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PEER REVIEWED ARTICLE

Increasing Pesticide Use and Knowledge of the Health Effects of Endocrine Disrupting Chemicals in the Environment: A Study of Three Communities in Ghana

Benjamin Ason[1, 2]

University of Cape Coast, Cape Coast, Ghana
Council for Scientific and Industrial Research, Accra, Ghana

and

David Kofi Essumang[3]

University of Cape Coast, Cape Coast, Ghana

Abstract

Population growth and urbanisation are contributing to the growth of the use of pesticides in Africa. However, poor understanding of the health and environmental effects of these chemicals represents a significant risk to both human health and ecosystems. Knowledge of health effects of pesticide use and endocrine disrupting chemicals (EDCs) was assessed using 300 respondents in three communities of Ghana. The data were fitted to bivariate and multivariate ordinary least squares regression models. About 76 per cent of the respondents used pesticides while

1 soilresearchbenn@gmail.com Department of Chemistry, School of Physical Science, College of Agriculture and Natural Sciences, University of Cape Coast, Cape Coast, Ghana

2 Soil Research Institute, Council for Scientific and Industrial Research, Accra, Ghana

3 kofiessumang@yahoo.com Department of Chemistry, School of Physical Science, College of Agriculture and Natural Sciences, University of Cape Coast, Cape Coast, Ghana

82 per cent had no knowledge of human diseases associated with pesticide use and EDCs. At the bivariate level, individuals who used pesticides had less knowledge of health effects of EDCs and pesticide use compared to their counterparts who did not use pesticides. Urban residents had more knowledge compared to rural dwellers and this robust relationship persisted at the multivariate level. Females of all ages had more knowledge of pesticides and EDCs' effects than their male conterparts. Formal and informal education is required to improve knowledge on appropriate chemical use.

Keywords: knowledge; endocrine disruptors; pesticides; environment; urbanisation; population growth.

Introduction

Hormone mimicking substances referred to as endocrine disrupting chemicals (EDCs) comprise a wide variety of environmental contaminants including pesticides, pharmaceuticals, metals, industrial chemicals and natural compounds (Foster, 2001; Choi et al., 2004). EDCs interfere with metabolic functions that are responsible for homeostasis, reproduction and developmental processes (Thomas Zoeller et al., 2012; Diamanti-Kandarakis et al., 2009).

Studies indicate an adverse effect of this group of substances when found in food, consumer products and the environment (Frye et al., 2012; Kumar et al., 2020; Yilmaz et al., 2020). As early as the 1930s, the ability of both natural and synthetic chemicals to interact with endogenous hormone receptors was already well established (Marty et al., 2011). However, most individuals are unaware of the health risks. EDCs have such subtle effects that they may be extremely difficult to detect instantly and yet have significant impacts on human health over an extended time period where they remain 'out of sight out of mind'.

Despite significant advances in understanding of EDCs, gaps still exist in the knowledge required to protect humans that cannot be overlooked. For example, exposure of an adult to EDCs may have very different consequences compared to exposure of a developing foetus or infant. Similarly, there is a lag between the time of exposure and the manifestation of a disorder (Arendrup et al., 2018; Heindel and Vandenberg, 2015). Effects of EDCs may also be additive or even synergistic (Diamanti-Kandarakis et al., 2009; Bergman et al., 2012). Indeed, any level may cause endocrine or reproductive abnormalities if exposure is during a critical developmental period (Sisk et al., 2016; Diamanti-Kandarakis et al., 2009). Humanity as a whole, and Africa in particular, is faced with activities that make it susceptible to the effects of EDCs (Bornman et al., 2017). Lack of sound management of chemicals as well as poor hazardous waste disposal systems pose risks to human health (Taherzadeh et al., 2019).

Demographic changes have considerable influence on consumption patterns through population growth, urbanisation and lifestyle changes. These factors principally influence the demand for chemicals and products that contain EDCs, further increasing the likelihood of human exposure (WHO, 2018). Additionally, developing countries seem to attract the development of economic sectors that are among the most polluting (UNEP, 2012). Africa is faced with rural to urban migration by its youths in search of jobs due to rapid population growth (Moses et al., 2017; Mutandwa et al., 2011) with accompanying shifts in lifestyle and consumption patterns (Cockx et al., 2018). The shift to urban living in Africa and other developing countries continues to increase the amount of contaminants and EDCs released into water, air and soil (Miller et al., 2016). Moreover, high rates of population growth also result in inadequate investment in human capital: education, health, employment, infrastructure and poor waste disposal systems (Ganivet, 2020) which exacerbate the problems associated with the increased use of EDCs.

Africa has the fastest-growing rate of population, which is directly related to the growth in size and intensity of agricultural production (United Nations, 2019). The use of pesticides has increased in an attempt to increase food production in response to increased demand from population growth whilst reducing poverty. This trend is exacerbated by urbanisation, which leads to a continuous decline in the available area of agricultural land through housing, fully-fledged industry, cottage industry and the provision of other social amenities.

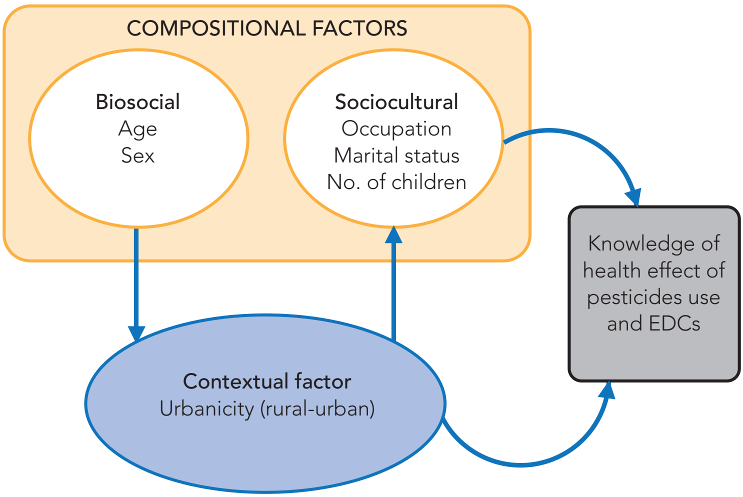
In Ghana, pesticides applied in agriculture for pest control constitute a widely used category of EDCs (Denkyirah et al., 2016; Dinham, 2003; Mattah et al., 2015). Dinham (2003) estimated that 87 per cent of Ghana’s vegetable farmers use chemical pesticides for pest and disease control. There are also indications of adverse effects on productivity, environment and human health due to overuse and misuse of pesticide in Ghana (Denkyirah et al., 2016; Gerken et al., 2001; Mattah et al., 2015). Farmers and consumers are also faced with health problems from the effect of these chemicals (Owusu-Boateng and Amuzu, 2013; Ntow et al., 2006). This puts every Ghanaian at risk and thus there is a need to properly regulate use.

