Pesticide or Wastewater, Which One is Bigger Culprit for Acute Health Symptoms among Vegetable Growers in Pakistan's Punjab

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Abstract

Past studies highlight harmful effects of using pesticides and untreated wastewater on farmers' health in agriculture. However, none of the studies explore these sources to determine the magnitude of deleterious health effects simultaneously. Vegetable growers in peri-urban areas of developing countries are facing severe problems of acute symptoms, not only because of intensive use of hazardous pesticides but also due to irrigation with untreated wastewater. The objective of this article is to quantify pesticide and untreated wastewater induced health symptoms among vegetable growers. A sample of 830 vegetable growers was selected by stratified random sampling from three major vegetable growing districts of Pakistan's Punjab. A two stage estimation technique was employed to estimate unbiased health effects of vegetable growers after controlling for the endogeneity of pesticide use. The results demonstrate that both untreated wastewater and pesticide quantities are responsible for acute symptoms but comparison of their coefficients indicates that one litre of pesticide quantity is causing 3 times more symptoms than one hour of untreated wastewater use. Therefore, in order to minimize these negative health effects, the policy makers in under developing countries need to focus more on the reduction of hazardous pesticide use than untreated wastewater. Although, untreated wastewater is also significantly responsible of acute symptoms and therefore, it should not be ignored.

Key words: *Pesticide; Wastewater; Acute symptoms; Endogeneity; Two stage estimation technique, Pakistan*

Jel Classification: *I12, Q53, Q15*

1. Introduction

Farmers' vulnerability of acute and chronic illnesses is associated with intensive use of hazardous pesticides (Antle et al., 1998; Crissman et al., 1998; Garming and Waibel, 2009; Harper and Zilberman, 1992; Kouser and Qaim, 2011; Maumbe and Swinton, 2003; Okello and Swinton, 2007; Rola and Pingali, 1993; Travisi and Nijkamp, 2008; Travisi et al., 2006; Zilberman et al., 1991). World Health Organization (WHO) estimated that three million cases of pesticide symptoms occur worldwide each year, with 220,000 deaths (WHO, 1998). Though these numbers are extrapolated from a few small studies and are, therefore, much debated (Karalliedde et al., 2001). Pesticide symptoms undoubtedly represent an enormous economic and human health cost to the society. Soares and Porto (2009) concluded that only health costs accounts for 86% of the benefits of pesticide use. Similarly, Travisi and Nijkamp (2008) observed that annual willingness to pay (WTP) of an Italian household is €1286 to eliminate all cases of acute pesticide intoxications. A higher proportion of pesticide symptoms and deaths arise in developing countries (Wilson and Tisdell; 2001) due to inadequate occupational safety standards, protective clothing and washing facilities; insufficient regulations; poor labelling of pesticides; illiteracy and insufficient knowledge about pesticide hazards (Pimentel and Greiner, 1996; WHO, 1998). The most vulnerable groups to pesticide exposure are farm workers, pesticide applicators and inhabitants who live adjacent to heavily treated agricultural land. Farmers and hired sprayers directly handle 70-80% of the pesticide activities due to which they are at the greatest risk to pesticide exposure (McDuffie, 1994).

Farmers face varying degrees of severity of acute symptoms of pesticides which includes coughing, fever, headache, general weakness, sleeplessness, nausea, stomach pain, diarrhoea, dizziness, muscular twitching, eye and skin irritation and respiratory discomfort (Beshwari et al., 1999; Dung and Dung, 1999; Huang et al., 2003; Kouser and Qaim, 2011; Krishna and Qaim, 2008; Mancini et al., 2005; Murphy et al., 2005; Yassin et al., 2002). More or less, similar symptoms have also been observed among vegetable growers due to untreated wastewater use (Abedullah et al., 2012; Weldesilassie et al., 2010; Drechsel et al., 2010; Scheierling et al., 2010).

