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Risk Assessment of Applicator Exposure to Pesticides on Cotton Farms in Ghana

Abukari Wumbei
Centre for Continuing Education and Interdisciplinary Research (CCEIR)
University for Development Studies (UDS)
P. O. Box 1350, Tamale, Ghana
Tel: +233244570426, Email: awumbei@uds.edu.gh

ABSTRACT
The efforts of Ghana at increasing and sustaining Agriculture production has resulted in the increasing use of plant protection products (PPP) since the 1960s. The major areas of Ghana's Agriculture sub-sector in which these products are widely used include; the cocoa sector, the vegetables and fruits sector and the cotton sector. The wide spread and indiscriminate use of these products in recent times has drawn public concerns about their human health and environmental impacts. This has resulted in some efforts within the scientific community of Ghana to investigate the levels of these products in the Ghanaian environment, food stuffs and human fluids by way of biological monitoring. This particular study was commissioned to assess the risk of applicator exposure to pesticides on cotton farms in Ghana. Applicator exposure was evaluated by means of modeling, using two well known and recognized exposure models, namely; the UK-POEM and the German model. The results of the study revealed that in the course of applying pesticides on cotton farms in Ghana, farmers are exposed to unacceptably higher levels of some pesticides. The pesticides classes for which these higher exposure levels were observed are; the dien-organochlrine insecticide (endosulfan) and an organophosphate insecticide (chlorpyrifos). For each of the two insecticides the exposure level was higher than the acceptable operator exposure level (AOEL) of 0.006mg/kgBW/day and 0.01mg/kgBW/day respectively. This exposure levels equally resulted in higher risk to applicators. For the other pesticides considered in this study, including; a neonicotinoid (acetamiprid) and pyrethroids (cypermethrin and λ-cyhalothrin), the exposure levels were below the AOEL of 0.07mg/kgBW/day, 0.05mg/kgBW/day and 0.003mg/kgBW/day respectively. Hence there was less risk in using the latter group of pesticides. It was also observed that there is high risk in applying pesticides on cotton farms during the late season than during the early season.
Key Words: Pesticides, Exposure, Applicator, Cotton Farms, Ghana

1. INTRODUCTION

Agriculture is still the major economic sector in Ghana accounting for a 44% share of the GDP in 1990 and 37% in 2005 (MoFA, 2007). The sector employs around 60% of the work force, and accounts for 40% of the total exports. It is practiced mainly on small-scale farms of less than two hectares (2ha), as a combination of cash alongside subsistence crops. Agricultural growth in Ghana increased from about 4% in 2000 to 6% in 2005 (MoFA, 2007). It is expected that export performance can be improved via non-traditional exports, particularly horticulture. The promotion of these non traditional crops is based on increasing productivity through the use of improved varieties and crop protection measures including the use of pesticides (Ezeria M., 2002).

The objectives of the agricultural sector of Ghana are to increase production on a sustainable basis, to improve storage and processing at the farm level, to organize better marketing locally and internationally and to promote non-traditional export crops and processing of raw products in Ghana. The intensification and structural changes in Ghana's agriculture production over the years are linked with increased use of pesticides. Since a good part of production is lost through diseases in the field and storage, to policy makers, the increased use of inputs like fertilizers and agro-chemicals seems often to be one of the most effective ways to increase agriculture production and food supply (Gerken A. *et al*, 2001).

Among the areas that pesticides are intensively used in Ghana's agriculture are: the cocoa sector in the south, the vegetables sectors in the north and south and the cotton sector in the north. Cotton is indeed one of the export crops from which Ghana earns foreign exchange. The use of pesticides on cotton and the other crops is not only intensive, but most of the time those who handle these plant protection products (PPP) lack basic training in their use and do not also pay attention to safety measures. Farmers most of the time in their desire to achieve fast knockdown of the target pests and to maximise their incomes tend to indulge in using overdoses and neglect of safety precautions (Ntow W. J. *et al,* 2008).

As a result of the intensive use of pesticides and the lack of proper training for workers and the inadequate utilization of personal protective equipment, there has been public concern about the health impacts of the wide spread use of these PPPs. This has led to some investigations into the environmental and human health impacts of these products in Ghana. A few of the studies that have been done in this area include: Aquah O. (1997), Ntow W. J. (2001) and Ntow W. J *et al* (2008). Most of the studies done in this area are monitoring studies based on and restricted to a few crops in the southern part of Ghana. No work has been done so far in Ghana to ascertain the levels of worker exposure to pesticides by way of modelling.

