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Wagner Lopes Soares[I]

Marcelo Firpo de Souza Porto[II]

Pesticide use and economic impacts on health

ABSTRACT

OBJECTIVE: To estimate the externalities associated with acute poisoning from pesticides.

METHODS: The probabilities of acute poisoning were estimated according to characteristics of rural properties and cities in the state of Paraná, Southern Brazil. Information about acute poisoning obtained from the 1998-1999 Harvest Forecast Survey was used. The expected costs with poisoning in these properties were calculated from the sum of medical-hospital expenses and days spent on sick leaves, required for the recovery of intoxicated individuals. A multilevel model was constructed for the analysis.

RESULTS: The costs associated with acute poisoning can total up to US$ 149 million for the state of Paraná, i.e. for each dollar spent to purchase pesticides in this state, approximately US$ 1.28 may be spent with the external costs of poisoning. This situation could be changed with the implementation of public policies, such as the adoption of an organic agriculture promotion program in the cities where the social cost with acute poisoning could be reduced by approximately US$ 25 million.

CONCLUSIONS: Society, especially the populations mainly affected by pesticides, could be benefited by the identification and elimination of the risks of acute intoxication associated with the current model. It is necessary to implement public policies and integrated actions that involve the fields of economics, public health, agronomy, environmental issues, education, and science and technology, among others.

DESCRIPTORS: Pesticides, poisoning. Occupational Exposure. Poisoning, economics. Health Expenditures. Rural Workers.

INTRODUCTION

There has been a relevant growth in Brazilian agriculture and agribusiness in recent years. However, there is a price to pay for the increase in agricultural production and this "success" is partly due to the negative impacts on health and the environment not being taken into account in the final cost of the products, socialized according to what is described as negative externalities in economics.[12] Very few or no impacts are included in the price of these inputs or food products manufactured in Brazil, becoming the responsibility of the health system and social security, among others. This flaw in the market price system could be corrected with economic disincentive instruments, higher tax burden and command and control approaches (laws and regulations). This imposes an additional cost on these products, contributing to greater rationalization of their use and, consequently, a reduction in negative externalities.[11]

On the other hand, the policy in favor of pesticide use is frequently supported by the strength of rural politicians in the Brazilian National Congress. Two

[I] Coordenação de Agropecuária. Diretoria de Pesquisas. Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro, RJ, Brasil

[II] Centro de Estudos da Saúde do Trabalhador e Ecologia Humana. Escola Nacional de Saúde Pública Sergio Arouca. Fundação Oswaldo Cruz. Rio de Janeiro, RJ, Brasil

Correspondence:
Wagner Lopes Soares
Av. República do Chile 500
3º andar – Centro
20031-170 Niterói, RJ, Brasil
E-mail: wagner.soares@ibge.gov.br

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representative examples are pesticide licensing, as the cost of registration with the *Agência Nacional de Vigilância Sanitária* (Anvisa – National Health Surveillance Agency) is very low (between R$180/US$106 and R$1,800/US$1,059 – Law 9782/99), and the exemption from the *Imposto sobre Comercialização de Mercadorias e Serviços* (ICMS – Goods and Services Tax) in the majority of states.[a]

The economics literature provides several methods in the area of valuing externalities. This methodological diversity and the difficulty in obtaining data translate into different results, as each study includes one or more externalities caused by pesticide use that affect health or the environment.[b] Table 1 summarizes the main results found in the Scopus, SciELO and Medline databases in chronological order. Regardless of the set of social costs included and the methodology used in each study, it is important to observe that all results point to a significant volume of socialized resources.

The present study aimed to estimate the externalities associated with acute poisoning from pesticides.