In developing countries, wastewater comprises of both domestic sewage and industrial effluents. Therefore, it contains a variety of pollutants including pathogens and heavy metals which can potentially harm human health and the environment (Srinivasan and Reddy, 2009). The first epidemiological evidence on the health risks due to untreated wastewater use in agriculture is provided by Shuval et al. (1986). They prove that untreated wastewater is the cause of relatively higher prevalence of ascariasis symptoms (cough, nausea, diarrhoea, shortness of breath, and wheezing) and hookworm symptoms (abdominal pain, nausea, fever) among field workers than control group. Some studies have examined the possible risk associated with untreated wastewater use for agricultural purposes, particularly, the transmission of geohelminthic and bacterial infections among farm workers and symptoms of these diseases are weight loss, irritability, poor appetite, abdominal pain and diarrhoea (Blumenthal and Peasey, 2002; Fliermans, 1996; Habbari et al., 2000; Wilson and Fujioka, 1995). Weldesilassie et al. (2010) and Srinivasan and Reddy, (2009) also observe that acute symptoms of illness is significantly higher among wastewater farmers than those irrigating their farms with freshwater. Hence, untreated wastewater use along with its benefits can also pose substantial risks to farmers' health.

Wastewater generates considerable value in urban and peri-urban agriculture despite farmers' health and the environmental risks associated with this practice (Bahri, 2008; Ensink, 2002; Scott et al., 2010; 2004). Comparison of vegetable production with freshwater and untreated wastewater in Haroonabad district of Pakistan indicates that the gross margins are significantly higher for wastewater users (US$150 per hectare), because they spend less on chemical fertilizers and achieve higher yields (Van der Hoek, 2002). Similar findings are observed by Hussain et al. (2002). Although untreated wastewater use is associated with significant health symptoms. Abedullah et al. (2012) have shown that net benefits of vegetable production after internalizing the farmers' health costs of untreated wastewater use become negative and the value of net economic loss is US$ 1328.2 per acre per annum which cannot be easily ignored.

Antle and Pingali (1994) conclude that pesticide use has negative effects on farmers' health while farmers' health has a positive effect on agricultural productivity. Ensink et al. (2004) have same conclusion for wastewater use. Hence, consensus is rapidly growing that farmers' health issues are serious threat to rural development and to reverse the gains made in agricultural growth (Binswanger and Townsend, 2000). A growing body of literature suggests that the benefits of pesticides and untreated wastewater are obtained at a substantial cost to the society (Abedullah et al., 2012; Antle et al., 1998; Antle and Pingali, 1994; Cole et al., 1998; Crissman et al., 1994; Czapar et al., 1995; Ensink et al., 2004; Haruvy, 1997; Kouser et al., 2009; Pingali et al., 1995).

Use of untreated wastewater in vegetable production is common in developing countries. Therefore, in addition to pesticides, untreated wastewater use should be considered in the determination of acute symptoms among vegetable growers. Although the existing literature on vegetable production is mainly focusing on pesticides to investigate the acute health problems of farmers (Asfaw et al., 2010; Atreya, 2008; Krishna and Qaim, 2008), ignoring other potential factors like untreated wastewater use.

This research contributes to the existing literature by providing empirical evidence about the role and extent of pesticide and untreated wastewater use in determining vegetable grower's acute symptoms simultaneously. This helps to quantify the negative health impacts of pesticide and untreated wastewater usage in vegetable production. We considered six common symptoms that appears due to pesticide and wastewater use in our analysis, these includes skin irritation, coughing, nausea, vomiting, diarrhoea and fever. We used cross sectional data of 830 vegetable growers of three major vegetable growing districts of the Punjab province of Pakistan and employ two stage estimation technique to quantify the acute symptoms of untreated wastewater and hazardous pesticide use. Pakistan is an interesting example where 26 per cent of vegetables are mainly grown with untreated wastewater.

The rest of the article is organized as follows: the next section describes sampling design and data collection procedure. The following section delineates the empirical model. Section 3 discusses the descriptive analysis before presenting the empirical results of pesticide and untreated wastewater contribution in growers' acute health symptoms. The last section concludes the study.

