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ARTICLE

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HEALTH EFFECTS OF PESTICIDES ON AGRICULTURAL WORKERS

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Present paper has made an attempt to investigate the pesticide-induced toxic impacts on agricultural farmers. This analysis is based on the data sets of different kinds of pesticide sales and different quality of life variables relating to health parameters collected from Organisation for Economic Co-operation and Development (OECD), environment statistics and World Health Organisation (WHO) health statistics. Canonical correlation analysis depicted that lung cancer, cardiovascular and muscular diseases are strongly correlated with different kinds of pesticide sales and other life quality variables are negatively correlated. So, emphasis should be given on biological pest management and good agricultural practices.

Introduction

The use of pesticides is an inevitable management practice to protect the crops for the benefit of agricultural productivity. Indian economy is largely dependent on agricultural production; therefore, crop protection and crop production during growing season as well as storage of harvested crops are of paramount importance. In particular, agriculture and its allied sectors contribute approximately 24 per cent of Indian Gross Domestic Product (GDP), ensure food security over 1.21 billion Indian populations and subsequently provide employment approximately 65-70 per cent of Indian populations[1]. Accordingly, the use of agrochemicals by Indian farmers is growing rapidly about 25 to 30% per annum, in which insecticides account for 73 per cent, herbicides14 per cent, fungicides 11 per cent and others 2 per cent. Pesticides among them are an essential part for agricultural practices all over the world. Pesticide covers a wide range of compounds including herbicides, insecticides, rodenticides, fungicides, molluscicides, nematicides, plant growth regulators and others. Organochlorine (OC) insecticides among them are used successfully to control the diseases like malaria and typhus, simultaneously its use was restricted or banned after 1960s in most of the technologically advanced countries. Further, the introduction of other insecticides – organophosphate (OP) insecticides in 1960s, carbamates in 1970s and pyrethroids in 1980s and the introduction of herbicides and fungicides in 1970 - 1980s contributed greatly to control pest for increasing the agricultural output. Currently, over 300 million pounds of different chemically poisonous constituents in the form of fertilizers and pesticides are now produced under different brand names. In addition to this, according to an estimate of Food and Agricultural Organization (FAO) currently in the market there are about 2.7, 6.5, 240, 11.3, and 4.5 million kg of obsolete pesticides available in Africa, Asia, Eastern Europe, Latin America, and the Middle East respectively. The use of herbicides is considered as beneficial tool in one hand, but in other hand it is considered as a pollutant because of its bioaccumulation, and non-biodegradable properties. So, the selective and judicial use of pesticide must be ensured

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not to become lethal to the non-target species, including man, because the widespread use of pesticides may augment the pollution in water, air and soil.

WHO has classified agricultural pesticides in three categories: Class I (extremely poisonous), Class II (moderate poisonous) and Class III (mildly poisonous)[2].Human exposure to these pesticides during work activities is almost inevitable. According to WHO, over five million severe acute poisoning recorded worldwide each year and out of this, about 370,000 death cases have been attributed to deliberate exposure of pesticides. The incidence of poisoning in developing countries is 13 times greater than that of developed countries[2]. These health effects were due to multiple pathways such as inhalation, skin contact, ingestion, residing close to agricultural fields, consumption of contaminated food, and agricultural occupation[3,4]. Additionally, this exposure risk depends on the type of pesticide, the duration and route of exposure, and even health status of each individual. Further, the situation of pesticide poisoning can be exacerbated owing to frequent use of banned/obsolete pesticides and unsafe pesticide applications[5,6]. Occupational pesticide poisoning caused numerous negative health effects among farmers such as dermatological, liver carcinogenicity, gastrointestinal, thyroid dysfunction, neurological, carcinogenic, congenital abnormalities, respiratory, diabetes, reproductive effects, malformation of the deoxyribonucleic acid (DNA), sleep apnea and even death[7–9]. In addition, pesticide residues have been detected in human breast milk samples, while there are concerns about prenatal exposure and health effects on children and even develop cancer[10]. Actually, many of the farmers are not aware of the risks associated with pesticide use, whereas the lack of training and equipment for safely handling pesticides increases health risk[10]. Therefore, detailed understanding of pesticide exposure among farmers is essential to understand and make firm conclusions about health risks associated with occupational exposure to pesticides among farmers who regularly involved in agricultural activities. Thus, the objectives of this study were to determine the impact of pesticides used in agriculture applications on human health based on secondary data like OECD environment statistics and WHO health statistics across the globe with a particular emphasis on Indian farmers.