In the northern parts of Ghana where cotton is predominantly produced, cotton is viewed as an important cash crop and as a source of employment to a large number of the youth. Cotton farming is the single most important cash crop in the northern parts of Ghana that brings bulk income to the farmers at the end of every farming season (Wumbei *et al,* 1999, unpublished). The production of cotton however, entails the use of enormous amounts of pesticides. This can result in pesticides poisoning (personal communications with EPA Tamale staff and staff of the Ghana cotton company) in cotton growing communities every year. Farmers often tell the EPA staff in their environmental monitoring and outreach programmes that they sometimes feel dizzy, vomit and have stomach problems after spending hours on the farm applying pesticides.

The objectives of this study, therefore, were to for the first time evaluate the level of operator exposure to pesticides on cotton farms and to assess the risk associated with these exposure levels.

The EPA of Ghana through it's chemicals control and management centre (CCMC) in collaboration with the customs excise and preventive service (CEPS) and the plant protection and regulatory services directorate (PPRSD) of the ministry of food and agriculture (MoFA) is responsible for the registration of pesticides that come into the country. The agency with her collaborators relies on laboratory based analysis to ascertain the exposure and risk associated with the use of a particular pesticide so as to enable them make a decision as to whether to register it for use in the country or not. Since these laboratory based analysis are quite expensive and also time consuming, the agency usually relies on data from other countries to take registration decisions on pesticides.

In other parts of the world as pertains in Europe, registration authorities make extensive use of exposure models. The exposure models are used to estimate the amount of exposure for different situations and the prediction is compared with an Acceptable Operator Exposure Level (AOEL) to assess whether it is safe to apply a pesticide using recommended application techniques. This method, as a first tier approach is quite simple, straight forward and cost effective and should be recommended for a developing country which does not have money to conduct regular laboratory analysis for the purpose of pesticides registration.

It was against this background that this research was commissioned in the hope that at the end of the work one would become conversant with modelling pesticides exposures so as to contribute this expertise to the agenda of the EPA in ensuring that only pesticides that are safe to humans and the environment are registered to be used in the country.

2.0 Objectives

The objectives of this study, among other things were to;

- for the first time evaluate the level of operator exposure to pesticides on cotton farms
- assess the risk associated with these exposure levels
- assess whether the level of exposure depends on the method and season of spraying

3. METHODOLOGY

The main issues to be cleared in this investigation are two; the first being the gathering of relevant available data on information necessary for risk assessment of applicator exposure to pesticides. The second issue is to do with actually assessing the risk of applicator exposure to pesticides on cotton farms in Ghana. In this scientific investigation, the UK-POEM (1990) and the German Model (1992) were applied in order to achieve the research objectives.

3.1 Selection and Description of Study Area

In order to achieve risk assessment of applicator exposure to pesticides which represents the cotton industry at the national level, a number of factors including *land use* were considered for the site selection. The selected area

(Northern Ghana) is involved in Agriculture as a whole and cotton production in particular as it's main economic activity. The selected area, including the Northern region, Upper East and Upper West regions, put together as northern Ghana is the main area of cotton production in the country. Therefore, it forms a reliable representative of the cotton sector of Ghana. The other most important factor considered for the selection of Northern Ghana for this study was the availability and accessibility of data.

Northern Ghana lies between latitude 8°N and 11°N and at an altitude of 200-300m. Mean annual temperatures are 25-30°C. Rainfall is highly variable, ranging from 800mm to 1300mm per annum. The wet season starts from May to September. The soils in the area are coarse sandy loam and are moderately to strongly acidic with relatively low organic matter content. Available N is 10-30kg/ha and P is less than 10kg/ha in some parts of the region such as Sandema in the Upper East region.

Much of Northern Ghana is characterized by woodland savannah. The administrative regions of Upper East, Upper West and Northern Region account for 41% of the nation's territory and 20% of its population. Population densities vary from 125persons/km^2 in the Upper East Region to 25persons/km^2 in the Northern region. There is 3% population growth despite the continual out-migration of the landless and unemployed youth. More than 90% of the population is farmers. Shifting cultivation dominates the less populated areas (5ha/household) and permanent agriculture dominates the densely populated regions (0.8ha/household). The major food crops grown in the area are; millet and maize while the major cash crops are; cotton, groundnuts and cowpea (ACDEP, 1995).