2. Data collection and empirical model

2.1. Data collection

In the survey years of 2010-2011, three major vegetable growing districts named Gujranwala, Faisalabad, and Multan were purposively selected in the Punjab province of Pakistan. In addition to agricultural activities in the peri-urban areas of these districts, they are also industrial hubs of the province and are generating large amount of wastewater, which is being used by farmers for irrigation purposes without getting any treatment. In the peri-urban areas, majority of farmers are growing vegetables with wastewater. They believe that vegetables require heavy doses of fertilizers which are present in the wastewater, implying that wastewater permits them to use no or only little amounts of fertilizer. However, farmers living away from peri-urban areas also grow vegetables but with freshwater (canal or tube well water). Hence, in the first stage we constructed two strata (wastewater and freshwater farmers) in each district. In the second stage we selected three tehsils from each district and two villages growing vegetables with freshwater in each tehsil. Finally, we randomly selected 23 farmers growing vegetables with freshwater from each village and making 138 farmers in each district growing vegetable with freshwater. However, wastewater farmers are scattered in peri-urban areas and 138 farmers were randomly selected growing vegetables with wastewater from each of the two districts and from the third districts 140 wastewater farmers were randomly selected. This makes a total sample of 830 farmers, comprises of 414 freshwater and 416 wastewater farmers. Growers were randomly selected within each stratum and face to face interviews were conducted. A well-structured questionnaire was used to interview sampled farmers to provide information about socio-economic characteristics, input-output details including frequency and quantity of pesticide use and irrigation hours. In addition farmers were particularly asked about the frequency and type of acute symptoms during the last vegetable growing season. Moreover, farmers suffered from these symptoms were asked to report medical expenses such as treatment costs, physician costs, travel cost to visit physicians, work days lost and the opportunity cost of lost labour days for each symptom. Agri-graduates were trained to conduct face to face interviews. The questionnaire was pre-tested and improvements were made in the light of farmers' response during the pre-testing.

2.2. Empirical model

The main objective of this article is to investigate whether pesticide and/or untreated wastewater has a significant effect on vegetable grower's acute symptoms. We used number of common acute symptoms as dependent variable in our main model. This variable is a non-negative integer count, therefore, we assume a Poisson distribution. The Poisson regression model is described in detail by Cameron and Trivedi (1998) which is as:

$$Prob\ (Y_i = y_i/x_i) = \frac{e^{-\lambda_i}\,\lambda_i^{y_i}}{y_i\,!} \qquad (1)$$

where y_i is the number of acute symptoms faced by the farmer during last crop season., which varies across farmers (i = *1,…., n*). Poisson distribution is assumed to have conditional mean (λ_i) which in turn depends on a vector of exogenous variables x_i. The most common formulation of λ_i used in the literature is loglinear model which can be expressed as:

$$\ln \lambda_i = \beta' x_i \qquad (2)$$

where β is a vector of coefficients. To test the influence of pesticide on acute symptoms, we used pesticide quantity on per farm basis, measured in litres, as part of vector x_i. Previous studies have shown that pesticide has an increasing effect on symptoms (Hossain et al., 2004; Kouser and Qaim, 2011; Krishna and Qaim, 2008; Maumbe and Swinton, 2003). We hypothesize from the existing literature that untreated wastewater use has positive effect on acute symptoms. To capture this effect, first we included dummy for wastewater. In the later specification of this model we replace it with untreated wastewater and freshwater irrigation hours used to irrigate the total cultivated area, which provide us net average effect of wastewater use on acute symptoms. Among exposure related variables we use a dummy for self spray, to distinguish this effect from those who partially or fully hired labourers for this operation. Farmer adopts various kinds of protective measures to avoid health risks from pesticide spray and untreated wastewater use (gloves, safe clothing and long plastic shoes etc). We also use dummy for protective measures which is one if farmers use any of these measures. Pesticide studies have shown the positive effects of self spray and negative effects of protective clothing on acute symptoms (Kouser and Qaim, 2011; Krishna and Qaim, 2008; Maumbe and Swinton, 2003).

Other important variables are farmers' vegetable experience and education (years of schooling), which are proxy for farmers' management. Literature has shown that experience and education have negative effects on symptoms (Asfaw et al., 2010; Hossain et al., 2004; Maumbe and Swinton, 2003). To capture the difference in climatic factors across districts (e.g., temperature, humidity, precipitation) we included two district dummies for Faisalabad and Gujranwala, using Multan district as a reference.

Eq. (1) can be estimated with Poisson regression. However, if any unobserved factor is correlated with the incidence of symptom as well as with one or more of the endogenous explanatory variables, the estimates of the associated parameters became biased. In our case total pesticide quantity used by the farmer is an endogenous regressor and depends on many factors (e.g., pesticide price, cultivated area, severity of pest pressure, unobserved factors (farmers' attitude towards risk)), which could systematically influence our dependent variable.