Materials and Methods

Data Collection: For this study we have collected data from 19 countries (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, India, Ireland, Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, Switzerland, United Kingdom and United States) based on WHO health statistics and OECD environment statistics. In particular, WHO health statistics were used as data source (Estimates are based on Comparative Risk Assessment, evidence synthesis and expert evaluation for regional exposure and WHO country health statistics-2004). WHO data set was used to estimate the health condition of farmers includes the following symptoms and these data set was considered as Y variables set:

- Y1: Diarrhoea (disability-adjusted life years (DALYs) / 1,000 capita) per year
- Y2: Respiratory infections (DALYs/1,000 capita) per year
- Y3: Lung cancer (DALYs/1,000 capita) per year
- Y4: Neuropsychiatric disorders (DALYs/1,000 capita) per year
- Y5: Cardiovascular disease (DALYs/1,000 capita) per year
- Y6: Chronic Obstructive Pulmonary Disease-COPD (DALYs/1,000 capita) per year
- Y7: Asthma (DALYs/1,000 capita) per year
- Y8: Musculoskeletal diseases (DALYs/1,000 capita) per year
- Y9: Under age 5 mortality rate per 1,000 live births
- Y10: Deaths per year

On the other hand, the OECD environment statistics were used as pesticide data source (sales tonnes of active ingredients, average 1994-2010). These data sets are presented as X variable following the methodology defined as follows:

- X1: Total pesticide sales (tonnes as active ingredients)
- X2: Insecticide sales (tonnes as active ingredients)
- X3: Fungicide sales (tonnes as active ingredients)
- X4: Herbicide sales (tonnes as active ingredients)
- X5: Other pesticides sales (tonnes as active ingredients)

Statistical Method: Canonical correlation analysis (CCA) was used to determine the linear correlation matric between X and Y variables by using SPSS package (v26).

Results

Agricultural workers are at higher exposure risk as they have no guidance or training of pesticide spraying,

and they are not using any protective measures during its application. Apart from these, most of the workers had a superficial knowledge about detrimental health effects of pesticide. Table 1 demonstrates the descriptive statistics mainly mean values and standard deviation of each variables, *i.e.*, pesticide sales and pesticide induced-health effects.

Table 1. Descriptive Statistics of the Studied Variables

Type	Variables	Mean	Std. Deviation
Y1	Diarrhoea	1.011	3.388
Y2	Respiratory infections	0.689	1.752
Y3	Lung cancer	1.168	0.493
Y4	Neuropsychiatric disorders	2.242	0.267
Y5	Cardiovascular disease	3.674	1.187
Y6	COPD	0.842	0.693
Y7	Asthma	0.821	0.299
Y8	Musculoskeletal diseases	0.937	0.1707
Y9	Under age 5 mortality rate	8.737	16.339
Y10	Deaths	255110.526	664890.931
X1	Total pesticide	27620.237	7045.924
X2	Insecticide	2250.902	836.235
X3	Fungicide	6081.007	707.800
X4	Herbicides	14453.337	4203.517
X5	Other pesticides	4876.856	1544.622