The Government of Ghana has enacted standards aimed at regulating imports of pesticides and ensuring their proper use; however the use of pesticides by individuals remains difficult to control (Onwona Kwakye et al., 2019). Illiteracy and apathy of farmers about the health risks and environmental implications results in greater reliance on chemically-synthesised pesticides and increased use of cheap, mislabelled and adulterated pesticides in Ghana (Onwona et al., 2019; Imoro et al., 2019). Furthermore, rural poor who are employed to work as farm hands, and also smallholder farmers, fail to wear protective equipment and observe good agricultural practices (Wumbei et al., 2019).

Despite the reported adverse health effects of pesticides and EDCs, public awareness is low in Ghana. In 2019, the Government of Ghana launched the Health and Pollution Action Plan (HPAP), seeking to regulate EDCs and other types of pollutants that affect human health in an effort to sensitise the public and regulate the use of EDCs.

Despite advances made, few studies exist on exposure and perception of communities. Community perception is important as it underpins behavioural responses to the adverse health effects of exposure to pesticides. This study looks at general pesticide use and public understanding of health effects of EDCs in three communities in Ghana in the context of the changes in lifestyles of urban and peri-urban dwellers. Though the use of pesticides, personal care products and other chemicals cannot be done away with entirely, it is imperative to ensure their proper use. Pesticide use within three communities of Ghana and knowledge of the health effects of EDCs on humans and the environment is conceptualised as being composed of three main factors – biosocial, sociocultural and contextual factors, as shown in Figure 1. Biosocial factors (age and sex) are intrinsically personal. These personal attributes are ascribed at birth and not easily amenable to change (Pol and Thomas, 2013). The second set of compositional factors, namely sociocultural attributes, reflects the position of individuals within the social structure. These attributes are achieved rather than ascribed. Further, these attributes are inherently 'cultural', in that those affected take on characteristics assigned by society (Pol and Thomas, 2013). Some cultural and nature-based practices that protected rural people from excessive exposure to EDCs are being phased out through urbanisation. For instance, in the rural setting, food was cooked and served in earthenware bowls; however with rural-urban drift and increased population, food is mostly served in plastic packs that may contain chemicals that are endocrine disrupting.

Figure 1. Conceptualisation of the relationship between Knowledge of health effect of EDCs and compositional and contextual factors.



Material and methods

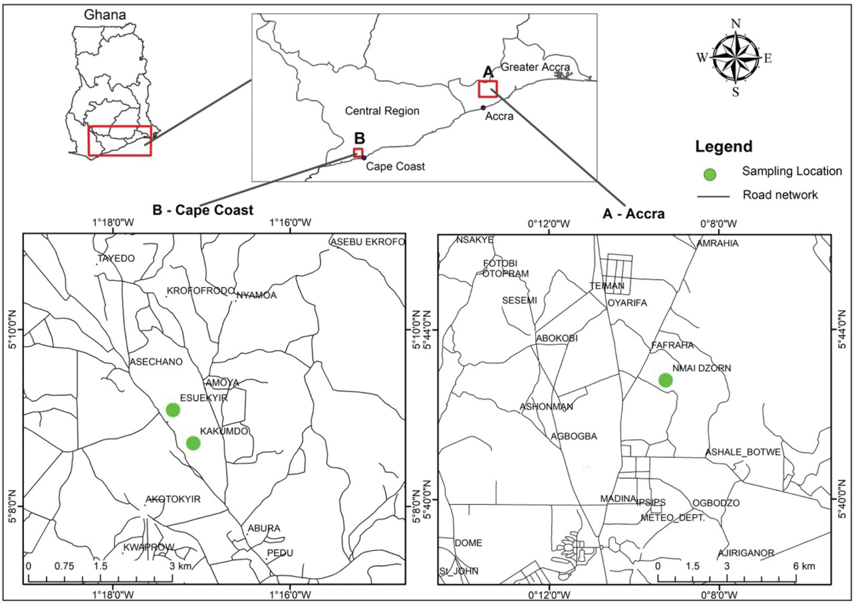
Study area

This study was conducted in three communities in two different regions of Ghana. Two communities, Kakumdo and Essuekyir, are in the Central Region and the third, Nmai Dzorn, in Greater Accra Region. Kakumdo and Essuekyir are adjoining communities within the Cape Coast metropolis with Cape Coast as the regional capital. The Cape Coast Metropolitan area is one of the oldest districts in Ghana and is bounded to the South by the Gulf of Guinea. It occupies an area of approximately 122 square kilometres, with the farthest point at Brabedze located about seventeen kilometres from the regional capital (Ghana Statistical Service, 2010). The population of the

Cape Coast Metropolis, according to the 2010 Population and Housing Census, is 169,894 representing 7.7 per cent of the region's total population. Males constitute 48.7 per cent and females 51.3 per cent (GSS, 2010).

The metropolis has a few rivers and streams including its major waterway, the Kakum. This serves as the main source of water for domestic and industrial purposes. Kakumdo and Essuekyir take their names from the river Kakum that separates the communities. Kakumdo means 'on' the Kakum and Essuekyir means 'behind the river' in the local Fante dialect and indicates their location. They are at outskirts of the regional capital, about eight kilometres from the Cape Coast castle and close to one of the forest reserves of Ghana (Kakum National Park). These communities are mainly residential and can be classified as peri-urban. The inhabitants are mostly traders, artisans and peasant farmers.

Figure 2. Map of Ghana showing regions, districts and study area.



Our third study area, Nmai Dzorn, is an urban community within the Adentan Municipality. The population of Adentan Municipality, according to the 2010 Population and Housing Census, is 78,215. Males constitute 50.3 per cent and females 49.7 per cent. The Total Fertility Rate (TFR) for the metropolis, at 2.2, is the lowest in the Greater Accra Region. The Adentan Municipal Assembly, with Adentan as the Central Business District, lies ten kilometres to the Northeast of Accra and it is specifically located on latitude 5' 43" north and longitude 0' 09" west. The Municipality has a land area of about 928.4 sq. km. (GSS 2010). It is mainly a residential area with few commercial activities. These communities were selected to represent the lifestyles of individuals in urban and peri-urban setting.