METHODS

Microdata from the *Pesquisa de Previsão de Safras* (PREVS – Harvest Forecast Survey) of the *Instituto Brasileiro de Geografia e Estatística* (IBGE – Brazilian Institute of Geography and Statistics)[c] were used in this study. The PREVS provided new supplementary information about pesticide use in the state of Paraná, Southern Brazil, in the 1998-1999 harvest. A total of 1,637 rural producers whose establishments or areas of exploitation represented approximately 0.42% of the total state area, and the expansion of this sample estimated a total of 382,998 farming and cattle raising establishments in this state, considering a sample error of 5%.[c]

The following variables associated with pesticide use were analyzed: application equipment; the way pesticides were obtained; frequency of use; use of individual protection equipment and prescription farming; disposal of empty containers; type of crop (corn, soybean, cotton, bean, cassava); number of poisoning cases and medical-hospital visits during the summer harvest; pesticides applied per crop (number of applications and amount applied, form of application, classes of pesticides); and area of establishments. The pieces of information about poisoning were declarations from those responsible for rural establishments or their informers. Although there is more current information about poisoning per pesticide in rural establishments (such as the 2006 Farming and Cattle Raising Census), the PREVS is the only source that covers a large area of land and enables the establishment of associations between pesticide use with a higher level of details (toxicological aspects, amount used, number of applications, among others) and acute poisoning.

Other sources of data were used to raise environmental and economic variables that characterized the cities included in the PREVS sample. Among these, there is the *Pesquisa de Informações Básicas Municipais* (Municipal Basic Information Survey),[d] which assessed environmental information from different cities provided by the environmental managers themselves. This survey informs about the following: the existence of an organic agriculture promotion program; water or soil contamination by pesticides; Agenda 21 in the cities; ICMS *verde* (a type of ecological tax that involves the Brazilian goods and services tax); inspection and control of pesticide and fertilizer use; and whether workers' organizations are part of the *Conselho Municipal de Meio Ambiente* (CMMA – Municipal Environmental Council). Municipal variables such as the agricultural GDP, per capita income, rural employment and human development index in 2000[e] were used, in addition to spending on pesticides from the 1995-1996 Farming and Cattle Raising Census (IBGE)[f] to establish reference costs assessed in the workplace.

The methodology was divided into two stages, considering the fact that the assessment of costs associated with poisoning goes through the modeling process of probabilities of poisoning by pesticides in rural establishments. The R software, version 2.81, was used to perform the computer-assisted procedures.

As land is influenced by climate, soil, production and commercialization dynamics, wealth and sector policies, among other aspects, the statistical model should consider a possible hierarchical structure of data. These relationships may influence the rural establishment's agricultural activity, which could thus influence

[a] Terra FHB, Pelaez V, Silva LR. A regulamentação dos agrotóxicos no Brasil: entre o poder de mercado e a defesa da saúde e do meio ambiente. In: XIV Encontro Nacional de Economia Política; 2009 Jun 09-12; São Paulo, BR. São Paulo: Sociedade Brasileira de Economia Política; 2009.

[b] Soares WL. Uso dos agrotóxicos e seus impactos à saúde e ao ambiente: uma avaliação integrada entre a economia e a saúde pública, a ecologia e agricultura [doctorate thesis]. Rio de Janeiro: Escola Nacional de Saúde Pública Sergio Arouca da Fiocruz; 2010.

[c] Instituto Brasileiro de Geografia e Estatística. Pesquisa de Previsão de safras do Paraná: uso de agrotóxicos no estado do Paraná, 1998/1999. Rio de Janeiro; 2001.

[d] Instituto Brasileiro de Geografia e Estatística. Pesquisa de informações básicas municipais. Perfil dos municípios brasileiros: meio ambiente. Rio de Janeiro; 2002.

[e] Instituto de Pesquisa Economia Aplicada. Base de dados macroeconômicos - IPEADATA. Brasília; [s.d.][cited 2008 Jun 01]. Available from: http://www.ipeadata.gov.br/

[f] Instituto Brasileiro de Geografia e Estatística. Censo Agropecuário 95/96. Rio de Janeiro; 1996[cited 2008 Jun 01]. Available from: http://www.ibge.gov.br/home/estatistica/economia/agropecuaria/censoagro/1995_1996/default.shtm

poisoning and its association with the characteristics of the establishment itself. In this case, the observations related to the characteristics of rural establishments would not be independent, which could suggest the adoption of a more robust model that incorporated the effects associated with this hierarchical dependence, described here as "context effects".[9]