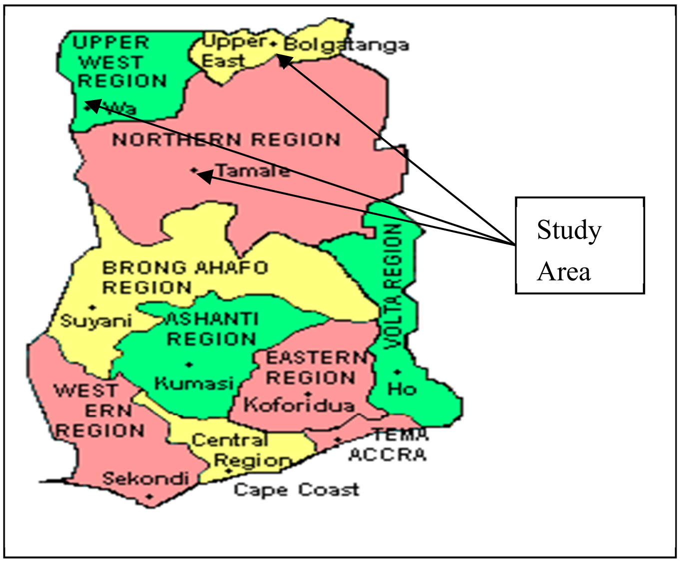

Figure 1: The study area

3.2 Collection of Data

In the process of pesticides risk assessment by the use of models such as the UK-POEM and the German model, an important step to start with is data collection. In order to have a good scientific study, data collected must be reliable and representative. However, in Ghana, just as in many other developing countries the culture of record keeping by private and public institutions is very poor. Some times, when the information is even available it is either insufficient or out of date. Thus, obtaining information for a scientific study like this is sometimes a daunting task to accomplish.

The above not withstanding, an initial attempt was made to obtain data from certain public institutions such as the EPA and the ministry of Food and Agriculture (MoFA) to no avail. The difficulty as pointed out earlier on was that they did not have such records. They consequently referred the researcher to go down to the farm level. Considering this difficulty in obtaining accurate and up-to-date data and the fact that one needed to do a good risk assessment a short questionnaire on pesticides use, use of PPE, areas treated, number of sprayings and times of spraying and the general issues of the cotton production and pesticides use was prepared and administered in several cotton growing districts in Northern Ghana through staff of the Environmental Protection Agency (EPA) and the Ghana Cotton Company Limited (GCCL).

The questionnaire at the farm level did not yield satisfactory results due the high illiteracy rate among farmers.

Eventually, most the data used in this investigation came from unpublished records of the GCCL and a study carried out by Alfred Gerken, Jack-Vesper Suglo and Mathias Broun on pesticides use and policies in Ghana. Besides these sources, another source from which vital information was obtained to accomplish this study was the EFSA final report 2008 in the department of crop protection Chemistry of the Gent University.

3.3 Models of Applicator Exposure Assessment

The exposure/risk assessment was performed by applying the UK POEM and the German Model. With all the data required for the application of the above models ready, the assessment was performed by the following steps;

- Pesticides use data from Ghana were fed into the respective models to generate exposure values; Potential Dermal Exposure (PDE) and Potential Inhalation Exposure (PIE).
- These values were aggregated into total exposures.
- The total exposure values for the various scenarios were divided by an acceptable operator exposure level (AOEL) to get the risk index (RI) values for the various scenarios.
- The exposure values were plotted into graphs to allow for clear assessment of the exposure levels.
- The risk index values were log transformed and the log values plotted into graphs to allow for an easy evaluation of the risk levels.

4. RESULTS AND DISCUSSION

4.1 Evaluation of Exposure by Modeling

In this study, operator exposure to pesticides on cotton farms in Ghana was evaluated by modeling. The models employed were the UK-POEM and the German Model. Four exposure scenarios, including exposure with no protection, exposure with protection during only mixing/loading, exposure with protection during only application and exposure with complete protection were evaluated. The results of the modeling as described in chapter 3 are given in the following figures:

As will be seen in figures 2, 3, 6, 7, 10, 11, 14 and 15 the totals of the potential dermal exposure (PDE) during mixing and loading, potential dermal exposure during application and potential inhalation exposure (PIE) are given.

Also, through this study as will be seen later in the results presented, it is observed that the predominant group of pesticides used on cotton farms in Ghana are the insecticides, the most toxic of all pesticides. The other groups of pesticides such as herbicides, fungicides and growth regulators are seldom used. Among the insecticides used are; the dien-organochlorin or cyclodien (endosulfan), the organophosphate (chlorpyrifos), the pyrethroids (λ-cyhalothrin and cypermethrin) and neonicotinoid (acetamiprid).

