external cost of any negative, toxicological impacts that may happen from the time of producing the pesticide till its end-of-life. The external cost related to, generated or induced by, the toxicological impacts of individual pesticides will be the price that the producer pays. This upstream responsibility should be solely borne by the producer, especially if the user is applying the pesticide according to the producer's labeling instructions. The downstream responsibility management is typically a post-consumption or end-of-life responsibility. It is called *'Extended Pesticide User Responsibility' (EPUR)* that mostly covers the cost of managing the physical pollution associated with pesticide use. Wastes, discards or disposals of the pesticide and its containers during the post-consumption phase should be the main responsibility of the pesticide user. It is unfortunate that the downstream management system for agricultural pesticides is expected to be the weakest point in the responsibility chain, especially with small farms in developing countries. The levied taxes from pesticide producers may be used in these countries mainly for fiscal consolidation and partially to subsidize small farms for managing the end-of-life of their used pesticides. As stated in EPPUR definition, the take-back of unused or expired pesticides should always be the responsibility of the producer, sometimes the importer.

Toxicologically-induced pesticide externality

There are two key questions that should be addressed if an EPPUR-related policy is to be designed and formulated. First, how accurately can the external cost be assessed? Second, what would be the mechanism(s) of levying this cost? The author will eventually provide regulators with answers to these two questions, as well as a new Pesticide Negative Externality Assessment (PNEA) system that easily puts price to the negative toxicological impacts of individual pesticides.

Various attempts have been made to describe and quantify the external cost caused by the negative impacts of pesticides on human health and the environment. The leading studies in assessing the external cost of agricultural pesticides were those of Waibel and Fleischer [**39**] in Germany; of Pretty et al., [**40**] in UK, US, Germany and of Pimentel [**41**] in the USA. In these studies, as it has been always the case, the audit method was used. The audit method searches the actual costs of: (1) monitoring food, soil, and water contamination; (2) dealing with pollution incidents; (3) losing wildlife, biodiversity and non-target organisms (fish, bee colonies, birds, natural enemies, etc.); (4) intoxicating humans and domestic animals; (5) etc. during a certain period of time (usually a year). When these audited costs were summed and divided by the amounts of pesticides' active ingredients that had been used during such period, an average baseline cost as per kg a.i. of any of the pesticides used was determined. Pretty et al., [**40**] estimated three basic environmental costs, one for each of the USA, UK and Germany. When those values were averaged and converted to Euros as of 2005/2006 exchange rates, a baseline cost of Euro 8.78/kg a.i. was obtained [**42**]. Although this *'undifferentiated'* baseline cost is highly valuable, it cannot be used to fairly levy individual pesticides, because it is a fixed cost for pesticides that may differ by orders of magnitude in their toxicologically-inherent negative impacts. Given this disadvantage, Adrian Leach and John Mumford at the Centre for Environmental Policy, the Imperial College in London developed a Pesticide Environmental Accounting (PEA) approach to price the negative externality of *'individual'* pesticides [42]. Their main objective was to calculate a species-specific external cost for each individual pesticide from the average/constant baseline cost that was determined for all pesticides. The PEA hybridizes the average baseline cost as per kg active ingredient with the environmental impact quotient (EIQ), also as per kg active ingredient, to calculate the external cost of each individual pesticide. Although one cannot agree more with the basic concept of Externality-EIQ hybridization, Leach and Mumford [42] made some mistakes and invalid assumptions. For example, there have been some minor; yet fundamental, errors in the quotient classification for each EIQ category (please refer to Table 6 in Leach and Mumford's manuscript [42]). In that table, the ground water was counted twice; once as a separate entity and the other as an added value to the consumer effects. In a personal communication with Dr. Adrian Leach, the senior founder of the PEA approach, he appreciatively acknowledged the mistakes. It is unfortunate that the PEA, along with its faulty assumptions and miscalculations, have been used repeatedly in other studies [43,44 and others]. Some scientists did not carefully examine the basics upon which EIQ-equation was built, and eventually made serious calculation errors. For example, Lois Levitan [45] mistakenly dropped the chronic toxicity value from the picker component of the EIQ equation and ended up with a maximum value of 25, instead of 125 for this component. This error was reflected on Levitan's calculation [45] of the maximum EIQ value, as he came up with 176.7 instead of 210. The problem with those mistakes is that they spread and spin in the literature without being noticed. For the accurate measures of the environmental impact components, please refer to **Table 1** below.