There are hierarchical or multilevel models among these model categories, which enable the inclusion of variables on a second hierarchical level, represented by the cities' characteristics in the present study. The selection strategy of the best model was based on logistic regression (model 1), selecting the statistically significant variables on the first hierarchical level. In the multilevel models, the following variants were tested: the random intercept (model 2); the random coefficients (model 3); the random intercept with variables from the second hierarchical level (model 4). The last model was that with the best adjustment to the data, formally represented by:

$$\log it\,(\pi_{j[i]}) = \phi_{00} + (\sum_{k=1}^{p} \beta_k x_{k[i]}) + u_i$$

where k, i and j describe the indices of the estimated parameters, establishments and cities, respectively, and π_{ij} describes the probability of occurrence of the event of interest for the establishment i (i=1,...,1637) in the j-th city (j=1,...,226). The ϕ_{00} parameter was the intercept that represented the expected response of the population, β_k (k=1,...,p) represented the k-th regression coefficient and the u_i term described the random effect of the i-th establishment, used to estimate the changes in the probability of response among cities. The second stage consisted in estimating the probabilities of poisoning in a certain rural establishment i, in the city j. In this stage, the estimate of spending on poisoning is based on the Cost of Illness Method.[6]

This method implies assessing the mean cost of acute poisoning treatment by surveying the responses to questions such as "How much does the hospital treatment for poisoning cost on average?" and "How many days does an individual need to be on sick leave on average?". The average cost of treatment for poisoning was calculated by the sum of the hospital cost and opportunity cost associated with the worker's recovery, indirectly counted according to the number of days of absence from work, i.e. the days when they did not receive their daily pay. The specific literature supports this survey.[4,8,18,20,g] The cost of poisoning resulted from the sum of medical/hospital expenses with the cost of absence from work. In the present study, this cost was assessed according to the following two scenarios:

γ_1 = US\$129.00 + US\$131.34 = US\$260.34;

γ_2 = US\$740.21 + US\$358.2 = US\$1,098.41

Scenario γ_1 was more conservative, with lower reference values found in the specific literature,[4,8,18,20,g] whereas scenario γ_2 considered the greatest costs surveyed, with higher reference values.

The expected cost of poisoning was estimated in a certain rural establishment i, in the city j. This cost was calculated from the product of probability of poisoning (obtained from the most adequate model estimated) and the survey of the cost associated with poisoning treatment, in the perspective of both γ scenarios whose expected cost was expressed by the following equation:

$$\mathbf{E(ci_{j[i]}) = (p_{j[i]}=1) \times \gamma)\ ;}$$

for i= 1,...,1637 and j = 1,...,226; where i represented the number of establishments and j represented the number of groups (226 cities that included these establishments).

The results were shown as two distinct groups of risk of establishments: "Type 1" (all risk factors were present) and "Type 2" (all risk factors were absent). When the probabilities of poisoning between Type 1 and Type 2 establishments are compared, the control variables and their values were equal for all types of establishments, thus enabling the assessment of the impacts of certain factors on the probability of poisoning and on their economic impact.

RESULTS

Table 2 shows the results of the estimated models. The coefficient of partition of variance of model 2 showed that approximately 20% of the variability of intoxication was due to factors among the cities, justifying the use of the random intercept. The same did not occur when an estimate of the random coefficient for the area was included (model 3) (Table 2).

When the estimates of the fixed effect of the best model (4) are considered, the probabilities of poisoning in an establishment and the results of expected costs of acute poisoning are available according to the characteristics of establishments (Table 3). The risk factors were as follows: indication of use provided by the seller; very dangerous toxicological class; workers' organization being a part of the CMMA; the city not promoting organic agriculture; inexistence of the Agenda 21 in the city; and inspection of fertilizers and pesticides in the city. The control variables followed the average profile obtained for the corn crop (10 ha of area, ten

[g] Fundação Getúlio Vargas. Preços agropecuários. Remuneração do trabalho agrícola eventual – Paraná. Série histórica FGV/Dados. São Paulo; 2006 [cited 2008 Jun 01]. Available from: http://portalibre.fgv.br/main.jsp?lumChannelId=402880811D8E34B9011D92C493F131B2

Table 1. Main results found in the literature on valuing of externalities of pesticides.