As far as pests control on cotton farms is concerned, three types of treatments are done in a year, namely; the early season applications, the mid season applications and the late season applications.

4.1.1 Exposure without protection

The results of exposure without protection for both the UK-POEM and the German models can be seen in figures 2, 3, 4 and 5.

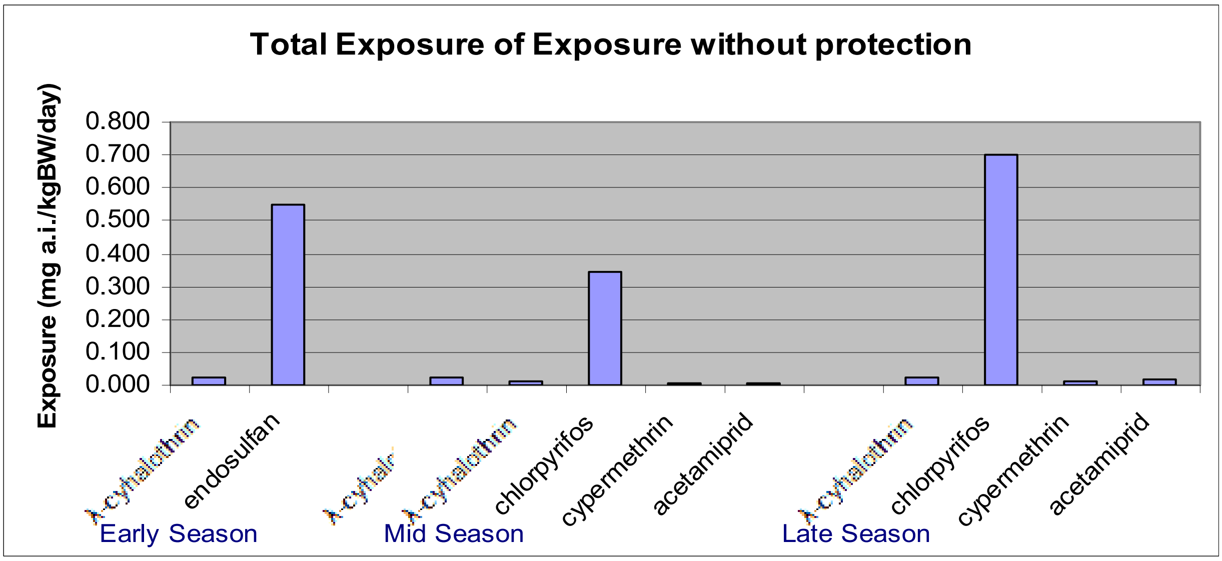

Figure 2: Total operator exposure to pesticides without protection during both mixing/loading and application, by using UK-POEM.