To correct endogeneity of pesticide quantity we used the two-stage estimation technique suggested by Wooldridge (1997) and employed in many studies (Asfaw et al., 2010; Hossain et al., 2004). We employ linear regression model in the first stage as shown in Eq. (3).

$$x_{1i} = c + \gamma_1 Z_{1i} + \gamma_2 Z_{2i} + \upsilon_i \qquad (3)$$

where x_{1i} is pesticide quantity in litres used on total cultivated area and varies across farmers (i = *1,…., n*). Z_{1i} is the pesticide price, measured in Pakistani rupees per litre (Rs/litre) and Z_{2i} indicates cultivated area measured in acres. We also tried farmers' perceptions about severity of pest pressure on their farm, measured in Likert scale ranging from 1 to 4 as an instrumental variable but it did not significantly affect the pesticide quantity and therefore, dropped from the analysis. Finally, we used pesticide price and cultivated area as instruments for pesticide quantity to correct its endogeneity. Many studies have used pesticide price as an instrument to correct for the endogeneity of pesticide quantity (Hossain et al., 2004; Huang et al., 2002; Qaim and De Janvry, 2005). c and υ_i are intercept and random error term, respectively. After correcting the endogeneity of pesticide quantity we use its predicted value in Eq. (2) which is the second stage Poisson regression model. Hence, two-stage Poisson regression model helps to account for the endogeneity of pesticide use in estimating acute symptoms incurred due to pesticide and untreated wastewater use. However, there is no problem of self selection of wastewater use by growers because in wastewater area canal water (or freshwater) is not available and prices of wastewater are negligible across the sample. Hence, untreated wastewater is the only choice for farmers and thus, considered as exogenous.

3. Results and Discussions

3.1 Descriptive analysis

Descriptive statistics for the variables used in empirical model are presented in Table 1, by differentiating wastewater and freshwater areas. It is observed that in terms of experience and education wastewater farmers are not significantly different from freshwater farmers. However, comparison of pesticide quantities on per acres basis reveals that wastewater farmers are using significantly higher pesticide quantities than freshwater farmers. This is further analyzed in Fig. 1, which illustrates that higher pesticide quantities in wastewater areas are not only observed on an average but along the entire variable distribution. A Kolmogorov-Smirnov test (Chakravarti et al., 1967) confirms that the two distribution functions are significantly different at less than one percent level of significance. These results suggest that wastewater farmers are using significantly higher pesticide quantities than the freshwater farmers, indicating that higher returns motivates wastewater farmers to intensify production using more pesticides.

Table 1 about here

Fig 1 about here

Our particular interest here is the number of acute symptoms, faced by the farmer (respondent) mainly responsible for all farm related activities. On an average, 3.48 symptoms per vegetable season are reported by wastewater farmers, as compared to 2.35 symptoms by freshwater farmers. This difference is highly significant. Fig. 2 shows that the majority of freshwater farmers fall in the category of symptoms 0, 1 and 2 but on the other hand, majority of the wastewater farmers report higher symptoms (4, 5, 6 and 7), indicating that wastewater farmers are facing acute symptoms more frequently than freshwater farmers during the vegetable production season.

Fig 2 about here

Average number of irrigation hours applied in wastewater fields is significantly lower than in freshwater fields. The reason is high velocity of wastewater flow. The number of wastewater farmers who spray pesticide themselves and also adopt protective measures during the spray is not significantly different from the number of freshwater farmers.

3.2. Econometric analysis

3.2.1 General impact evaluation

It is hypothesized that vegetable grower's acute symptoms are associated with intensive use of pesticide and untreated wastewater use. However, pesticide quantities applied by farmers on their farms are endogenous and depend on many observed and unobserved factors. To correct its endogeneity we used two instruments, i.e. pesticide price and cultivated area in the first stage pesticide model. The results of the first stage regression are presented in column (1) of Table 2. The significant coefficient of cultivated area indicates that increase in one acres of cultivated area increases pesticide quantity by 5.3 litres. The coefficient of pesticide price is highly significant and negative, implying that as pesticide price increases by one rupee, pesticide quantity decreases by 0.002 litre (2 ml). The expected signs of these instruments are consistent with other studies (Hossain et al., 2004; Kouser and Qaim, 2011). Over-identification test does not reject the validity of these instruments and therefore, these instruments have been used to correct the endogeneity of pesticide quantity. The F-statistics of joint significance of the excluded instruments is greater than 10, implying that they are not weak instruments.