Country (year)	Negative externalities associated with pesticides and estimated per year
USA (1992)[14]	Absences from work due to poisoning totaled US$ 1.76 million. Non-hospital treatment totaled US$ 17 million, spending on public health and environment was US$ 8.1 billion. Spending on the purchase of pesticides in the USA totaled US$ 4 billion, which means that for each US$ 1 spent on the purchase of pesticides, US$ 2 were spent on externalities.
Philippines (1994)[1,16]	Change from one to two doses of pesticide in rice crops increased the profit by 492 pesos and spending on health by 765 pesos, thus resulting in a net loss of 273 pesos.
Thailand (1996)[a]	Spending on externalities with pesticides varied from US$ 18 million to US$241 million per year.
Vietnam (1999)[9]	Spending on health totaled nearly US$ 7 per household during the rice harvest.
Germany (1999)[b]	For each DM 1 spent on pesticides, DM 0.25 were spent on externalities.
United Kingdom (2000)[7]	The willingness to pay was € 3 per household per year to reduce one case of acute poisoning in the UK and € 20 per year to save one entire species of birds.
West Africa (2000)[c]	Spending on health totaled approximately US$ 4 per household per rice and cotton harvest.
Brazil (2002)[18]	Spending on workers' health totaled nearly 25% of the benefits from pesticide use in corn and bean crops in nine cities of the state of Minas Gerais.
Zimbabwe (2003)[11]	The direct and indirect costs of acute poisoning in cotton crops totaled US$ 4.74 in Sanyati and US$8.31 in Chipinge.
USA (2005)[15]	Spending on health associated with chronic and acute health problems totaled US$1.1 billion, while hospitalization and absences from work totaled 2.4% and 0.2% of these costs, respectively, of which 81% referred to cancer treatment.
Nepal (2005)[d]	Total household spending due to pesticide use in Nepal varied from zero to US$ 59.60, with an average of US$ 16.81. Willingness to pay for safe pesticide use varied from US$ 20 to US$ 666 per year.
Italy (2008)[21]	The willingness to pay to reduce the number of cases of acute poisoning by pesticides to zero was € 1,286 per household per year on average. Individuals were willing to tolerate six additional cases of poisoning in exchange for the conservation of one species of birds or a reduction in soil and water contamination of approximately 1%, for example.

[a] Jungbluth F. Crop Protection Policy in Thailand: Economic und Political Factors Influential Pesticide Use. Hannover: Pesticide Policy Project, GTZ/University of Hannover, Publication Series No. 5; 1996. 75 p.
[b] Waibel H, Fleischer G, Kenmore PE, Feder G. Evaluation of IPM Programs - Concepts and Methodologies. Hannover: Pesticide Policy Project Publication Series No. 8; 1998.
[c] Ajayi OC, Camara M, Fleischer G, Haidara F, Sow M, Traore A, Van der Valk H. Socio-economic assessment of pesticide use in Mali. Hanover: Pesticide Policy Project special issue publication series no 6; 2002.
[d] Atreya K. Health costs of pesticide use in a vegetable growing area, central mid-hills, Nepal. Kathmandu: Aquatic Ecology Centre (AEC); 2005

applications, two workers involved with pesticide application, US$ 1,000.00 of average budget and 600 establishments of soil conservation in the city), which was the only crop that provided a relevant explanation for poisoning caused by pesticides in the establishments. Table 3 shows the "amounts saved", represented by the social gain obtained from the changes in the characteristics of pesticide use in the establishment, according to the two scenarios of survey of costs.

In the first scenario (survey of costs γ_1) in rural establishments of Type 1, the expected cost of acute poisoning was approximately US$ 201 (0.77 x 260.34). When the risk factors (Type 2) are removed, the cost decreases to US$ 3 (0.002 x 260.34), the amount saved or net social benefit (US$ 198 per establishment). This amount would be greater if the second scenario (survey of costs γ_2) was considered (gain of approximately US$ 836). The most efficient measure to reduce the social cost of Type 1 establishments would be the removal of the indication of pesticide use provided by the seller (Type 3 establishments), as the amount saved with this measure would total US$92 and US$389 in the first and second scenarios, respectively. The implementation of an organic agriculture promotion and practice program (Type 4 establishment) could help to reduce the expected cost of poisoning in Type 1 establishments by approximately US$ 144 in the second scenario.