Data collection

Respondents who volunteered for and participated in the study were drawn from three different communities made up of homogeneous and heterogeneous localities in terms of ethnic and cultural diversity. Residents who were of sound mind, either household heads or their wards, were selected to participate in the study. Respondents who migrated to their current location less than a year before were classified based on their former place of residence. In all 300 participants were selected randomly and interviewed. The sample consisted of 211 females and 89 males between the ages of eighteen and fifty. Modified Cochran formula for sample size calculation at 95 per cent confidence level was used (Bartlett et al., 2001)inadequate, or excessive sample sizes continue to influence the quality and accuracy of research. This manuscript describes the procedures for determining sample size for continuous and categorical variables using Cochran's (1977, as shown in equations (1) and (2).

$$\mathrm{n} = \frac{n_0}{1 + \frac{(n_0 - 1)}{\mathrm{N}}} \quad \text{.............................} \ (1)$$

Where n_0 is Cochran's sample size recommendation,

N is the population size, N= 1350

n is the new, adjusted sample size.

n_0 is Cochran's sample size recommendation, n_0 =385

Considering the target population of 1350 households, equation (2) was used to determine sample size.

385 / (1 + (384 / 1350)) = 300 .... (2)

The questionnaire was tested before it was administered after approval from the ethical clearance review committee of the Ghana Medical Association, due to the sensitive nature of some of the questions.

Stratified surveys, informal interviews and individual interviews were used to gather information about the prevalence of pesticide use and the level of awareness of EDCs. Stratified sampling was used to select the proportion of male to female interviewees based on the health impact of EDCs on gender. Informal and individual interviews dealt with the interviewee's pesticide use and level of awareness of EDCs. The questionnaire focused on four thematic data areas: (1) personal information; (2) knowledge of the effects of EDCs by listing possible diseases; (3) lifestyle change, i.e. nutrition, social life and work history; and (4) possible reproductive irregularities (though it was not used as an indication of possible EDC effects).

Knowledge on the specific adverse health effects associated with exposure to EDCs and pesticides was measured using a 5-point Likert scale. Responses to the questions were: strongly disagree, disagree, neutral, agree and strongly agree. A Likert scale is composed of a series of four or more Likert-type items that represent similar questions (adverse health outcomes) combined into a single composite score/variable. Likert scale data can be analysed as interval data, i.e. the mean is the best measure of central tendency (Sullivan and Artino, 2013).

Other questions were a combination of closed and open-ended questions in a multiple choice format so that respondents had to select 'yes' or 'no' as an answer. However, some questions demanded explanation for the answer. The questionnaire was administered to the general public by the principal investigator at various locations, including homes, churches/mosques and schools. The objectives of the study were explained to the respondents and their consent to participate in the study was obtained. Respondents were at liberty to withdraw from the study any time they felt they could not respond to sensitive questions. In instances where respondents were not English language literate, the questions were translated into a local language understood by the interviewee without altering their original meaning. In situations where the principal investigator could not speak the preferred local language of the respondent, an interpreter was employed. The identities of respondents were coded and data recorded manually. Respondents' knowledge of human health effects of pesticide use and

EDCs were gathered based on whether they agreed, were unaware or disagreed with indicated human related diseases.

Statistical analysis

Data collected were first cleaned to eliminate double entries, missing values and other irregularities. Inferential and multivariate techniques were applied to examine the relationship between knowledge of the health effects of EDCs and pesticide use while controlling for theoretically relevant sociocultural and biosocial variables using STATA 13SE software. The ordinary least square technique was employed for the analysis. Analyses were preceded by diagnostic tests to establish whether variables met the assumptions of the regression model. Univariate analysis of the predictors on each of the questions that measured knowledge of health effect of EDCs was operationalised using Pearson's Chi-square statistics. Bivariate analysis was initially performed to examine zero-order correlations between the dependent variable and theoretically relevant independent variables. A further three models were employed for the data analysis. Model 1 is Bivariate and biosocial factors, model 2 comprises Bivariate, biosocial and sociocultural factors and model 3 is Bivariate, biosocial, sociocultural and contextual factors. The analysis has a hierarchical structure with respondents nested within survey clusters, which could potentially bias the standard errors. STATA 13 SE (Stata Corp, College Station, TX, USA), which has the capacity to address this problem, is used by imposing on our models a 'cluster' variable – that is, the identification numbers of respondents at the cluster level. This in turn adjusts the standard errors (SE), producing statistically robust parameter estimates. Multivariate models were estimated to explore the net effects of the predictor variables using the stepwise selection approach. For analytical purposes, the unstandardised regression coefficients were estimated. Positive coefficients for any of the predictors indicate higher knowledge of the health effects of EDCs and pesticide use while negative coefficients show lower knowledge of the health effects of EDCs and pesticide use.

Results

Relationship between knowledge of health effects of pesticides and EDCs and demographic attributes

The distribution of responses on knowledge of health issues associated with the use of pesticides and EDCs is shown in the appendices. Pesticide use is widespread in the communities; 76 per cent of the respondents interviewed used pesticides, though there were differences in the way the pesticides were actually employed. The majority of the respondents (82 per cent) had no knowledge of the health effects of pesticides use and EDCs. The remaining eighteen per cent demonstrated they had some knowledge relating to one or more human diseases, mostly cancers. Different age groups of respondents showed varied levels of knowledge with respect to cancers while married respondents also demonstrated more knowledge of health effects of EDCs with respect to cancers only. The results show that higher percentages of males (48 per cent) know that pesticide use and EDCs could lead to prostate cancer and other forms of cancers than their female (22 per cent) counterparts. Only one per cent of males and four per cent of females know that pesticides and EDCs could lead to behaviour disorders. A few individuals, eleven per cent of the 82 per cent with no knowledge, had doubts about possible adverse health effects and disagreed with the notion that pesticide use and EDCs could cause diseases.