Table 2 about here

Other significant variables in this model are, dummy for wastewater, dummy for self spray, and dummies for Gujranwala and Faisalabad districts. The positive coefficient of dummy for wastewater indicates that wastewater farmers are using 3 litres more pesticide than freshwater farmers, implying that marginal productivity of pesticide use is higher on wastewater fields compared to freshwater. It also indirectly point out that wastewater provides favourable environment for pests to grow and consequently increases pesticide demand (Ensink, 2002). The coefficient of the self spray dummy indicates that farmers, who spray themselves, spray 2 litres more pesticides than those who employ hired labourers for spraying, indicating that compared to hired labourers farmers are spraying intensively to reduce yield loss due to pests. The results are consistent with Kouser and Qaim (2011). Dummy for protective measures has negative but insignificant effects on pesticide quantity. The significant coefficient of Faisalabad and Gujranwala dummy represents that pesticide consumption in these districts is higher than Multan. It could be because of different ecological factors and pest pressure across districts.

We manually performed the robustified Durbin-Wu-Hausman test to check the endogeneity of pesticide quantity. The results reject the null hypothesis of exogeneity at one percent level of significance, suggesting that pesticide quantity is endogenous. To correct this endogeneity we estimate predicted pesticide quantity from the first stage pesticide model, where we use pesticide price and cultivated area as instruments and use in the second stage Poisson regression which is our main model. The results of the second stage regression are reported in column (2) of Table 2. We use bootstrapping procedure for correcting the standard errors of the second stage regression (Freedman, 1984), which are given in parentheses in column (2) of Table 2. Predicted pesticide quantity, dummy for wastewater and dummy for self spray have positive and highly significant effects on farmers' acute symptoms. Under the *ceteris paribus* assumption, the coefficient of predicted pesticide quantity indicates that one liter increase in pesticides causes 0.01 percent increase in acute symptoms. However, irrigation with wastewater increases acute symptoms by 0.25 percent than freshwater. The coefficient of self spray dummy indicates that farmers who spray pesticides themselves report 0.39 percent more symptoms per vegetable season than farmers who employ hired labourers for spraying. The positive effect of the self spray dummy is not surprising and consistent with other studies (Kouser and Qaim, 2011). The coefficient of predicted pesticide quantity is smaller than the wastewater use dummy, but such comparison can be made on the base of different types of variables (e.g., continuous and categorical variables). But simply if we compare, the coefficient of self spray dummy which represents only partial effect of pesticide use with wastewater dummy, it reflects that impact of pesticide (only partial effect) is higher than wastewater on acute symptoms. The negative and significant coefficient on the dummy for protective measures represents the reducing effect on acute symptoms. We also include district dummies to capture variation in agro-climatic conditions. The coefficient of dummy for Faisalabad district is significant with positive sign, indicates that farmers of Faisalabad districts are facing more frequent problems of acute symptoms than district of Multan. It might be because Faisalabad district is highly industrialized and wastewater is more polluted than Multan. The results of log-likelihood ratio and F-statistics indicate the overall significance of both stages. However, we have explored it in a comprehensive way in the next section.

3.2.2 Specific impact evaluation

General impacts analyses have shown that both pesticide and untreated wastewater are responsible for vegetable growers' acute symptoms but there are indications that pesticide quantity is playing a dominant role in determining acute symptoms. Here we replace the dummy for wastewater with wastewater and freshwater irrigation hours in both stages, to explore this effect in more detail. These changes allow us to compare the contribution of pesticide quantity and untreated wastewater in farmers' acute symptoms. The results of pesticide and Poisson regression models are reported in columns (1) and (2) of Table 3, respectively. The positive and significant coefficient of untreated wastewater in pesticide model indicate that one hour increase in untreated wastewater usage results in 0.015 litre (15 ml) increase in pesticide quantity. However, the coefficient of freshwater irrigation hours is significant with negative sign, implies that one hour increase in freshwater irrigation hours decreases pesticide quantity by 0.016 litre (16 ml). These results elaborate the fact that wastewater provides favourable environment for pests to grow, which ultimately encourage the farmers to use more pesticide.