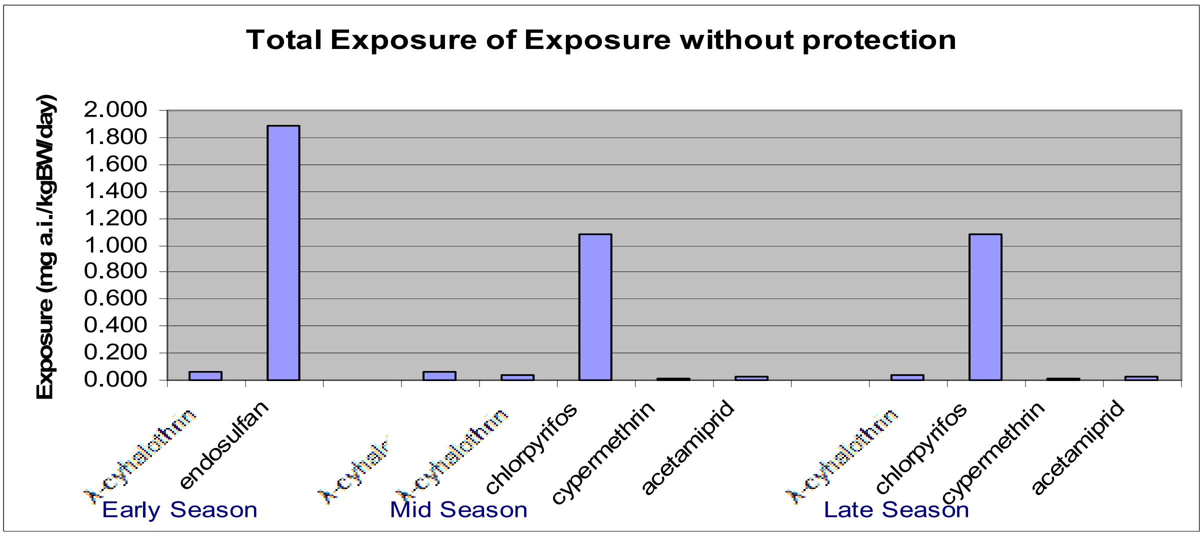

Figure 3: Total operator exposure to pesticides without protection during both mixing/loading and application, by using the German Model.

From figures 2 and 3 which depict pesticides use scenario where farmers do not use any personal protective equipment (PPE), it is observed that farmers are exposed more to two of the insecticides used, namely; endosulfan and chlorpyrifos. Each of the two pesticides had their exposure values exceeding the Acceptable Operator Exposure Level (AOEL) of 0.006mg/kg/d and 0.01mg/kg/d respectively. The other pesticides (acetamiprid, cypermethrin and λ-cyhalothrin) had relatively lower exposure values. This could be explained by the fact that pyrethroids are generally poorly absorbed into the body through the skin (NPIC, 2009). Both the UK-POEM and the German models estimated higher exposure for endosulfan and chlorpyrifos.

While endosulfan is only applied as an early season insecticide, chlorpyrifos is applied as mid and late season insecticide. With regards to the season, there was significant difference in operator exposure to chlorpyrifos during mid-season and late season with the late season exposure higher than the mid-season exposure. This could be attributed to the different spraying methods adopted in the two seasons. In the early and mid seasons, when the cotton plants are still young and very low to the ground at a height of only a few centimetres, spraying is done in a downward direction, whereas in the late season when the crops have achieved a reasonable height,

spraying is done in upward direction, thereby leading to more deposits of the spray solution on the operator (farmer). In the German model, there was no significant difference in operator exposure to chlorpyrifos during mid season and late season.
Both models estimated higher exposure values for endosulfan, with the German model value being higher than the UK-POEM value. This difference could be attributed to the fact that the German model used high crop for both the mid-season and the late season applications.

From the above results it is observed that during the spraying of cotton without the use of personal protective equipment (PPE) farmers are exposed more to endosulfan and chlorpyrifos than other insecticides. Both pesticides pose risk to human health. Endosulfan is a cyclodien and relatively stable in sunlight. It also undergoes hydrolysis and oxidation very slowly in the presence of growing vegetation (FAO, 2000). Chlorpyrifos on the other hand, is an organophosphate which is very toxic and can stimulate cholinesterase inhibition in humans; that is it can over stimulate the nervous system causing nausea, dizziness, confusion, and at very high exposures, respiratory paralysis and death (US EPA, 2002).