Problems with the PEA approach

This section is not intended to discredit the PEA approach [42] and/or its founders, but to explain some flaws in both their formula and underpinning assumptions. The PEA approach seems to work against its own merit by drastically diminishing the cost variability among individual pesticides. This makes the information provided by the PEA either misleading or invaluable. Given these disadvantages, the author of this manuscript developed two simpler, more accurate, and highly reliable systems; one of them will be explained in the next section.

Data from Leach and Mumford [42] were reanalyzed to test if EIQ enhances the specificity of the PEA approach and emphasizes the heterogeneity of external costs among different pesticides with different impacts. This examination was simply done by comparing the correlation between the amount of individual pesticides used per hectare (field use rating or FUR) either alone or multiplied by EIQ and the PEA-calculated external cost of these pesticides per hectare. If the PEA approach is specific, valid and reliable, one expects that introducing EIQ would improve the correlation significantly. This hypothetical test is based on two rationally valid assumptions. First, when FUR (=rate of pesticide application x % of active ingredient) is multiplied by EIQ, the product represents the risk, which should correlate better than just the dosage (FUR alone) with the external cost of tested pesticides. Second, since the per hectare cost equals 'FUR x individual pesticide cost', then correlating 'FUR x EIQ' versus 'FUR x individual pesticide cost' will cancel FUR and emphasizes the correlation between pesticide's EIQ/kg a.i. and its specific external cost/kg a.i. This correlation should be an excellent one as it relates the external cost of each pesticide to its toxicological impacts that eventually lead to such cost. As seen in **Figure 2A**, there is an excellent relationship (R^2=0.977) between FUR/hectare and external cost/hectare of the tested pesticides. This means that the amount of used pesticide alone explains almost 98% of the differences in external costs among all the pesticides reported in Leach and Mumford's study [42]. As stated implicitly above, if the PEA approach is valid, one expects that multiplying the FUR with the EIQ for each tested pesticide would improve the correlation significantly. However, the opposite is true as seen in **Figure 2B**, wherein, the correlation worsens and has an

Table 1. The seven main EIQ components and their upper and lower limits. Note that the consumer component includes the impact of the pesticide on ground water (L).

EIQ Component	Calculated Impact	Minimum Score	Maximum Score	Maximum/Minimum Ratio
Applicator	C*DT*5	5	125	25
Picker	C*DT*P	1	125	125
Consumer	(C*((S+P)/2)*SY)+(L)	2	80	40
Fish	F*R	1	25	25
Birds	(D*((S+P)/2)*3)	3	75	25
Honey Bee	Z*P*3	3	75	25
Natural Enemies	B*P*5	5	125	25
Total score	N/R	20	630	31.5
EIQ=Total score/3	N/R	6.7	210	31.3

R^2 of only 0.815. The comparison shown in **Figure 2A** and **2B** illustrates true major failing in the PEA approach and explains - along with other reasons - why this approach did not continue to see significant use in the literature.