Table 3 about here

After replacing dummy for wastewater with untreated and freshwater irrigation hours we do not find any significant change in the sign and size of other coefficients except predicted pesticide quantity (see Table 2 and 3). Predicted pesticide quantity and untreated wastewater use have positive and significant effects on farmers' acute symptoms. The coefficient of pesticide quantity indicates that one litre increase in pesticide quantity increases acute symptoms by 0.003 percent, while on the other hand, the coefficient of wastewater use indicates that one hour increase in untreated wastewater use increases acute symptoms only by 0.001 percent. Comparison of their coefficients demonstrates that pesticide is three times more responsible for acute symptoms among vegetable growers than untreated wastewater, which is consistent with other studies that pesticide is playing a dominant role in determining acute symptoms among farmers (Harper and Zilberman, 1992; Maumbe and Swinton, 2003; Travisi and Nijkamp, 2008; Garming and Waibel, 2009; Kouser and Qaim, 2011). However, freshwater irrigation hours have negative and significant effect on acute symptoms, implying that freshwater use contributes in the reduction of acute symptoms. The explanation of the remaining variables is the same as discussed above.

4. Conclusions

Use of untreated wastewater for vegetable production in peri-urban agriculture is a common practice. Many studies demonstrate positive impacts of wastewater use on crop productivity and farm income. Although a few studies have pointed negative effects of untreated wastewater irrigation on farmers' health. These health effects aggravate in the presence of hazardous pesticide sprays.

The existing literature either shows harmful effects of pesticides and/or untreated wastewater on farmers' acute symptoms. However, according to the best of our knowledge no study has concurrently quantified the effect of pesticide and untreated wastewater on farmers' acute symptoms. The contribution of this article is to provide empirical evidence about the role and extent of pesticide and untreated wastewater use in determining acute symptoms among vegetable growers. This not only helps to quantify the negative health impacts of pesticide and untreated wastewater usage on vegetable growers' health, but their comparison also provides clear guidelines for policy makers.

We conducted cross sectional survey in three major vegetable growing districts of the Punjab province of Pakistan and employ two-stage Poisson regression model in determining acute symptoms after correcting for the endogeneity of pesticide quantity. The results demonstrate that both pesticide and untreated wastewater have notably increased acute symptoms among vegetable growers. Further comprehensive analysis provide insight that one litre increase in pesticide quantity increases acute symptoms by 0.003 percent while one hour increase in untreated wastewater irrigation increases symptoms only by 0.001 percent. Comparison of their coefficients illustrates that pesticide quantity is 3 times more responsible for symptoms than untreated wastewater. This implies that toxic pesticide cause more serious risk to farmers' health than untreated wastewater in peri-urban vegetable production. Hence, policy makers of under developing countries need to take serious steps to reduce pesticide use through price-response mechanism or through awareness campaign. Any reduction in pesticide use in vegetable production will not only help to improve farmer's health but it could also help to provide safe vegetables to consumers with less pesticide residues.

Despite of negative health impacts of untreated wastewater use, municipal authorities in developing countries encourage farmers to use untreated wastewater for their vegetable crops in peri-urban areas. After proper treatment according to WHO guidelines (WHO, 2006) wastewater use could be the feasible option to dispose bulk of municipal wastewater. The installation of treatment plant by collecting pollution premium from industrialists for the disposal of untreated wastewater seems to be the most feasible and practically viable option. However, awareness campaign and training programs about the safe use of hazardous pesticides and untreated wastewater need to launch to reduce their negative health effects.

More research needs to focus to quantify short and long term pesticide and wastewater induced health and environmental impacts over time. An estimation of socially optimum level of pesticide use in peri-urban agriculture can also help to formulate future pesticide policy.