The Pearson's correlation between pesticide variables and health risk are presented in Table 2. According to Table 2, total pesticide sales are negatively correlated with health risks such as diarrhoea (-0.553), respiratory infections (-0.550), COPD (-0.461), asthma (-0.469), under age 5 mortality rate per 1,000 live births (-0.584) and deaths (-0.525). Total pesticides also positively correlated with lung cancer and muscular diseases. The association between diarrhoea (-0.526), respiratory infections (-0.528), under age 5 mortality rate per 1,000 live births (-0.553) and deaths (-0.554) and insecticide sales is very strong and significantly correlated. Insecticide is again positively correlated with lung cancer and musculoskeletal diseases. Likely, the association between diarrhoea (-0.497), respiratory infections (-0.499), and under age 5 mortality rate per 1,000 live births (-0.511) and fungicide sales is very strong and significantly correlated. Fungicide is positively (significantly) correlated with lung cancer disease (0.469). Fungicide is also positively correlated with musculoskeletal diseases (0.294). The association between diarrhoea (-0.546), respiratory infections (-0.544), COPD (-0.47), asthma (-0.491), under age 5 mortality rate per 1,000 live births (-0.578) and deaths (-0.519) and herbicide sales is very strong and significantly correlated. Herbicides also positively correlated with musculoskeletal diseases and lung cancers. There is also a positive relationship between other pesticides sales and lung cancer and musculoskeletal diseases. The association between diarrhoea (-0.531), respiratory infections (-0.524), COPD (-0.454), under age 5

Table 2. Correlation Matrix of the Studied Variables

Variables	Diarrhoea	Respiratory	Lung cancer	Neuropsychiatric	Cardiovascular	COPD	Asthma	Musculoskeletal	Mortality rate	Deaths	Total pesticide	Insecticide	Fungicide	Herbicides	Other pesticides
Diarrhoea	1														
Respiratory	0.997	1													
Lung cancer	-0.476	-0.455	1												
Neuropsychiatric	0.149	0.148	0.162	1											
Cardiovascular	0.061	0.107	0.577	0.331	1										
COPD	0.754	0.736	-0.279	-0.010	0.092	1									
Asthma	0.313	0.298	-0.552	-0.067	-0.436	0.456	1								
Musculoskeletal	-0.340	-0.294	0.787	0.183	0.699	-0.211	-0.484	1							
Mortality rate	0.997	0.995	-0.441	0.162	0.093	0.768	0.309	-0.293	1						
Deaths	0.887	0.879	-0.420	0.122	0.077	0.646	0.223	-0.329	0.892	1					
Total pesticide	-0.553	-0.550	0.336	-0.214	0.060	-0.461	-0.469	0.276	-0.584	-0.525	1				
Insecticide	-0.526	-0.528	0.347	-0.233	0.061	-0.329	-0.385	0.299	-0.553	-0.554	0.961	1			
Fungicide	-0.497	-0.499	0.469	-0.022	0.086	-0.436	-0.406	0.294	-0.511	-0.345	0.806	0.716	1		
Herbicides	-0.546	-0.544	0.290	-0.251	0.037	-0.470	-0.491	0.244	-0.578	-0.519	0.995	0.954	0.767	1	
Other pesticides	-0.531	-0.525	0.333	-0.161	0.082	-0.454	-0.431	0.294	-0.564	-0.534	0.986	0.955	0.760	0.973	1

mortality rate per 1,000 live births (-0.564) and deaths (-0.534) and herbicide sales is very strong and significantly correlated.

The canonical correlation analysis is presented in Table 3. The canonical correlation between the first pair (0.926) was found to be not significant (p>0.05) from the likelihood ratio test. The remaining canonical correlation is also statistically non-significant (p>0.05). The first canonical variate depicted that about 8.7% variation in Y variables could be explained by the X variables and about 7.4% variation in X variables could be explained by the Y variables. On the other hand, second canonical variate depicted that about 19.3% variation in Y variables could be explained by the X variables and about 15.4% variation in X variables could be explained by the Y variables. Apart from these, to explain the important accounts of canonical function, canonical loadings were also used. In this regard, the canonical loadings value greater than ± 0.30 were considered as important aspect.

The variable-variate correlations *i.e.,* represented by canonical loadings and canonical cross loadings are presented in Tables 4 and 5. Diarrhoea, respiratory diseases, lung cancer, under age 5 mortality rate per 1,000 live births, total pesticide sale, insecticide sales, fungicide sales, herbicide sales, other pesticides sales and COPD disease are most influential variables. This means that pesticide use (total pesticide sale, insecticide sales, fungicide sales, herbicide sales, other pesticides sales) has the most negative effect on the health.