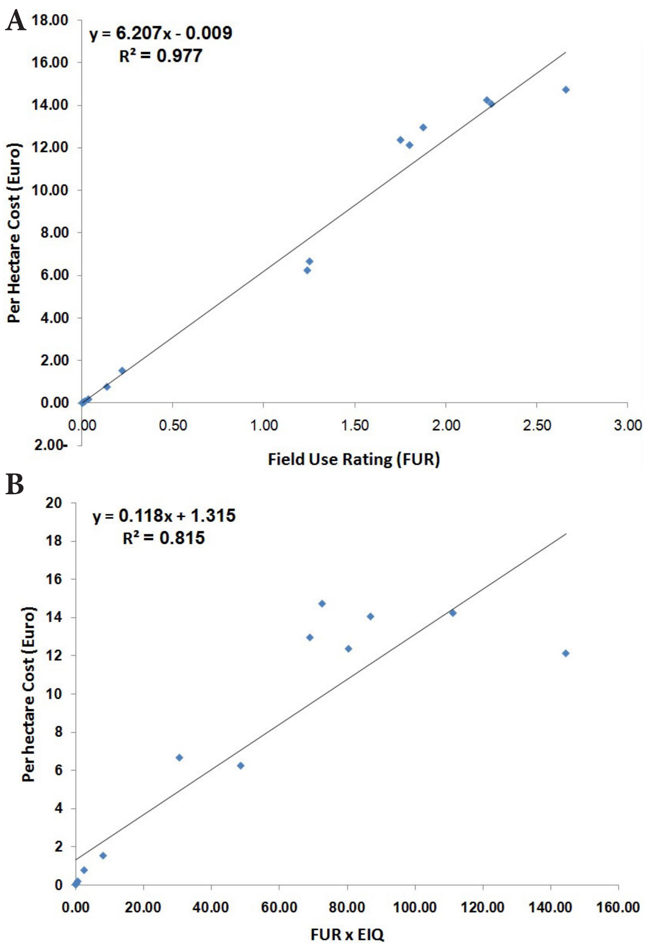

Figure 2. A correlation between filed use rating (FUR) and the external cost (**A**) and between the product of EIQ times FUR and the external cost (**B**). This figure was based on reanalyzing the data of Leach and Mumford [42] for the 14 pesticides used against the Mediterranean flies in citrus.

When other two sets of data [46,47] were re-analyzed, a pattern similar to that of **Figure 2** was obtained and the coefficients of determination for the three re-analyzed sets are summarized in (**Table 2**). This table clearly indicates that EIQ did not enhance the specificity the PEA approach; to the contrary its introduction diminished the cost heterogeneity among tested pesticides.

The falling of PEA is due to the fact that its founders [42] used a constant variation range of only 3-fold for all the EIQ categories that theoretically varies by 25-125 folds (**Table 1**). In theory, there should be a perfect correlation between the EIQ value and external cost of individual pesticides. With this theory in mind, the author of this manuscript innovatively established two systems that accurately quantify the negative external costs of individual pesticides and establish a perfect correlation between EIQ/kg a.i. and the external cost/kg a.i. for 188 pesticide active ingredients [48]. One of these systems will be simplified and explained in the next section.

Table 2. Coefficient of determination (R^2) for the correlation between field use rating (FUR) per hectare, either alone or multiplied by the environmental impact quotient (EIQ), and the external cost as per hectare. The coefficients were obtained from reanalyzing data of the references shown in the last column.

Coefficient of determination (R^2)		References of reanalyzed data
Without EIQ	With EIQ	
0.977	0.815	[42]
0.938	0.838	[46]
0.996	0.950	[47]

Pesticide negative externality assessment (PNEA)

Due to the complicated nature and diverse functions of pesticides, it is almost impossible to precisely measure their *'actual'* external costs. However, it is possible to design an instrument that will compute this cost and levy each individual pesticide relatively fairly if an approximation is made between this cost and the pesticide's potential to damage human health and the environment. Proposed in this manuscript is a new Pesticide Negative Externality Assessment (PNEA) system which simply and accurately calculates the external cost of individual pesticides. The PNEA system is simple, specific, and reliable. It is based on equally distributing the average external baseline cost (Euro 8.78/kg a.i.) for the pesticides used in the three abovementioned reference countries [40,42] to the average EIQ value/kg a.i. of these pesticides. Unfortunately, it was hard to find databases for the pesticides that were used to generate the above value. EIQ values were compiled and/or calculated for a total of 188 pesticide active ingredients representing all classes and groups of pesticide chemicals [48]. When these EIQ values were subjected to the normal distribution analysis using the Autograph 3.3 software [49], **Figure 3** was obtained.