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Table 1 Descriptive Statistic of variables used in the analysis

Variables	Wastewater (n_1=418)	Freshwater (n_2=412)
Vegetable experience (years)	17.66**	16.04
	(10.96)	(10.83)
Education (years)	4.22***	5.12
	(4.38)	(4.34)
Pesticide quantity (Liter/acre)	4.32***	3.61
	(2.25)	(2.19)
Pesticide cost (Rs/acre)	6118.07***	4906.71
	(3188.02)	(2886.35)
Number of pesticide spray (No/acre)	15.10***	13.39
	(7.64)	(7.38)
Number of acute pesticide symptoms during vegetable season	3.48***	2.35
	(1.82)	(1.88)
Irrigation hours (hrs)	32.29***	36.71
	(19.20)	(19.90)
Dummy for protective measures	0.41	0.46
Dummy for self spray	0.86	0.87

***, **, and * indicate that the mean values between wastewater and freshwater observations are significantly different at 1%, 5%, and 10%, respectively.
Notes: t-tests are used for continuous and chi-square tests for categorical variables to identify differences in mean values. Values in parentheses are standard deviations.

Table 2 Preliminary models for the determinants of pesticide quantity (Liter/acre) and acute symptoms in vegetable production

Variables	1 Pesticide regression model Coefficients	2 Poisson regression model Coefficients
Vegetable experience	-0.041 (0.033)	-0.001 (0.002)
Education	-0.042 (0.078)	-0.009* (0.005)
Cultivated area	5.331*** (0.245)	-
Pesticide price	-0.002*** (0.001)	-
Predicted pesticide quantity	-	0.009*** (0.001)
Dummy for wastewater	2.885*** (0.620)	0.254*** (0.049)
Dummy for self spray	2.106** (1.057)	0.387*** (0.077)
Dummy for protective measures	-1.221 (0.786)	-0.205*** (0.046)
Dummy for Faisalabad district	2.824*** (0.887)	0.095* (0.049)
Dummy for Gujranwala district	2.893*** (0.831)	-0.018 (0.049)
Constant	-3.274* (1.766)	0.553*** (0.097)
Number of observations	830	830
R-squared	0.77	-
F(9, 820)	72.46***	-
Log likelihood	-	-1628.22
Wald χ^2 (8)	-	337.31***

***, **, and * indicate significance at 1%, 5% and 10%, respectively.

Note: Robust standard errors and bootstrap standard errors are reported in parentheses in column 1 and 2, respectively.

Table 3 Comprehensive models for the determinants of pesticide quantity (ml/acre) and acute symptom in vegetable production

Variables	1	2
	Pesticide regression model	Poisson regression model
	Coefficients	Coefficients
Vegetable experience	-0.048 (0.033)	-0.001 (0.002)
Education	-0.038 (0.076)	-0.008* (0.005)
Cultivated area	5.055*** (0.351)	-
Pesticide price	-0.002*** (0.001)	-
Predicted pesticide quantity	-	0.003** (0.001)
Wastewater irrigation hours	0.015** (0.007)	0.001*** (0.0002)
Freshwater irrigation hours	-0.016** (0.007)	-0.001* (0.0004)
Dummy for self spray	1.771* (1.039)	0.400*** (0.071)
Dummy for protective measures	-0.950 (0.765)	-0.184*** (0.046)
Dummy for Faisalabad district	2.332*** (0.841)	0.048 (0.049)
Dummy for Gujranwala district	2.496*** (0.840)	-0.033 (0.048)
Constant	-0.667 (1.742)	0.704*** (0.095)
Number of observations	830	830
R-squared	0.78	-
F(10, 819)	69.16***	-
Log likelihood	-	-1605.19
Wald χ^2 (9)	-	388.75***

***, **, and * indicate significance at 1%, 5% and 10%, respectively.

Note: Robust standard errors and bootstrap standard errors are reported in parentheses in column 1 and 2, respectively.