If the 176,179 rural establishments that produce corn estimated by the PREVS had the same characteristics as Type 1 establishments, the expected cost of poisoning would total approximately US$ 35 million (US$201.22 x 176,179) and US$ 149 million (848.99 x 176,179) in the first and second scenarios, respectively (Table 4). The average spending on pesticides was US$ 663, according to data from the 1995-1996 Farming and Cattle Raising Census, thus resulting in a total spending of approximately US$ 116 million (US$663 x 176,179) for the federal government. For each dollar spent on pesticides in Type 1 establishments, nearly US$ 0.30 would result as costs associated with acute poisoning

Table 2. Estimates of models – Endogenous variation – Poisoning by pesticide in rural establishments. State of Paraná, Southern Brazil, 1998-1999.

Variables	MODELS							
	1		2		3		4	
	OR	p	OR	p	OR	p	OR	p
FIXED EFFECTS								
1 LEVEL (rural establishment)								
Intercept	0.034	0.00	0.018	0.00	0.025	0.00	0.024	0.00
Indication of use								
Seller	3.483	0.00	5.388	0.00	5.118	0.00	4.674	0.00
Land owner	2.024	0.15	2.565	0.09	2.527	0.10	3.065	0.03
Agronomist	1.005	0.99	0.987	0.97	0.962	0.91	0.768	0.41
Prescription farming								
Receives the prescription								
Yes	0.561	0.05	0.628	0.17	0.621	0.16		
Follows the recommendations								
No	1.198	0.75	0.824	0.77	0.814	0.76		
Toxicological class								
Very dangerous	1.580	0.02	1.454	0.11	1.457	0.10	1.376	0.15
Number per each ten applications/harvest	1.012	0.04	1.016	0.02	1.015	0.03	1.016	0.02
Poisoning use (100 kg)	1.069	0.08	1.049	0.26	1.050	0.26		
Number of workers (who handle pesticides)	1.041	0.04	1.155	0.04	1.157	0.05	1.158	0.02
Type of crop								
Corn	2.903	0.01	3.736	0.00	3.356	0.00	3.647	0.00
Area of establishment (10 ha)	1.008	0.30	1.011	0.20	1.001	0.90	1.001	0.30
Area of establishment (10 ha) X Corn	0.980	0.04	0.974	0.02	0.976	0.03	0.998	0.03
2 LEVEL (city)								
Average budget with vegetable products (R$ 1,000)							0.964	0.03
Number of establishments with Soil conservation (1,000 establishments)							1.044	0.00
Workers' organizations that are part of the Municipal Environmental Council								
Yes							2.759	0.00
Local Agenda 21 deals with environmental issues								
Yes							0.184	0.01
Organic agriculture promotion								
Yes							0.532	0.04
Inspection and control of the use of fertilizers and pesticides								
Yes							1.599	0.06
RANDOM EFFECTS	Var.	DP	Var.	DP	Var.	DP	Var.	DP
Intercept	-	-	0.878	0.94	0.224	0.473	0.367	0.60591
Area of establishment (ha)					0.000	0.001		
DEVIANCE (gl)	783.34		752.8		751		730	
Akaike information criterion	811		780.8		783		764	

[a] Model 1 (generalized linear model with a logistic link function); [b] model 2 (hierarchical model with a random intercept);
[c] Model 3 (hierarchical model with intercept and random coefficient); model 4 (best model estimated – hierarchical model with random intercept and first and second level variables).
[d] Reference categories in order: other indication of use; no prescription; yes, farmer follows recommendations; other toxicological class; cultures (soybean, cotton, bean or cassava); no workers' organizations are part of the Municipal Environmental Council; no Agenda 21; no organic agriculture; an no inspection.
Source: Microdata from the PREVS (1999), and municipal data from the Farming and Cattle Raising Census (1995-1996) and MUNIC (2003), both from the IBGE.

Table 3. Scenarios of expected spending on acute poisoning by pesticide, according to type of establishment. State of Paraná, Brazil, 1998-1999.