Table 3. Canonical Correlations Data of the Studied Variables

Variable	Correlation	Eigenvalue	Wilks Statistic	F	Num D.F	Denom D.F.	Sig.
1	0.926	6.036	0.007	0.845	50.000	21.607	0.695
2	0.892	3.903	0.050	0.695	36.000	20.475	0.834
3	0.742	1.225	0.246	0.467	24.000	18.003	0.959
4	0.599	0.559	0.547	0.352	14.000	14.000	0.970
5	0.383	0.172	0.853	0.229	6.000	8.000	0.955

Table 4. Variable-variate Correlations (Canonical Loadings)

Variable	1	2	3	4	5
Diarrhoea	-.125	-.559	.223	.279	-.159
Respiratory	-.122	-.560	.205	.312	-.100
Lung cancer	-.353	.424	-.405	-.283	.057
Neuropsychiatric	-.206	-.246	-.459	.396	-.397
Cardiovascular	-.185	.104	-.169	.116	.237
COPD	-.544	-.259	.510	.007	-.081
Asthma	-.504	-.329	.221	.278	.042
Musculoskeletal	-.239	.372	-.230	.013	.085
Mortality rate	-.162	-.585	.229	.253	-.162
Deaths	-.046	-.630	.001	-.058	-.132
Total pesticide	.310	.910	-.242	-.115	.067
Insecticide	.160	.981	-.061	-.068	-.057
Fungicide	.096	.640	-.638	-.404	-.104
Herbicides	.383	.894	-.178	-.130	.075
Other pesticides	.271	.920	-.270	.048	.071

Table 5. Variable-variate Correlations (Canonical Cross Loadings)

Variable	1	2	3	4	5
Diarrhoea	-.116	-.498	.166	.167	-.061
Respiratory	-.113	-.499	.152	.187	-.038
Lung cancer	-.327	.378	-.301	-.170	.022
Neuropsychiatric	-.191	-.220	-.341	.237	-.152
Cardiovascular	-.171	.093	-.126	.069	.091
COPD	-.504	-.231	.379	.004	-.031
Asthma	-.467	-.293	.164	.166	.016
Musculoskeletal	-.221	.332	-.171	.008	.032
Mortality rate	-.150	-.522	.170	.152	-.062
Deaths	-.043	-.562	.001	-.034	-.051
Total pesticide	.287	.812	-.180	-.069	.026
Insecticide	.148	.876	-.045	-.040	-.022
Fungicide	.089	.571	-.473	-.242	-.040
Herbicides	.355	.797	-.132	-.078	.029
Other pesticides	.251	.821	-.200	.029	.027

Discussion

Pesticidal pollution and associated occupational health problems of farmers are the serious problems worldwide. Pesticides are recognized as an important health risk and a serious threat to public health because of their inherent toxicity and widespread use. Additionally, illiteracy and the lack of information available to farmers regarding pesticide aggravate the pesticide poisoning more adversely. Accordingly, several studies demonstrated associations between pesticides exposure and their health effects. Becker et al.[11] reported that exposure of pesticide to human caused different types of cancers, neurologic disorders, respiratory problems, hormonal and reproductive abnormalities. Apart from these, they also pointed out that pesticides are known to cause abnormalities in the eyes associated with blurred vision, pain in the eyes, lacrimation, red swollen eyes, and irritation of eyes, following pesticide exposure, and this was higher among the spraying workers[12]. In particular, children are most vulnerable because of age-related potential pesticide exposure risk and more exposure effect on their small body mass.

Accordingly, a positive correlation between direct exposure of children to pesticides and cancer has been well established[13]. Recently, several studies have reported that the occurrence of relative cancer risks in children are associated with parental exposure to pesticides[14]. Parallel to these results we have explored the negative relationship between pesticide (all kinds of pesticide sales) and under age 5 mortality rate. On contrary to our findings, Salam et al[15] reported a strong relationship between herbicides/ insecticides and asthma diagnosis before 5 years of age.