Table 1 shows zero-order relationships between the explanatory variables and knowledge of health effects of endocrine disruptors and pesticide use. Individuals who use pesticides had less knowledge of the health effects of EDCs and pesticides compared to their counterparts who did not use pesticides. There were differences in the knowledge that pesticide use could disrupt the function of the endocrine system based on age groups. The younger respondents had greater knowledge of health risks than the older counterparts. Individuals above 45 years were less knowledgeable about the health effects of EDCs than respondents in the 15–25 age groups. Similarly, females had more knowledge of the health effects than their male counterparts. The evidence demonstrates that urban dwellers have greater knowledge of the health effects than respondents in rural communities. Unmarried individuals were also more aware than married respondents as indicated in Table 1. Robust standard errors used accounted for heteroskedasticity in the model's unexplained variation.

Table 1. Bivariate OLS regression model of the relationship between knowledge of health effects of Endocrine disruptors and pesticide use, and compositional and contextual factors.

Variables	Coef.	Std. Error	p-value	[95% Conf. Interval]	
Pesticide use (ref: No)					
Yes	-0.338	0.135	**0.013**	-0.602	-0.073
Age (ref:15–25 years)					
26–35 years	0.003	0.153	0.982	-0.299	0.306
36–45 years	0.080	0.155	0.606	-0.229	0.385
Above 45 years	-0.350	0.173	**0.043**	-0.690	-0.010
Gender (ref: male)					
Female	0.621	0.121	**0.000**	0.3817	0.860
Marital Status (ref: not married)					
Married	-0.459	0.113	**0.000**	-0.681	-0.238
Children (ref: No Child)					
1–3 children	0.134	0.130	0.302	-0.121	0.390
4–5 children	-0.115	0.175	0.511	-0.460	0.229
Above 5 children	-0.449	0.240	0.058	-0.913	0.016
Occupation (ref: unemployed)					
Self-employed	-0.149	0.133	0.263	-0.410	0.112
Formally employed	0.052	0.190	0.786	-0.323	0.427
Residence (ref: Rural)					
Urban	0.369	0.148	**0.013**	0.078	0.660

The multivariate model (Table 2) shows that gender was a significant predictor of knowledge of the health effects of EDCs, even when socioeconomic and contextual factors were taken into account. However, the relationship between pesticide use and knowledge was not robust and disappeared, indicating that biosocial and contextual factors completely mediated the relationship. Females of all ages had greater knowledge of the effects of pesticide use and EDCs than their male counterparts. Unmarried women demonstrated more knowledge of health effects of pesticides and EDCs than their married counterparts and remained statistically significant; however, it was not robust when contextual factors were taken into account. The age group of 36–45 years was significant in model 2, though not in model 1, signifying a suppressed relationship between biosocial factors and knowledge of health effects of pesticides. Suppression occurred when the relationship between an independent variable and the dependent variable was increased following the statistical removal of variance associated with a third variable.

The place of residence of respondents was significant when all factors were considered, indicating that it fully mediates the relationship between compositional variables and knowledge of the health effects of pesticides. This shows the effect that the independent variable has on the dependent variable via its association with a third variable. Urban residents had higher levels of knowledge of health effects of EDCs and pesticide use compared to rural dwellers and this robust relationship persisted when sociocultural and biosocial variables were introduced.

Discussion

The vast majority of the respondents (82 per cent) were ignorant of the diseases associated with pesticide use and EDCs, which is comparable to a similar study conducted by Hui et al. (2017). This is attributed mainly to poor information dissemination and regulatory policy. Our research shows that people who knew more about pesticide toxicology were less likely to use pesticides. Other studies, such as Dasgupta and Meisner (2005), Gesesew et al., (2016) and Sabran and Abas (2021), also support our observation. We also found that, besides the relationship between pesticide knowledge and use behaviour, there were other individuals who did not use pesticides simply because they could not afford them and/or they preferred natural methods of pest control.

Table 2. Multivariate regression model of the relationship between knowledge of health effects of endocrine disruptors and pesticide use, compositional and contextual factors.

	Model 1 (pesticide use + biosocial factors)					Model 1+ socioeconomic					model 2 + contextual				
Variables	Coef.	Std. Error	p-value	[95% Conf. Interval]		Coef.	Std. Error	p-value	[95% Conf. Interval}		Coef.	Std. Error	p-value	[95% Conf Interval]	
Pesticide use (ref: No)															
Yes	-0.197	0.134	0.141	-0.461	0.066	-0.161	0.133	0.225	-0.422	0.100	0.131	0.130	0.316	-0.388	0.126
Age (ref:15–25 years)															
26–35 years	0.111	0.150	0.458	-0.184	0.406	0.161	0.176	0.363	-0.186	0.507	-0.011	0.180	0.952	-0.365	0.344
36–45 years	0.269	0.155	0.083	-0.035	0.573	0.407	0.203	**0.046**	0.008	0.807	0.239	0.205	0.246	-0.165	0.643
Above 45 years	0.299	0.185	0.871	-0.334	0.394	0.278	0.250	0.267	-0.214	0.769	0.089	0.251	0.724	-0.406	0.583
Gender (ref: male)															
Female	0.602	0.139	**0.000**	0.329	0.875	0.487	0.147	**0.001**	0.198	0.776	0.542	0.145	**0.000**	0.256	0.828
Marital Status (ref: not married)															
Married						-0.496	0.151	**0.001**	-0.792	-0.200	-0.473	0.148	**0.002**	-0.764	-0.182
Children (ref: No Child)															
1–3 children						0.328	0.160	**0.042**	0.012	0.643	0.243	0.160	0.129	-0.070	0.556
4–5 children						0.974	0.219	0.656	-0.333	0.528	0.088	0.215	0.683	-0.335	0.511
Above 5 children						-0.075	0.280	0.790	-0.625	0.476	-0.098	0.275	0.722	-0.638	0.443

Table 2. continued

Occupation (ref: unemployed)										
Self employed	-0.019	0.165	0.907	-0.344	0.306	-0.053	0.162	0.743	-0.373	0.266
Formally employed	0.097	0.203	0.635	-0.303	0.496	0.042	0.200	0.834	-0.351	0.435
Residence (ref: Rural)										
Urban						0.559	0.162	**0.001**	0.239	0.879