Scenarios (US$)	Estab. Rural	Pr. (Y=1)[a]	E(ci) (US$) (Pr.(y=1) x γ	Amount saved for Type 1 (US$)
1(γ = 260.34)	Type 1	0.77	201.22	-
	Type 2	0.002	3.03	198.20
	Type 3	0.42	108.85	92.38
	Type 4	0.64	166.94	34.28
2(γ = 1098.41)	Type 1	0.77	848.99	-
	Type 2	0.002	12.78	836.22
	Type 3	0.42	459.25	389.74
	Type 4	0.64	704.34	144.65

[a] Pr. (Y=1) = probability of poisoning in a rural establishment
Type 1: Indicated by the seller, very dangerous, ten applications, two workers involved, corn, 10 ha, R$1,000 of budget, 600 establishments, Yes - workers' organizations, No - Agenda 21, No - organic agriculture , Yes - inspection of fertilizers.
Type 2: Indicated by the agronomist, not very dangerous, tem applications, two workers involved, corn, 10 ha, R$1,000 of budget, 600 establishments, No, Yes, Yes, No.
Type 3: Type 1 – Indicated by the seller
Type 4: Type 1 + organic agriculture promotion

Table 4. Social cost of acute poisoning per each US$ 1 spent on the purchase of pesticides in Type 1 establishments. State of Paraná, Brazil, 1998-1999.[a]

Scenario	Expected cost of poisoning (E(C))[b] (US$1000)	Spending on pesticides for corn (D)[c] (US$1000)	E(C)/D (US$)
1	35,450	116,966	0.30
2	149,521	116,966	1.28

[a] Type 1: Indicated by the seller, very dangerous, ten applications, two workers involved, corn, 10 ha, R$1000 of budget, 600 establishments, Yes - workers' organizations, No - Agenda 21, No - organic agriculture, Yes - inspection of the use of fertilizers.
[b] Estimate based on the PREVS of the 176,179 establishments that produce corn in the state.
[c] Average spending on pesticides based on the 1995-1996 Farming and Cattle Raising Survey (US$ 663) – exchange rate in January 1996.

by pesticides and US$ 1.28 in the perspective of the second scenario (Table 4).

DISCUSSION

The following are among the factors that increase the chances of poisoning and its probability of occurrence and that influence the additional costs in rural establishments: farmers not being instructed by agronomists at the moment of purchase of pesticides; prescription farming not being used; and the use of substances that are less toxic to human health. These results corroborate other studies conducted in Brazil.[2,5]

The indication of pesticides provided by sellers as a risk factor could be explained by their attempt at selling larger amounts of products, thus revealing inadequate conditions of use. The results indicate that the lack of technical assistance is a problem. Small producers who use pesticides receive less assistance than larger producers.[b] Despite being a control variable, the area of establishment was positively associated with poisoning, although not in a statistically significant way. This association did not differ among cities, considering the fact that the model with a random coefficient for this variable was not significant.

Both soybean and cotton did not have statistically significant associations. In contrast, corn had increased chances of poisoning. However, the results of this study suggest that the larger the area of the establishment, the lower the risk effect of corn on poisoning. Once more, the relationship between area and technical assistance influences corn cultivation, which differs from soybean and cotton as it has the unique characteristic of being present in both small and large establishments. Data from the PREVS suggest that nearly 30% of pesticides used in corn cultivation were not recommended, higher than the figure found for soybean (4%), thus indicating the greater technical knowledge of producers when selecting pesticides for this particular crop.

The higher risk associated with the lack of technical assistance and corn cultivation among small producers should be carefully analyzed, because it may suggest inaccurate interpretations, such as small producers probably being more responsible than larger producers with regard to externalities caused by pesticide use. The risk could be greater because the externalities assessed in this study refer to acute poisoning with workers being inside establishments, i.e. those that needed to be in direct contact during a relatively short time of exposure. There is a greater use of backpack spraying in small rural establishments,[16,17] which requires individuals applying pesticides to be in closer contact with them. Harm to the biota and the general environment is more associated with more frequent large-scale applications and long-term exposures such as mid-air pulverizations, despite their possibly causing serious accidents that affect larger population groups.[13] This type of application is more frequent in larger establishments, where single-crop farming is typical, as is the case of soybean and cotton. Associations between the area planted and water and soil contamination by pesticide use were found in areas of the Brazilian grasslands where single-crop farming is practiced.[19]