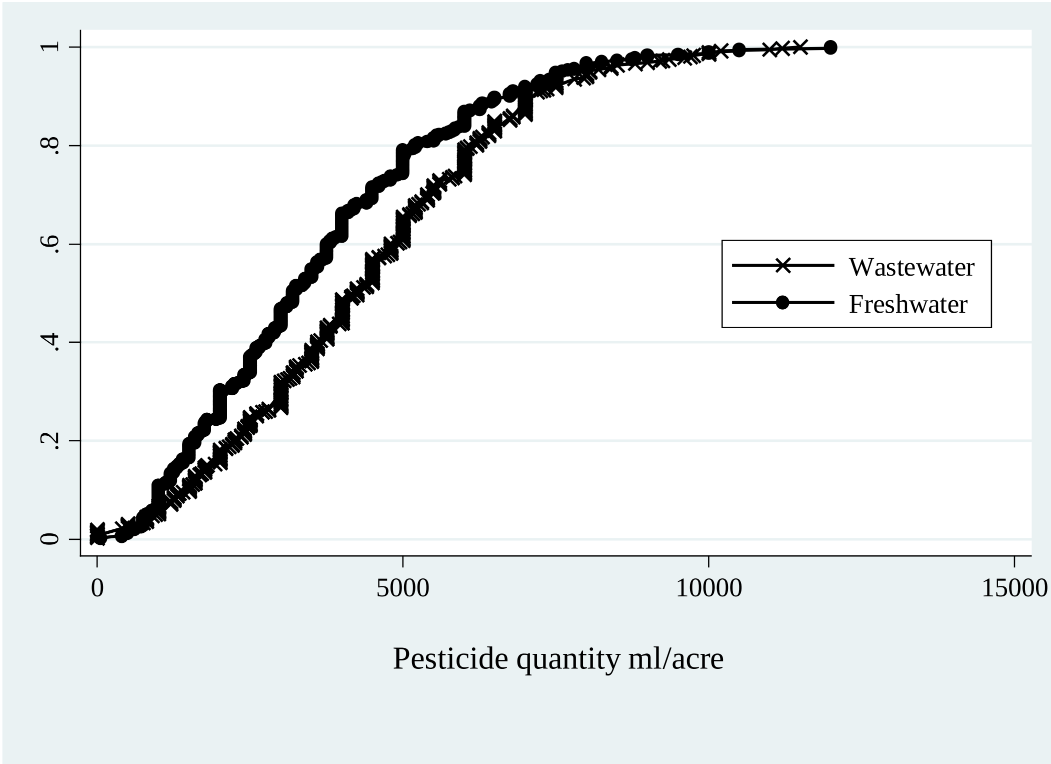

Fig. 1. Cumulative distribution of pesticide quantity used in wastewater and freshwater areas

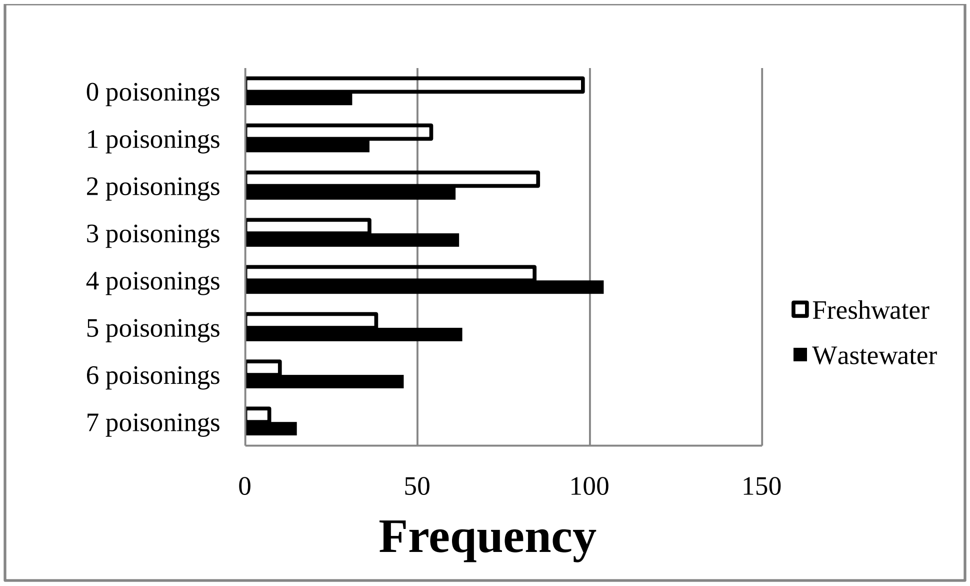

Fig. 2. Frequency of the incidence of acute symptoms of wastewater and freshwater farmers (χ^2= 83.57***).