There is no coordinated plan to evaluate and disseminate information on health and environmental effects of chemicals that are endocrine disrupting in nature. The government, in a bid to address this challenge, launched the Health and Pollution Action Plan (HPAP) that seeks to regulate EDCs and other types of pollutants affecting human health with the aim of sensitising individuals to the effects of EDCs. Dinham (2003), indicated that low level of knowledge and how pesticides are handled hinder the overarching goal of protecting human health and the environment from the adverse effects of EDCs. Knowledge gaps that exist are too important to overlook considering the low dose effect and time lapse between exposure and development of disease later in life. The current 76.3 per cent prevalence of synthetic pesticide use is partly attributed to ignorance of health effects as well as urbanisation and its associated problems. Several studies have reported improper use of pesticides and disposal of waste from EDCs (Amoako et al., 2014; Onwona Kwakye et al., 2019; Oteng-Ababio, 2012; Wumbei et al., 2019. For example, spraying household pests when food and cooking utensils are not properly covered, spraying pests without proper Personal Protective Equipment (PPE) and individuals not properly washing themselves after use of pesticides are some of the behaviours that predispose individuals to the various health effects. There is a lack of sound management of chemicals for industrial, agricultural and household use as well as poor hazardous waste disposal systems. This results in high levels of pesticide residues within the environment, thereby posing a risk to humans and the environment.

The finding that females of all ages are more knowledgeable about the effects of pesticide use and EDCs than their male counterparts was difficult to assign a specific reason. Females are generally provided with information on EDCs and pesticides during pregnancy as part of health education during antenatal care. Antenatal care is one of the three most important forms of welfare provided to women during pregnancy (Choi et al., 2004) to keep mother and unborn child safe. Pregnancy is a sensitive window for toxicant exposure and EDCs are of particular significance to pregnant women, since foetal development is sensitive to maternal nutritional, chemical and environmental stressors. EDCs may disrupt the maternal immune system, which may lead to poor pregnancy outcomes (Kelley et al., 2019). In Ghana, two-thirds of women who utilise antenatal care received information about the danger signs of pregnancy complications (Wang et al., 2011) and hospitals and health centres have served as one of the main sources of information on the adverse health effects of EDCs and pesticide use. Again, healthcare facilities and the provision of services are improved in the urban centres compared to rural areas. It therefore showed that individual female respondents who lived in the urban centres have more knowledge than their counterparts in the rural areas as a result of the better provision of healthcare (and hence antenatal care) in the urban centres compared to rural areas. This is supported by studies that revealed the existence of urban-rural differences and regional disparities between providers of antenatal care services (Afulani, 2015; Abor et al., 2011).

Study Limitations

Questionnaires have the advantage of quick, cheap and easy administration and can be crafted to capture specific items, aiming at evaluating knowledge, attitudes and perceptions. One obvious limitation of questionnaires is that they are subject to social desirability bias. There is also the likelihood of response bias in this study. Response bias is a widely discussed phenomenon in behavioural and healthcare research where self-reported data are used; it occurs when individuals offer self-assessed measures of some phenomenon (Rosenman et al., 2011), in this case diseases associated with pesticide exposure. Educational attainment of the respondents was not included in this study.

Conclusion

Demographic changes in the form of population growth, rural to urban migration and changes in lifestyle have had a considerable influence on the consumption of pesticides and EDCs. In particular, population growth and urbanisation have influenced the increase in the use of these chemicals in agriculture in order to increase yields. As the population becomes increasingly urban, some cultural and nature-based practices that protected rural people from excessive exposure to EDCs are being lost. Furthermore, unsustainable population growth has exacerbated the effects of insufficient investment in education, health, employment, infrastructure and poor waste disposal systems, increasing the vulnerability of people and ecosystems to the effects of pesticides and EDCs.

This study revealed low levels of knowledge of the health effects of endocrine disrupting chemicals among the three communities, especially amongst those in rural areas where pesticides are widely used. Indeed, it showed some individuals to be dismissive of any possible adverse health effects. Considering the low dose effect and the time-lapse between exposure and development of disease later in life, these knowledge gaps cannot be ignored.

Recommendation

Practical and effective measures are needed to reverse this disturbing trend among the populace. A coordinated plan is required to evaluate and disseminate information on health and the environmental effects of chemicals that are endocrine disrupting in nature. The Ghanaian government's Health and Pollution Action Plan (HPAP) seeks to regulate EDCs and other types of pollutant that affect human health; however there is also the need for an integrated and coordinated effort to define the role of pesticides and other EDCs in human health. Health institutions must be encouraged to scale up education on the adverse health effects of pesticides and other endocrine disrupting chemicals that have become part of everyday life.

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Appendix

Appendix 1.Knowledge of behaviour disorders due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 22.1551 Pr = 0.036
15–25yrs	5.81	8.14	84.88	0	1.16	Cramér's V = 0.1569
26–35yrs	13.58	16.05	69.14	0	1.23	
36–45yrs	7.59	6.33	81.01	3.8	1.27	
Above 45 yrs	11.11	20.37	62.96	5.56	0	
Gender						Pearson chi2(4) = 10.2952 Pr = 0.036
Male	3.37	8.99	86.52	0	1.12	Cramér's V = 0.1852
Female	11.85	13.27	71.09	2.84	0.95	
Marital Status						Pearson chi2(4) = 3.7965 Pr = 0.434
Not married/divorced	8.78	12.16	75.68	1.35	2.03	Cramér's V = 0.1125
Married	9.87	11.84	75.66	2.63	0	
Parity						Pearson chi2(12) = 19.8910 Pr = 0.069
No child	4.42	9.73	84.96	0	0.88	Cramér's V = 0.1487
1–3 children	14.05	13.22	69.42	1.65	1.65	

Appendix 1. continued

4–5 children	6.67	11.11	75.56	6.67	0	
Above 5 children	14.29	19.05	61.9	4.76	0	
Occupation						Pearson chi2(8) = 10.8447 Pr = 0.211
Unemployed	8.33	10.71	80.95	0	0	Cramér's V = 0.1344
Self employed	11.43	13.14	70.86	3.43	1.14	
Formal employment	2.44	9.76	85.37	0	2.44	
Vocation						Pearson chi2(20) = 40.1141 Pr = 0.005
Unskilled labour	20.83	20.83	50	0	8.33	Cramér's V = 0.1828
Farmer	5.66	15.09	79.25	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	18.75	3.13	75	3.13	0	
Student	6.25	7.81	85.94	0	0	
Others	8.47	14.41	72.03	4.24	0.85	