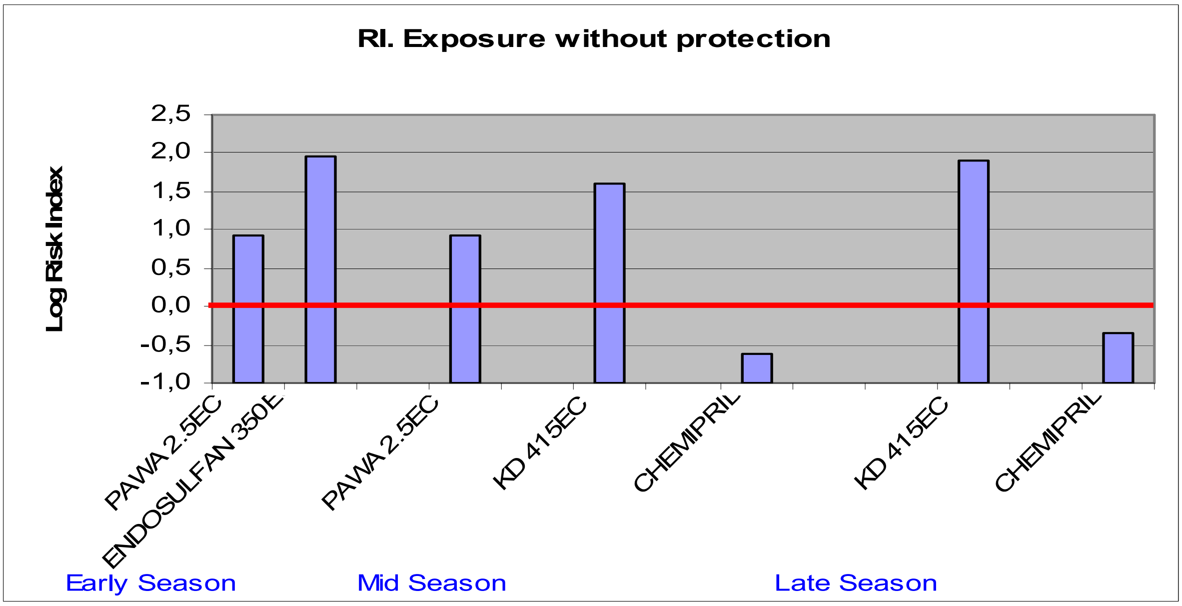

Figure 4: Risk index of operator exposure to pesticides without protection by using data of the UK-POEM (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

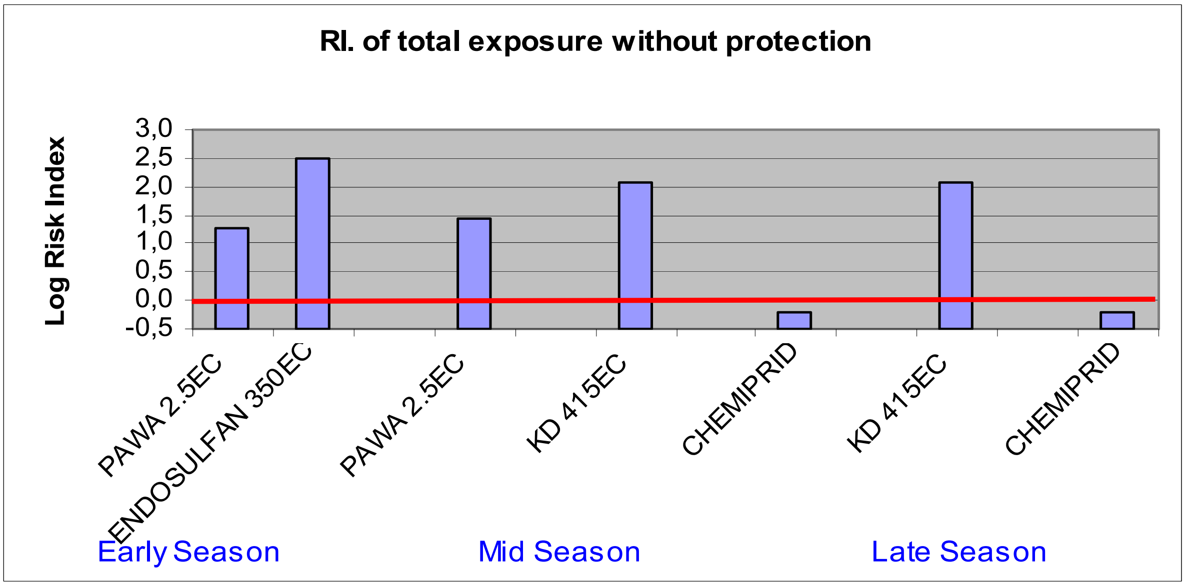

Figure 5: Risk index of operator exposure to pesticides without protection, by using data of the German model (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

From figures 4 and 5, it is observed that farmers are faced with significant risk in the use of pesticides (insecticides) on cotton farms in Ghana when no PPE are used. Farmers are faced with significant risk in using all the pesticides except Chemiprid (acetamiprid and cypermethrin). The risk index values as observed in figure 4 and 5 are consistent with the exposures observed in figure 2 and 3. Among the pesticides that pose significant risk to operators as can be seen above, both models estimated higher risks for Endosulfan and KD (chlorpyrifos) than for PAWA (λ-cyhalothrin). This is very understandable, because while λ-cyhalothrin is a pyrethroid and is less harmful to man, endosulfan and chlorpyrifos are both very harmful to man. Endosulfan as a cyclodien when gets into the body of man interferes with the Na^+/K^+ pump in the axon of the neuron leading to increased activity, tremors, convulsion and paralysis. Chlorpyrifos on the other hand, as an organophosphate when gets into the human body inhibits the functioning of the cholinesterase enzyme in the nervous system thereby leading to the accumulation of Acetylcholine at the neuromuscular junction and resulting in rapid twitching of voluntary muscles and finally paralysis.