The fact that rural establishments are found in cities with a higher budget resulting from the sales of agricultural products tends to reduce spending on workers' health. An increase of one thousand dollars in the city's average budget reduces the chances of poisoning in establishments by 4%. In addition to the effect of technical assistance, which tends to be better in areas with a higher budget, old-fashioned pesticides with a higher toxicity are usually cheaper[h] and this could promote their use, especially by poorer farmers such as small land owners. This problem can be even greater in the state of Paraná as it borders Paraguay, which facilitates the smuggling of pesticides, which are usually cheaper and of dubious quality. The value of these products can be 50% cheaper than the values set by the Brazilian Ministry of Agriculture.[i]

The chances of intoxication were greater in establishments located in cities that take soil conservation measures. Cities that take more responsibility for environmental issues may be expected to have lower risks of poisoning. However, certain pesticides cause soil impoverishment and erosion and other environmentally unsustainable agricultural practices, as they destroy the vegetation.[3] The exposed soil is more easily affected by the rain and creates another problem for agriculture: silting. Soil conservation measures can be a response to existing environmental degradation situations partly resulting from agricultural activities with intensive use of pesticides. This would explain the greater probability of poisoning in these areas.

Similar logic can be applied to inspection and workers' union participation in the CMMA, which was a risk factor rather than a protective factor. This probably reflects the fact that the cities prioritizing inspection are those whose problem has become relevant, i.e. inspection would be *a posteriori* action.

Brazil has a federal environmental legislation and states and cities have political, administrative and financial autonomy, so that some develop more environmental actions, inspection and control than others. The present study shows that, when a certain establishment is located in a city which follows the local Agenda 21 and this agenda deals with environmental issues, the chances of poisoning are reduced by 82%, emphasizing the importance of including these issues on a local basis.

Organic agriculture promotion has a key role. Establishments located in cities that follow such approach have a 47% lower chance of poisoning by pesticides. In addition to having a lower cost and reducing spending on health for obvious reasons, this action is more efficient. Countries such as Indonesia, Sweden, Norway, Germany, Holland and Guatemala have reduced their annual use of pesticides to between 33% and 75%, without decreasing the production of certain crops.[14]

The results found for variables on the second hierarchical level indicate that the variability in poisoning and its cost cannot be explained by regional factors such as climate and soil. This is because variables that primarily show this "agricultural aptitude", such as the agricultural GDP, were not significant like the second level variables. The model constructed enabled part of this variability to be explained by including variables that bring the following municipal management aspects to sectors that work with human health and environmental protection: implementation of the local Agenda 21, organic agriculture promotion programs and inspection and control of the use of fertilizers and pesticides. These results emphasize the role of public policies and municipal actions in the promotion of workers' and environmental health.

The present study focused on acute poisoning, considered to be the tip of the iceberg with regard to pesticides' economic impacts on health and the environment.[19] Based on the associations found, there are two possible lines of action to reduce spending on rural workers' health in the state of Paraná: 1) the increase in technical assistance for small farmers, especially when purchasing pesticides and controlling these substances according to the institutional strengthening of inspection organizations, environmental protection and workers' and environmental health surveillance; and 2) the promotion of policies that strengthen a fairer and healthier production model, applicable to small rural properties. Federal and state public policies are required to recognize, debate and interact with successful municipal actions, such as the implementation of the local Agenda 21 and organic agriculture promotion. After all, farmers live and work in cities and this is where they can change their agricultural practices to enable healthier land and foods.

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[h] Pesticidas y agrotóxicos: Veneno en la piel. *El País.* 01 Abr. 2006[cited 2008 Aug 01] Qué Pasa?. Available from: http://www.uruguayambiental.com/noticias/PesticidasAgrotoxicosVenenoPiel.html

i Agrotóxicos ilegais causam prejuízo de R$ 500 milhões. *Portal do Agronegócio.* 29 Out 2007[cited 2008 Jun 01] Agronegócio / Ecologia - Meio ambiente. Available from: http://www.portaldoagronegocio.com.br/conteudo.php?id=4890