Appendix 2. Knowledge of cancer due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 41.0911 Pr = 0.001
15–25yrs	0	2.33	69.77	25.58	2.33	Cramér's V = 0.2137
26–35yrs	6.17	2.47	44.44	44.44	2.47	
36–45yrs	3.8	3.8	39.24	40.51	12.66	
Above 45 yrs	7.41	5.56	25.93	55.56	5.56	
Gender						Pearson chi2(4) = 7.7957 Pr = 0.099
Male	4.49	2.25	38.2	44.94	10.11	Cramér's V = 0.1612
Female	3.79	3.79	50.71	37.91	3.79	
Marital status						Pearson chi2(4) = 13.0682 Pr = 0.011
Not married/divorced	2.7	2.03	56.76	35.14	3.38	Cramér's V = 0.2087
Married	5.26	4.61	37.5	44.74	7.89	
Parity						Pearson chi2(12) = 49.3734 Pr = 0.001
No child	2.65	2.65	61.06	30.97	2.65	Cramér's V = 0.2342
1–3 children	4.13	0.83	38.02	49.59	7.44	

Appendix 2. continued

4–5 children	8.89	2.22	42.22	40	6.67	
Above 5 children	0	23.81	33.33	33.33	9.52	
Occupation						Pearson chi2(8) = 44.3064 Pr = 0.001
Unemployed	0	2.38	69.05	26.19	2.38	Cramér's V = 0.2717
Self employed	2.86	4.57	39.43	45.71	7.43	
Formal employment	17.07	0	34.15	43.9	4.88	
Vocation						Pearson chi2(20) = 67.0732 Pr = 0.001
Unskilled labour	0	12.5	41.67	45.83	0	Cramér's V = 0.2364
Farmer	0	3.77	28.3	54.72	13.21	
Sanitary worker	22.22	0	55.56	22.22	0	
Beautician	9.38	3.13	53.13	28.13	6.25	
Student	0	1.56	78.13	18.75	1.56	
Others	5.93	2.54	37.29	48.31	5.93	

Appendix 3. Knowledge of cardiovascular disease due to pesticide use and EDC. (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 28.3227 Pr = 0.005
15–25yrs	1.16	2.33	81.4	13.95	1.16	Cramér's V = 0.1774
26–35yrs	6.17	2.47	75.31	16.05	0	
36–45yrs	0	8.86	72.15	18.99	0	
Above 45 yrs	5.56	18.52	61.11	12.96	1.85	
Gender						Pearson chi2(4) = 19.7412 Pr = 0.001
Male	2.25	10.11	85.39	2.25	0	Cramér's V = 0.2565
Female	3.32	5.69	68.72	21.33	0.95	
Marital status						Pearson chi2(4) = 10.9754 Pr = 0.027
Not married/divorced	3.38	3.38	71.62	20.95	0.68	Cramér's V = 0.1913
Married	2.63	10.53	75.66	10.53	0.66	
Parity						Pearson chi2(12) = 17.0215 Pr = 0.149
No child	1.77	3.54	81.42	12.39	0.88	Cramér's V = 0.1375
1–3 children	4.96	7.44	69.42	18.18	0	

Appendix 3. continued

4–5 children	2.22	11.11	71.11	15.56	0	
Above 5 children	0	14.29	61.9	19.05	4.76	
Occupation						Pearson chi2(8) = 6.9335 Pr = 0.544
Unemployed	1.19	2.38	79.76	15.48	1.19	Cramér's V = 0.1075
Self employed	4	8.57	70.29	16.57	0.57	
Formal employment	2.44	9.76	75.61	12.2	0	
Vocation						Pearson chi2(20) = 44.7750 Pr = 0.001
Unskilled labour	4.17	20.83	54.17	20.83	0	Cramér's V = 0.1932
Farmer	3.77	15.09	81.13	0	0	
Sanitary worker	0	11.11	88.89	0	0	
Beautician	0	0	71.88	25	3.13	
Student	0	1.56	82.81	14.06	1.56	
Others	5.08	5.08	68.64	21.19	0	

Appendix 4. Knowledge of diabetes due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 10.2956 Pr = 0.590
15–25yrs	0	4.65	79.07	16.28	0	Cramér's V = 0.1070
26–35yrs	1.23	4.94	66.67	25.93	1.23	
36–45yrs	1.27	5.06	72.15	21.52	0	
Above 45 yrs	0	11.11	70.37	18.52	0	
Gender						Pearson chi2(4) = 29.7047 Pr = 0.001
Male	0	10.11	87.64	2.25	0	Cramér's V = 0.3147
Female	0.95	4.27	65.88	28.44	0.47	
Marital status						Pearson chi2(4) = 9.4117 Pr = 0.052
Not married/divorced	0.68	3.38	68.92	26.35	0.68	Cramér's V = 0.1771
Married	0.66	8.55	75.66	15.13	0	
Parity						Pearson chi2(12) = 20.6875 Pr = 0.055
No child	0	4.42	78.76	15.93	0.88	Cramér's V = 0.1516
1–3 children	0.83	4.13	69.42	25.62	0	

Appendix 4. continued

4–5 children	0	8.89	73.33	17.78	0	
Above 5 children	4.76	19.05	52.38	23.81	0	
Occupation						Pearson chi2(8) = 10.9077 Pr = 0.207
Unemployed	0	4.76	77.38	16.67	1.19	Cramér's V = 0.1348
Self employed	1.14	8	67.43	23.43	0	
Formal employment	0	0	82.93	17.07	0	
Vocation						Pearson chi2(20) = 59.2815 Pr = 0.001
Unskilled	0	16.67	41.67	41.67	0	Cramér's V = 0.2223
Farmer	0	16.98	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	3.13	71.88	21.88	0	
Student	0	3.13	81.25	14.06	1.56	
Others	0.85	1.69	66.95	30.51	0	

Appendix 5. Knowledge of erectile dysfunction due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	1.16	4.65	81.4	12.79	0	Pearson chi2(12) = 25.0491 Pr = 0.015
26–35yrs	6.17	6.17	61.73	24.69	1.23	Cramér's V = 0.1668
36–45yrs	0	11.39	68.35	18.99	1.27	
Above 45 yrs	9.26	14.81	53.7	22.22	0	
Gender						Pearson chi2(4) = 68.5636 Pr = 0.001
Male	11.24	21.35	67.42	0	0	Cramér's V = 0.4781
Female	0.47	3.32	67.77	27.49	0.95	
Marital status						Pearson chi2(4) = 22.9389 Pr = 0.001
Not married/divorced	0.68	3.38	71.62	24.32	0	Cramér's V = 0.2765
Married	6.58	13.82	63.82	14.47	1.32	
Parity						Pearson chi2(12) = 18.6961 Pr = 0.096
No child	1.77	9.73	76.11	12.39	0	Cramér's V = 0.1441
1–3 children	5.79	4.96	63.64	23.97	1.65	