Again, the higher risk associated with the use of endosulfan could be explained by the fact that as a cychlodien, endosulfan has positive temperature coefficient *ie* the toxicity increases with increasing temperature. Therefore, since temperatures in Ghana especially in the cotton growing areas can usually get very high (42°C maximum) it could be very risky using such a chemical under those conditions. On the other hand, the low risk associated with the use of λ-cyhalothrin could be attributed to the fact that, as pyrethroids they have negative temperature coefficient that is their toxicity increases with decreasing temperature, hence the higher temperatures as pertain in the cotton growing areas of Ghana may be impeding their toxicities.

From the above results, it is again observed that the German model estimates higher risk for the respective pesticides than the UK-POEM. This, again could be attributed the spraying method (hand held to high crops) adopted in the use of the German model.

4.1.2 Exposure with protection during only mixing/loading

The results for operator exposure with protection during mixing/loading, but without protection during application for both the UK-POEM and the German models can be seen in figures 6, 7, 8 and 9.

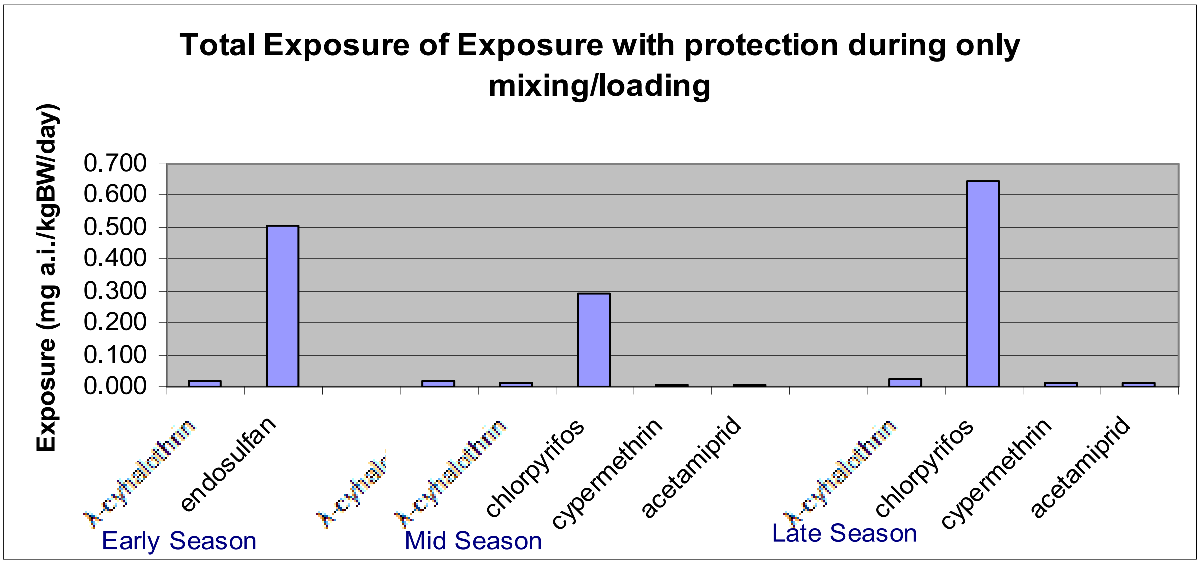

Figure 6: Total operator exposure to pesticides with protection during mixing/loading, but without protection during application, by using UK-POEM.