REFERENCES

1. Antle JM, Pingali PL. Pesticides, productivity, and farmer health: a Philippine case study. *Am Agric Econ Assoc.* 1994;76(3):418-30. DOI:10.2307/1243654
2. Araujo AC, Nogueira DP, Augusto LG. Impacto dos praguicidas na saúde: estudo da cultura de tomate. *Rev Saude Publica.* 2000;34(3):309-13. DOI:10.1590/S0034-89102000000300016
3. Brigante J, Espindola ELG. Limnologia Fluvial: um estudo no rio Mogi-Guaçu. São Carlos: RiMa; 2003.
4. Cole DC, Carpio F, León N. Economic burden of illness from pesticide poisonings in highland Ecuador. *Rev Panam Salud Publica.* 2000;8(3):196-201. DOI: 10.1590/S1020-49892000000800007
5. Delgado IF, Paumgartten FJR. Intoxicações e uso de pesticidas por agricultores do município de Pati do Alferes, Rio de Janeiro, Brasil. *Cad Saude Publica.* 2004;20(1):180-6. DOI:10.1590/S0102-311X2004000100034
6. Drummond MF, O'Brian B, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes. 2.ed. Oxford: Oxford Medical Publications; 1997.
7. Foster V, Mourato S. Valuing the multiple impacts of pesticides use in the UK: a contingent ranking approach. *J Agric Econ.* 2000;51(1):1-21. DOI: 10.1111/j.1477-9552.2000.tb01206.x
8. Garcia JE. Intoxicaciones agudas con plaguicidas: costos humanos y económicos. *Rev Panam Salud Publica.* 1998;4(6):383-7. DOI:10.1590/S1020-49891998001200003
9. Gelman A, Hill J. Data analysis using regression and multilevel/hierarchical models. Cambridge: Cambridge University Press; 2007.
10. Maumbe BM, Swinton SM. Hidden health costs of pesticide use in Zimbabwe's smallholder cotton growers. *Soc Sci Med.* 2003;57(9):1559-71. DOI:10.1016/S0277-9536(03)00016-9
11. Pearce D, Crowards T. Assessing the health cost of particulate air pollution in the UK. London: University College London; 1996.
12. Pignati WA, Machado JMH, Cabral JF. Acidente rural ampliado: o caso das "chuvas" de agrotóxicos sobre a cidade de Lucas do Rio Verde - MT. *Cienc Saude Coletiva.* 2007;12(1):105-14. DOI:10.1590/S1413-81232007000100014
13. Pimentel D, Greiner A. Environmental and socio-economic costs of pesticide use. In: Pimentel D, editor. Techniques for reducing pesticide use: economic and environmental benefits. Chichester: John Wiley & Sons; 1992. p.51-78.
14. Pimentel D. Environmental and economic costs of the application of pesticides primarily in the United States? *Environ Dev Sustainability.* 2005;7:229-52. DOI:10.1007/s10668-005-7314-2
15. Pingali PL, Marquez CB, Palis FG. Pesticides and Philippine rice farmer health: a medical and economic analysis. *Amer J Agr Econ.* 1994;76(3):587-92. DOI: 10.2307/1243669
16. Soares WL, Almeida RMVR, Moro S. Trabalho Rural e fatores de risco associados com o uso de agrotóxicos em Minas Gerais, Brasil. *Cad Saude Publica.* 2003;19(4): 1117-27. DOI: 10.1590/S0102-311X2003000400033
17. Soares WL, Moro S, Almeida RMVR. Rural workers' health and productivity: an economic assessment of pesticide use in Minas Gerais, Brazil. *Appl Health Econ Health Policy.* 2002;1(3):157-64.
18. Soares WL, Porto MF. Atividade Agrícola e externalidade ambiental: uma análise do uso de agrotóxicos no cerrado brasileiro. *Cienc Saude Coletiva.* 2006;12(1):131-43. DOI: 10.1590/S1413-81232007000100016
19. Sobreira AE, Garcia J, Adissi PJ. Agrotóxicos: falsas premissas e debates. *Cienc Saude Coletiva.* 2003;8(4):985-90. DOI: 10.1590/S1413-81232003000400020
20. Travisi M, Nijkamp P. Valuing environmental and health risk in agriculture: a choice experiment approach to pesticides in Italy. *Ecol Econ.* 1998;67(4):598-607. DOI: 10.1016/j.ecolecon.2008.01.011

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