Appendix 5. continued

4–5 children	2.22	11.11	66.67	20	0	
above 5 children	4.76	19.05	47.62	28.57	0	
Occupation						Pearson chi2(8) = 24.3362 Pr = 0.002
Unemployed	0	4.76	78.57	16.67	0	Cramér's V = 0.2014
Self employed	6.29	12.57	58.29	21.71	1.14	
Formal employment	0	0	85.37	14.63	0	
Vocation						Pearson chi2(20) = 135.4692 Pr = 0.000
Unskilled	0	12.5	45.83	41.67	0	Cramér's V = 0.3360
Farmer	18.87	35.85	45.28	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	0	65.63	28.13	3.13	
Student	0	3.13	82.81	14.06	0	
Others	0	1.69	72.03	25.42	0.85	

Appendix 6. Knowledge of decreased fertility due to Pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 33.0513 Pr = 0.001
15–25yrs	1.16	4.65	84.88	9.3	0	Cramér's V = 0.1916
26–35yrs	3.7	9.88	69.14	13.58	3.7	
36–45yrs	0	6.33	77.22	15.19	1.27	
Above 45 yrs	9.26	22.22	61.11	7.41	0	
Gender						Pearson chi2(4) = 19.7209 Pr = 0.001
Male	2.25	12.36	85.39	0	0	Cramér's V = 0.2564
Female	3.32	8.53	69.67	16.59	1.9	
Marital status						Pearson chi2(4) = 9.1725 Pr = 0.057
Not married/divorced	2.7	6.08	73.65	16.22	1.35	Cramér's V = 0.1749
Married	3.29	13.16	75	7.24	1.32	
Parity						Pearson chi2(12) = 19.2801 Pr = 0.082
No child	1.77	3.54	84.96	8.85	0.88	Cramér's V = 0.1464
1–3 children	3.31	10.74	68.6	14.88	2.48	

Appendix 6. continued

4–5 children	4.44	15.56	71.11	8.89	0	
Above 5 children	4.76	23.81	57.14	14.29	0	
Occupation						Pearson chi2(8) = 12.6806 Pr = 0.123
Unemployed	2.38	3.57	83.33	8.33	2.38	Cramér's V = 0.1454
Self employed	4	13.14	68	13.71	1.14	
Formal employment	0	7.32	82.93	9.76	0	
Vocation						Pearson chi2(20) = 42.1876 Pr = 0.003
Unskilled	0	29.17	50	20.83	0	Cramér's V = 0.1875
Farmer	3.77	20.75	75.47	0	0	
Sanitary worker	0	0	88.89	11.11	0	
Beautician	3.13	3.13	75	15.63	3.13	
Student	3.13	3.13	85.94	7.81	0	
Others	3.39	6.78	71.19	16.1	2.54	

Appendix 7. Knowledge of genital problems due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 18.2670 Pr = 0.108
15–25yrs	1.16	8.14	83.72	6.98	0	Cramér's V = 0.1425
26–35yrs	4.94	9.88	76.54	8.64	0	
36–45yrs	2.53	11.39	78.48	6.33	1.27	
Above 45 yrs	11.11	20.37	62.96	5.56	0	
Gender						Pearson chi2(4) = 8.9413 Pr = 0.063
Male	2.25	12.36	84.27	1.12	0	Cramér's V = 0.1726
Female	5.21	11.37	73.46	9.48	0.47	
Marital status						Pearson chi2(4) = 11.2451 Pr = 0.024
Not married/divorced	3.38	9.46	75.68	11.49	0	Cramér's V = 0.1936
Married	5.26	13.82	77.63	2.63	0.66	
Parity						Pearson chi2(12) = 20.2669 Pr = 0.062
No child	1.77	7.08	85.84	5.31	0	Cramér's V = 0.1501
1–3 children	6.61	10.74	71.9	9.92	0.83	

Appendix 7. continued

4–5 children	6.67	17.78	68.89	6.67	0	
Above 5 children	0	28.57	71.43	0	0	
Occupation						Pearson chi2(8) = 10.2229 Pr = 0.250
Unemployed	1.19	8.33	83.33	7.14	0	Cramér's V = 0.1305
Self employed	6.29	14.86	72	6.29	0.57	
Formal employment	2.44	4.88	82.93	9.76	0	
Vocation						Pearson chi2(20) = 37.8179 Pr = 0.009
Unskilled	4.17	25	58.33	12.5	0	Cramér's V = 0.1775
Farmer	3.77	20.75	75.47	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	6.25	3.13	84.38	3.13	3.13	
Student	0	6.25	87.5	6.25	0	
Others	6.78	11.02	71.19	11.02	0	

Appendix 8. Knowledge of miscarriage due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 8.8357 Pr = 0.717
15–25yrs	2.33	5.81	80.23	10.47	1.16	Cramér's V = 0.0991
26–35yrs	2.47	13.58	74.07	7.41	2.47	
36–45yrs	1.27	12.66	74.68	11.39	0	
Above 45 yrs	0	11.11	75.93	12.96	0	
Gender						
Male	1.12	8.99	87.64	2.25	0	Pearson chi2(4) = 11.9498 Pr = 0.018
Female	1.9	11.37	71.56	13.74	1.42	Cramér's V = 0.1996
Marital status						Pearson chi2(4) = 11.4383 Pr = 0.022
Not married/divorced	0.68	9.46	72.97	14.86	2.03	Cramér's V = 0.1953
Married	2.63	11.84	79.61	5.92	0	
Parity						Pearson chi2(12) = 23.3773 Pr = 0.025
No child	0.88	4.42	83.19	11.5	0	Cramér's V = 0.1612
1–3 children	2.48	13.22	72.73	9.09	2.48	