As seen in **Figure 3**, the average EIQ value is 29/kg a.i. If this value is taken as an average EIQ for the pesticides used in the three reference countries, an external cost of Euro 0.303 [(Euro 8.78/kg a.i.)/(29/kg a.i)] is estimated for each EIQ unit. The external cost of each EIQ unit is a *'standard value'* that can be adjusted for the Euro exchange rate of other currencies. In their recent publication, Pretty and Bharucha [50] reported that a crude external cost of pesticides worldwide in the range of $10-60 billion resulted from a global consumption of 3.5 billion kg active ingredients. If one takes the average value of the above range of cost in billion USD ((10+60)/2=35), and divide it by the total amount of pesticides used in billion kg a.i. (3.5), a global baseline cost is obtained ($35 billion/3.5 billion kg a.i. = $10/kg a.i.). If this value is corrected for the

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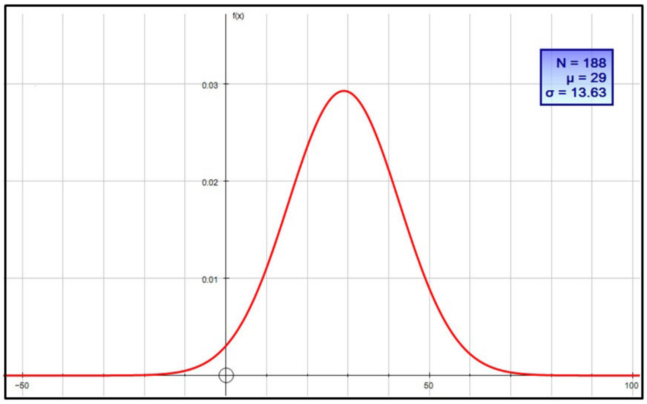

Figure 3. A normal distribution curve of the environmental impact quotients (EIQ's) of 188 pesticide active ingredients.

2015-average exchange rate ($1.0=Euro 0.90) that was calculated from the monthly rate reported in the X-RATESTM Website [**51**] from January 1st to December 14th of 2015, the global external baseline cost will be Euro 9.0/kg a.i. If one takes EIQ of 29/kg a.i., as an average global value, the external cost as per EIQ unit would be Euro 0.310 (=9/29); a value that is almost identical to the standard value (Euro 0.303). From the external cost as per EIQ unit, one can easily calculate the individual cost of any pesticide if its EIQ value as per kg a.i. is known. The external cost as per kg a.i. of any particular pesticide is then multiplied by the amount of its active ingredient produced to calculate its total external cost. This cost can be internalized/levied either fully or partially. If full liability or full internalization is the case, this total cost should be levied to the producer. This internalization approach will mostly fulfill the upstream EPPR which is basically the most important part of the EPPUR policy (please refer to **Figure 1**).

In addition to striking a good balance between simplicity and accuracy, the author's new Pesticide Negative Externality Assessment (PNEA) system could serve countries that suffer from inaccurate surveillance and/or insufficient transparency to price the negative externality of the pesticides they use and levy the responsible(s). By using some economic proxies, the cost of any pesticide can be calculated for any country. Since the standard value of external cost (Euro 0.303/EIQ unit) is calculated originally from the average baseline cost in three wealthy countries (Germany, UK, and USA), wherein the negative externality is economically more costly than other countries, this value should be customized or adjusted. One way is to multiply the standard value by a proxy value relating the GDP/capita of any country to the average GDP/capita for the three reference countries.