According to our results, diarrhoea and respiratory infections are negatively correlated with different kinds of pesticide sales. Consequently, several studies have reported that pesticide exposure negatively affects the diarrhoea and respiratory systems[16,17]. Apart from these, Hoppin et al.[18] reported correlation between pesticide exposure and chronic respiratory symptoms and respiratory disease. The epidemiological researches about pesticide exposure in humans and cancer risk have been studied for many years. Accordingly, in our study we have found that pesticide sales are positively correlated with lung cancer. Similar to our findings, several authors documented that pesticide exposure is closely associated with cancer[10]. In contrary to our findings, several reports documented no statistically significant consistent associations between agricultural pesticide use and lung cancer[19]. In particular, women workers are very prone to lung cancer due to pesticide exposures compared to male works[20]. A positive link has also been documented between pesticides and breast or prostate cancers in women and men respectively[20]. Mabuchi et al[21] reported lung cancer among vineyard workers exposed to arsenic-based pesticides. There is also a positive relationship between different pesticides sales and musculoskeletal diseases. Results from several studies, support our finding, reported that pesticide exposure positively affects the muscular diseases[16,17]. There is also a negative relationship between different pesticides' sales and cardiovascular diseases. Results from several studies, supported our finding and reported that pesticide exposure negatively affects the cardiovascular diseases[16,17].

The epidemiological researches about pesticide exposure in humans and asthma have been studied for several years. Although in our study we have recorded negative statistically significant association, most epidemiological studies have suggested positive links between agricultural pesticide use and asthma[18,22,23]. Negative correlation between pesticide exposures and asthma could be one of the risk factors among agricultural works to induce other diseases. Recently, it has been demonstrated that pesticides may be an overlooked contributor to asthma risk among farmers[18]. Accordingly, Henneberger et al[23] demonstrated that pesticide exposure plays a vital role in development of allergic asthma among agricultural workers. The negative relationship between COPD and different pesticide sales have also been supported by several studies. Apart from these, the common health risks that the farmers experienced like headache, eye irritation, flue/fever, skin infection/rash, dryness of throat, nausea and vomiting, dizziness, abdominal pain, sleeplessness, and other respiratory disorders[10]. Additionally, genotoxic effects of pesticide (organochlorine pesticides, organophosphorus pesticides, carbamate and pyrethroid pesticides) exposure on farmers have been reported by several authors[24–26]. Lerro et al[27] reported alteration in thyroid function as reproductive effects after long-term exposure to aldrin, pendimethalin and methyl bromide due to occupational exposure among male pesticide applicators. Waheed et al[28] reported that dust contaminated with pesticides engenders significant health risk particularly related to the nervous and endocrine system, not only for occupational farm-workers exposed to direct ingestion, but also for nearby residential community. Considering the abovementioned environmental hazards of pesticide exposure, it is very much necessary to improve the farmer's knowledge with the help of existing regulatory approaches. Further, providing training for farmers about ways to burn or to dispose of pesticide containers, how to use it, what precautionary approaches

should be taken to improve the knowledge. As occupational and safety requirements and trainings are helpful to promote occupational safety and health issues in workplace.

Conclusion

Present analyses demonstrated the relationship between health risk and pesticide sales in regards to protection of human health. The result showed that pesticides have an adverse effect on human health of agricultural workers. The findings also highlighted the necessity of association between community development policies and programs. Lack of necessary education and training in different methods of pesticides application has aggravated the health condition more severe. Farmers should be informed and educated about misuse, no-use of protective clothing during application, comply with personal hygiene, overdose and unnecessary duplication, exposure and contacting to chemicals. Additionally, proper monitoring of occupational exposure by the regulatory agencies is necessary to minimize the adverse health effects of pesticides. Prohibited (such as DDT) and restricted hazardous chemicals should be banned effectively. The excessive use of pesticides should be minimized by policy regulation such as biological pest management and good agricultural practices such as organic farming, biological farming, regenerative agriculture and permaculture, *etc*. Finally, the findings of the present study necessitate the importance of occupational health program for surveillance of health among farmers to reduce the toxic hazards of these pesticides.

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Declaration of Competing Interest

The authors declare no competing interests.

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