Appendix 8. continued

4–5 children	0	11.11	73.33	15.56	0	
Above 5 children	4.76	28.57	66.67	0	0	
Occupation						Pearson chi2(8) = 9.1385 Pr = 0.331
Unemployed	1.19	7.14	83.33	7.14	1.19	Cramér's V = 0.1234
Self employed	1.71	14.29	72	10.86	1.14	
Formal employment	2.44	2.44	80.49	14.63	0	
Vocation						Pearson chi2(20) = 38.4742 Pr = 0.008
Unskilled	0	29.17	41.67	25	4.17	Cramér's V = 0.1791
Farmer	1.89	15.09	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	12.5	78.13	6.25	0	
Student	1.56	3.13	85.94	9.38	0	
Others	1.69	9.32	72.88	14.41	1.69	

Appendix 9. Knowledge of obesity due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 17.1549 Pr = 0.144
15–25yrs	1.16	2.33	74.42	22.09	0	Cramér's V = 0.1381
26–35yrs	1.23	8.64	67.9	17.28	4.94	
36–45yrs	2.53	6.33	72.15	18.99	0	
Above 45 yrs	3.7	9.26	72.22	14.81	0	
Gender						Pearson chi2(4) = 21.9488 Pr = 0.001
Male	2.25	7.87	86.52	3.37	0	Cramér's V = 0.2705
Female	1.9	5.69	65.4	25.12	1.9	
Marital status						Pearson chi2(4) = 13.8302 Pr = 0.008
Not married/divorced	2.03	3.38	67.57	24.32	2.7	Cramér's V = 0.2147
Married	1.97	9.21	75.66	13.16	0	
Parity						Pearson chi2(12) = 30.0123 Pr = 0.003
No child	0.88	5.31	75.22	18.58	0	Cramér's V = 0.1826
1–3 children	3.31	3.31	69.42	20.66	3.31	

Appendix 9. continued

4–5 children	0	6.67	77.78	15.56	0	
Above 5 children	4.76	28.57	52.38	14.29	0	
Occupation						Pearson chi2(8) = 9.0683 Pr = 0.337
Unemployed	0	7.14	75	16.67	1.19	Cramér's V = 0.1229
Self employed	3.43	7.43	68.57	18.86	1.71	
Formal employment	0	0	78.05	21.95	0	
Vocation						Pearson chi2(20) = 71.8725 Pr = 0.001
Unskilled	0	25	37.5	25	12.5	Cramér's V = 0.2447
Farmer	3.77	13.21	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	0	3.13	75	21.88	0	
Student	1.56	1.56	78.13	18.75	0	
Others	2.54	3.39	66.95	26.27	0.85	

Appendix 10. Knowledge of Prostate cancer due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	1.16	3.49	82.56	10.47	2.33	Pearson chi2(12) = 27.4987 Pr = 0.007
26–35yrs	3.7	6.17	59.26	25.93	4.94	Cramér's V = 0.1748
36–45yrs	1.27	2.53	63.29	27.85	5.06	
Above 45 yrs	1.85	3.7	44.44	40.74	9.26	
Gender						Pearson chi2(4) = 22.3236 Pr = 0.001
Male	1.12	1.12	49.44	40.45	7.87	Cramér's V = 0.2728
Female	2.37	5.21	70.62	18.01	3.79	
Marital status						Pearson chi2(4) = 5.5585 Pr = 0.235
Not married/divorced	2.03	4.05	70.27	18.92	4.73	Cramér's V = 0.1361
Married	1.97	3.95	58.55	30.26	5.26	
Parity						Pearson chi2(12) = 28.0811 Pr = 0.005
No child	1.77	4.42	76.11	14.16	3.54	Cramér's V = 0.1766
1–3 children	2.48	2.48	56.2	33.06	5.79	

Appendix 10. continued

4–5 children	2.22	4.44	66.67	26.67	0	
Above 5 children	0	9.52	42.86	28.57	19.05	
Occupation						Pearson chi2(8) = 26.8001 Pr = 0.001
Unemployed	2.38	3.57	79.76	8.33	5.95	Cramér's V = 0.2113
Self employed	1.71	4.57	53.71	34.86	5.14	
Formal employment	2.44	2.44	78.05	14.63	2.44	
Vocation						
Unskilled	0	12.5	45.83	29.17	12.5	Pearson chi2(20) = 92.0091 Pr = 0.001
Farmer	0	1.89	22.64	64.15	11.32	Cramér's V = 0.2769
Sanitary worker	11.11	0	88.89	0	0	
Beautician	0	6.25	75	12.5	6.25	
Student	3.13	3.13	84.38	6.25	3.13	
Others	2.54	3.39	71.19	21.19	1.69	

Appendix 11. Knowledge of frequent urination due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	2.33	5.81	81.4	9.3	1.16	Pearson chi2(12) = 12.4863 Pr = 0.407
26–35yrs	2.47	12.35	69.14	16.05	0	Cramér's V = 0.1178
36–45yrs	0	8.86	81.01	8.86	1.27	
Above 45 yrs	3.7	16.67	66.67	12.96	0	
Gender						Pearson chi2(4) = 21.4533 Pr = 0.001
Male	0	13.48	86.52	0	0	Cramér's V = 0.2674
Female	2.84	9	70.62	16.59	0.95	
Marital status						Pearson chi2(4) = 8.4988 Pr = 0.075
Not married/divorced	2.7	7.43	72.97	16.22	0.68	Cramér's V = 0.1683
Married	1.32	13.16	77.63	7.24	0.66	
Parity						Pearson chi2(12) = 16.3333 Pr = 0.176
No child	2.65	6.19	81.42	9.73	0	Cramér's V = 0.1347
1–3 children	0.83	13.22	70.25	14.05	1.65	

Appendix 11. continued

4–5 children	0	11.11	77.78	11.11	0	
Above 5 children	9.52	14.29	66.67	9.52	0	
Occupation						Pearson chi2(8) = 14.8234 Pr = 0.063
Unemployed	1.19	5.95	78.57	14.29	0	Cramér's V = 0.1572
Self employed	2.86	14.86	71.43	9.71	1.14	
Formal employment	0	0	85.37	14.63	0	
Vocation						Pearson chi2(20) = 44.9259 Pr = 0.001
Unskilled	0	16.67	50	29.17	4.17	Cramér's V = 0.1935
Farmer	0	22.64	77.36	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	0	12.5	75	9.38	3.13	
Student	3.13	6.25	81.25	9.38	0	
Others	3.39	5.93	74.58	16.1	0	