A new classification system of pesticide hazard

One of the key components of any EPPUR-policy is the informative one. This manuscript suggests that a label of any pesticide should include an index or indicator of the overall health and environmental impacts of this pesticide. Unfortunately the labeling information and color-coding, currently recommended by WHO [**52**] and FAO [**53**], are based on the mammalian *'acute'* toxicity. Despite its importance, the acute toxicity figure only reflects a minor component that may not be the most critical one in determining the overall hazard of pesticides to human health and the environment. In addition, acute toxicity is only important when accidental exposure of undiluted formulations happens. However, once the pesticide is diluted and sprayed the risk of acute toxicity to humans becomes minimal, while the risk of chronic and environmental toxicity builds up and may become unavoidable. Most of the end points regarding the chronic and environmental toxicities need repetitive exposure or multiple doses of the pesticide(s) over certain period of time. Because it is a summative value of the adverse impacts of pesticides on seven major components of human health and the environment (see **Table 1**), EIQ is recommended here to be the basis for hazard classification, color-coding and labeling system of pesticides. EIQ is a simple, metric indicator that can be included in the label of the pesticide either alone, as a measure of potential hazard, or compounded with the field use rating (FUR), as a measure of actual risk. These two measures can help growers and IPM practitioners make environmentally friendly or sound choices/decisions and ultimately know which pesticide(s) or pest-management strategy/program is likely to have lower health and environmental impact. **Table 1** shows EIQ values of 210/kg a.i. for the utmost hazardous pesticide and 6.7/kg a.i. for the least hazardous pesticide. These two values were used to draw full scale upon which an EIQ-based hazard classification and color-coding system was established (**Figure 4**).

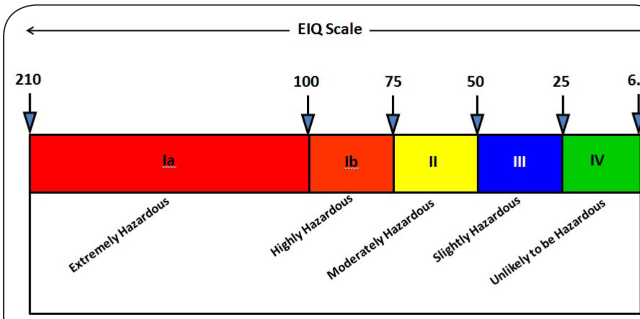

Figure 4. An EIQ-based hazard classification and color-coding system proposed for eco-labeling of pesticides. Note that this system is based on the Environmental Impact Quotient (EIQ) as a measure of the toxicological impacts of pesticides on human health and the environment.

Because the range of this new hazard classification system (from 6.7 to 210) is narrower than that of the WHO system (from 5000 or higher to less than 5), it can be used without any further adjustment to the percentage of active ingredient in individual pesticide formulations.

It is worth-noting that the new system is highly desirable from a practical point of view; logically acceptable from the conceptual point of view; yet subjectively debatable, especially with respect to the EIQ distance between the hazard categories. In fact this debate is also valid with the WHO classification [52].

Conclusions

Local governments cannot continue to bear the external costs on behalf of those who are responsible of generating negative externalities to the public and their environment. To restore responsibility to the responsible, many environmental principles have been campaigned since the seventies. The Extended Producer Responsibility (EPR) principle and its related policies deal mostly with the physical rather than the toxicological dimension of environmental contamination. This is probably one of the reasons why pesticides have never been targeted by EPR-policies despite the fact of being more dangerous than most of the products currently regulated by these policies. In trying to resolve such paradoxical situation, the author proposed the 'Extended Pesticide Producer and User Responsibility' (EPPUR) which aims at a fair and justified distribution of responsibility between the producer and user of pesticides for the negative impacts and associated costs of these pesticides throughout their life cycles. There are at least three categories of pesticide negative impacts: (1) the human health impact, (2) the environmental impact, and (3) the end-of-life impact. The first two impacts should be priced based on toxicological measures (health and environmental damages), while the third one may be resolved by physical measures; the purest of which is a take-back measure. To implement an EPPUR policy, three 'toxi-economic' requirements should be fulfilled. First is to assess the negative impacts of individual pesticides. This requirement can be fulfilled using the environmental impact quotient (EIQ). Second is to monetize the negative toxicological impacts of individual pesticides and calculate their external costs. This requirement can be fulfilled by using the author's new Pesticide Negative Externality Assessment (PNEA) system. Third, is to fully or proportionally internalize the external cost through a taxation instrument that takes into consideration the external cost of each pesticide as per kg a.i. and its total amount produced or used during a certain period of time. Obviously, this requirement cannot be fulfilled without government intervention. With regard to internalization, the author argues against the 'one-size-fits-all' whether in the form of a constant baseline cost [54] or in the form of certain percentages corresponding to the WHO classification of acute hazard [55]. As a complement to PNEA system, the author establishes a new hazard classification and color coding system that seems preferable than that of the WHO [52] and FAO [53], at least from the conceptual point of view. Instead of just relying on the acute toxicity, the new system is based on acute, chronic and environmental toxicities.

List of abbreviations

PPP: Producer Pays Principle
EPR: Extended Producer Responsibility
EPPR: Extended Pesticide Producer Responsibility
EPUR: Extended Pesticide User Responsibility
EPPUR: Extended Pesticide Producer and User Responsibility
EIQ: Environmental Impact Quotient
EOL: End-of-Life
PEA: Pesticide Environmental Accounting
PNEA: Pesticide Negative Externality Assessment
ETR: Environmental Tax Reform
a.i.: Active Ingredient

Competing interests

The author declares that he has no competing interests.

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References

1. Hock W. **Farm Chemicals Manual: A Guide to Safe Use and Handling**. *The Agricultural and Veterinary Chemicals Association. Aust. Ltd.* 1991. | Website
2. Pimentel D. **Plant protection: Trade and the environment**. *Proceedings of the Fiftieth New Zealand Plant Protection Conference*. 1997; 20-7. | Pdf
3. Pimentel D, Mclaughlin L, Zepp A, Lakitan B, Kraus T, Kleinman P, Vancini F, Roach WJ, Graap E, Keeton WS and Selig G. **Environmental and economic effects of reducing pesticide use in agriculture***. *Agriculture Ecosystems & Environment*. 1993; **46**:273-88. | Pdf
4. Olympic Horticultural Products (OHP). **Chemical Class Chart: Greenhouse and Nursery Production**. 2015. | Pdf
5. Weiss JF. **Essays on Externalities, Regulation, Institutions, and Firm Performance**. *Jönköping International Business School Jönköping University JIBS Dissertation Series No. 102*. 2015. | Pdf
6. Wikipedia. **Externality**. 2015. | Website
7. Pigou AC. **The Economics of Welfare**. London: Macmillan, 1920. *THE ONLINE LIBRARY OF LIBERTY*. 2005. | Pdf
8. Coase RH. **The Problem of Social Cost**. *Journal of Law and Economics*. 1960; **3**:1-44. | Article
9. Baumol WJ. **"On Taxation and the Control of Externalities"**. *American Economic Review*. 1972; **62**:307-322. | Pdf
10. Sjöberg P. **Taxation of pesticides and fertilizers**. *Master's Thesis, Luleå University of Technology, Sweden*. 2005. | Pdf
11. Piña CM and Forcada SA. **Effects of an environmental tax on pesticides in Mexico**. *UNEP Industry and Environment*. 2004; 33-36. | Pdf
12. Pearson S. **Environmental Externalities in the Policy Analysis Matrix**. 2015. | Pdf

13. Pearce D and Turner K. **Economics of Natural Resources and the Environment**. 1990. | Pdf
14. Wikipedia. **Pareto efficiency**. 2015. | Website
15. Koleva NG, Schneider UA and McCarl BA. **Pesticide externalities from the US agricultural sector – The impact of internalization, reduced pesticide application rates, and climate change**. *Procedia Environmental Sciences*. 2011; **6**:153-161. | Article
16. OECD. **Recommendation of the Council on Guiding Principles Concerning International Economic Aspects of Environmental Policies**. 1972. | Website
17. OECD. **Recommendation of the Council on the Implementation of the Polluter-Pays Principle**. 1974. | Website
18. OECD. **Recommendation of the Council concerning the Application of the Polluter-Pays Principle to Accidental Pollution**. 1989. | Website
19. Lindhqvist T and Lidgren K. **Modeller för förlängt producentansvar [Models for Extended Producer Responsibility]. In Ministry of the Environment**. 1990; Från vaggan till graven - sex studier av varors miljöpåverkan [From the Cradle to the Grave – six studies of the environmental impact of products]. (Ds 1991:9).
20. Lindhqvist T. **Mot ett förlängt producentansvar - analys av erfarenheter samt förslag [Towards an Extended Producer Responsibility - analysis of experiences and proposals]**. In Ministry of the Environment and Natural Resources, Varor som faror - Underlagsrapporter [Products as Hazards - background documents]. Ds 1992:82. The definition was published in English for the first time in: Lindhqvist, Thomas. (1992). Extended Producer Responsibility. In Lindhqvist, T., Extended Producer Responsibility as a Strategy to Promote Cleaner Products (1-5). Lund: Department of Industrial Environmental Economics, Lund University.
21. Lindhqvist T. **Extended Producer Responsibility in Cleaner Production: Policy Principle to Promote Environmental Improvements of Product Systems**. *IIIEE Doctoral Dissertation*, Lund: IIIEE, Lund University. 2000. | Pdf
22. OECD. **Extended Producer Responsibility: A Guidance Manual for Governments**. *Paris*. 2001; 164. | Pdf
23. Calliafas P. **IPR Working Group: Waste Electrical and Electronic Equipment (WEEE) Regulations: Individual Producer Responsibility (IPR) in a UK context**. 2012. | Pdf
24. Kaffine D and O'Reilly P. **What Have We Learned About Extended Producer Responsibility in the Past Decade?** *A Survey of the Recent EPR Economic Literature*. ENV/EPOC/WPRPW(2013)7/FINAL. 2015. | Pdf
25. Monier V, Hestin M, Cavé J, Laureysens I, Watkins E, Reisinger H and Porsch L. **Development of Guidance on Extended Producer Responsibility (EPR)**. *FINAL REPORT European Commission – DG Environment*. 2014. | Pdf
26. Fichtner K, Bartlett V, Seidel C, Gies G and Walker M. **Assessment of Economic and Environmental Impacts of Extended Producer Responsibility Programs in BC**. 2014. | Pdf
27. ISWA'15 WORLD CONGRESS ANTWERB. **EPR-Extended Producer Responsibiltiy**. 2015. | Website
28. New South Wales Consolidated Acts. **Protection of the Environment Administration ACT 1991-SECT 6**. 2015. | Website
29. Yongkook W. **Waste Management System in Korea**. 2004. | Pdf
30. Tong X, Lifset R and Lindhqvist T. **Extended Producer Responsibility in China: Where Is "Best Practice"?** *Journal of Industrial Ecology*. 2004; **8**:6-9. | Website
31. Manomaivibool P, Lindhqvist T and Tojo N. **Extended Producer Responsibility in a non-OECD context: The Management of Waste Electrical and Electronic Equipment in Thailand**. 2009. | Pdf
32. Sanborn H. **The Challenges of Implementing EPR: The CPSC is Leading the Way in the U.S. as Extended Producer Responsibility Moves Slowly Forward**. 2015. | Pdf
33. Withana S, ten Brink P, Illes A, Nanni S and Watkins E. **Environmental Tax Reform in Europe: Opportunities for the future**. 2014. | Pdf
34. Sanz VM, Rica ED, Palacios EF, Alsina AM and Mouriz NV. **REDESIGNING PRODUCER RESPONSIBILITY A new EPR is needed for a circular economy**. 2015. | Pdf
35. Kovach J, Petzoldt C, Degnil J and Tette J. **A method to measure the environmental impacts of pesticides**. *NY Food Life Sci. Bulletin*. 1992; **139**:1-8. | Pdf
36. Eshenaur B, Grant J, Kovach J, Petzoldt C, Degni J and Tette J. **Environmental Impact Quotient: "A Method to Measure the Environmental Impact of Pesticides."** New York State Integrated Pest Management Program, Cornell Cooperative Extension, Cornell University. 1992-2015. | Website
37. University of Hertfordshire. **Pesticide Properties DataBase (PPDB)**. 2011-2015. | Website
38. Joe Kovach. **Personal Communication**.
39. Waibel H and Fleischer G. **Kosten und Nutzen des chemischen Pflanzenschutzes in der Deutsen Landwirtschaft aus Gesamtwirtschaftlicher Sicht**. Vauk-Verlag, Kiel. 1998. | Pdf
40. Pretty J, Brett C, Gee D, Hine R, Mason C, Morison J, Rayment M, van der Bijl G and Dobbs T. **Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture**. *Journal of Environmental Planning and Management*. 2001; **44**:263-83. | Pdf
41. Pimentel D. **Environmental and economic costs of the application of pesticides primarily in the United States**. *Environment Development and Sustainability*. 2005; **7**:229-52. | Article
42. Leach AW and Mumford JD. **Pesticide Environmental Accounting: A method for assessing the external costs of individual pesticide applications**. *Environ Pollution*. 2008; **151**:139-147. | Article
43. Koleva, NG. **CLIMATE CHANGE AND PESTICIDE USE AN INTEGRATED ECONOMIC ANALYSIS**. Dissertation zur Erlangung des Grades eines Doktors der Wirtschaftswissenschaften (Dr. rer. pol.). der Fakultät Wirtschaft- und Sozialwissenschaften Department Wirtschaftswissenschaften Der Universität Hamburg, 2010. | Pdf
44. Praneetvatakul S, Schreinemachers P, Pananurak P and Tipraqsa P. **Pesticides, external costs and policy options for Thai agriculture**. *Environmental Science & Policy*. 2013; **27**:103-113. | Article
45. Levitan L. **An Overview of PESTICIDE IMPACT ASSESSMENT SYSTEMS (a.k.a. "Pesticide Risk Indicators") based on Indexing or Ranking Pesticides by Environmental Impact**. *Background Paper Prepared for the Organisation of Economic Cooperation and Development (OECD) Workshop on Pesticide Risk Indicators, Copenhagen, Denmark*. 1997.| Pdf
46. Leach AW, Mullie WC, Mumford JD and Waibel H. **Spatial and historical analysis of pesticide externalities in locust control in Senegal-first steps**. *Food and Agriculture Organisation, Rome, Italy*. 2009; 91. | Article
47. Leach AW and Mumford JD. **Pesticide Environmental Accounting: A decision-making tool estimating external costs of pesticides**. *Journal of Consumer Protection and Food Safety*. 2011; **6**:21-26. | Article
48. Ibrahim YA. A Novel Pesticide Health and Environmental Accounting System (PHEAS): Agricultural Pesticides in Egypt as a Case Study (in preparation).
49. Autograph 3.3 software. **3rd Generation Graph Plotter for Schools and Colleges**. 2015. | Website
50. Pretty J and Bharucha ZP. **Integrated Pest Management for Sustainable Intensification of Agriculture in Asia and Africa**. *Insects*. 2015; **6**:152-182. | Article
51. **X-RATES™**. | Website
52. WHO. **The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification**. 2009. | Pdf
53. FAO. **The International Code of Conduct on Pesticide Management**. 2014. | Pdf
54. Pretty J. **The Pesticide Detox: Towards a More Sustainable Agriculture**. *First published by Earthscan in the UK and USA*, 2005. | Pdf
55. Agne S, Fleischer G and Waibel H. **Economics of Pesticide Policy Reform in Developing Countries – selected results of a multi-country project**. *Deutscher Tropentag 2000 in Hohenheim*. 2000. | Pdf

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