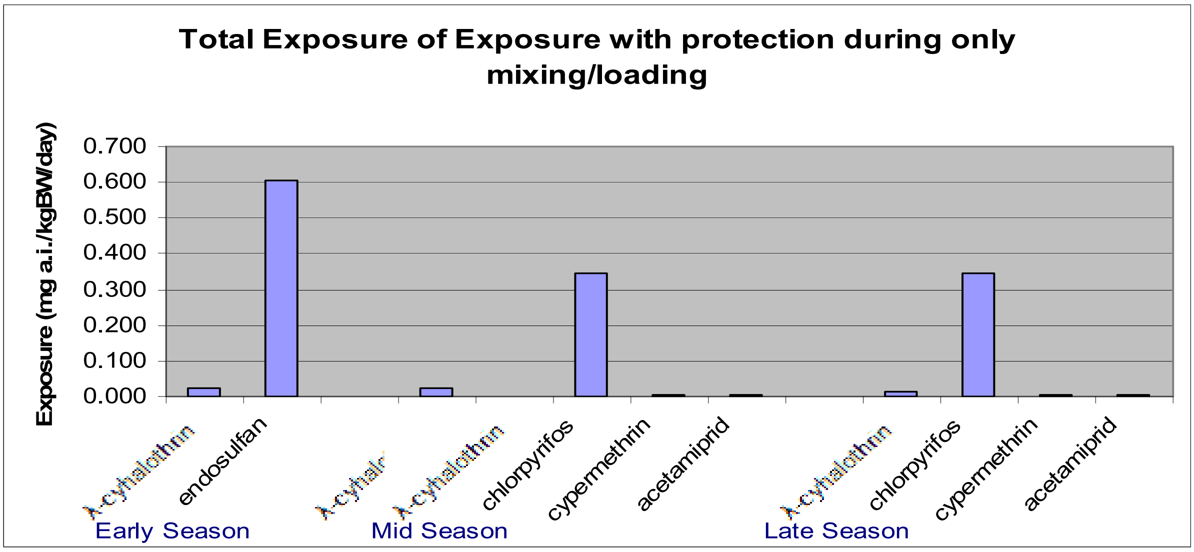

Figure 7: Total operator exposure to pesticides with protection during mixing/loading, but without protection during application, by using German model.

From figure 6 and 7 which show pesticides use scenario on cotton farms with protection during only mixing/loading it is observed that farmers are exposed to higher level of endosulfan and chlorpyrifos than the other pesticides just like in the no protection scenario, with the German model estimating higher levels of exposure than the UK-POEM. The levels of operator exposure to the two pesticides as indicated in the two figures (6 and 7) far exceed their respective acceptable operator exposure level (AOEL) values. However, unlike the no protection scenario, there were generally lower exposure levels with the introduction of PPE at the mixing/loading phase. For the UK-POEM, the exposure to endosulfan decreased from a no protection scenario exposure of 0.55mg/kg/d to 0.5mg/kg/d and that for chlorpyrifos decreased from 0.7mg/kg/d to 0.65mg/kg/d. For the German model, operator exposure to endosulfan decreased from 1.8mg/kg/d to 0.6mg/kg/d and that for chlorpyrifos decreased from 1.1mg/kg/d to 0.35mg/kg/d.

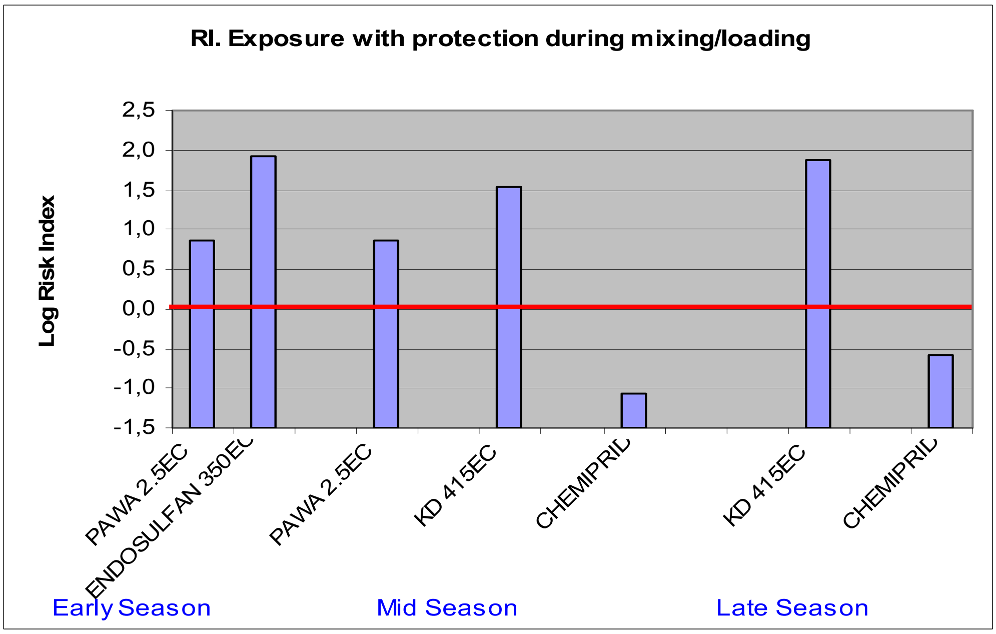

Figure 8: Risk index of operator exposure to pesticides with protection during mixing/loading, but without protection during application, by using data of the UK-POEM (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

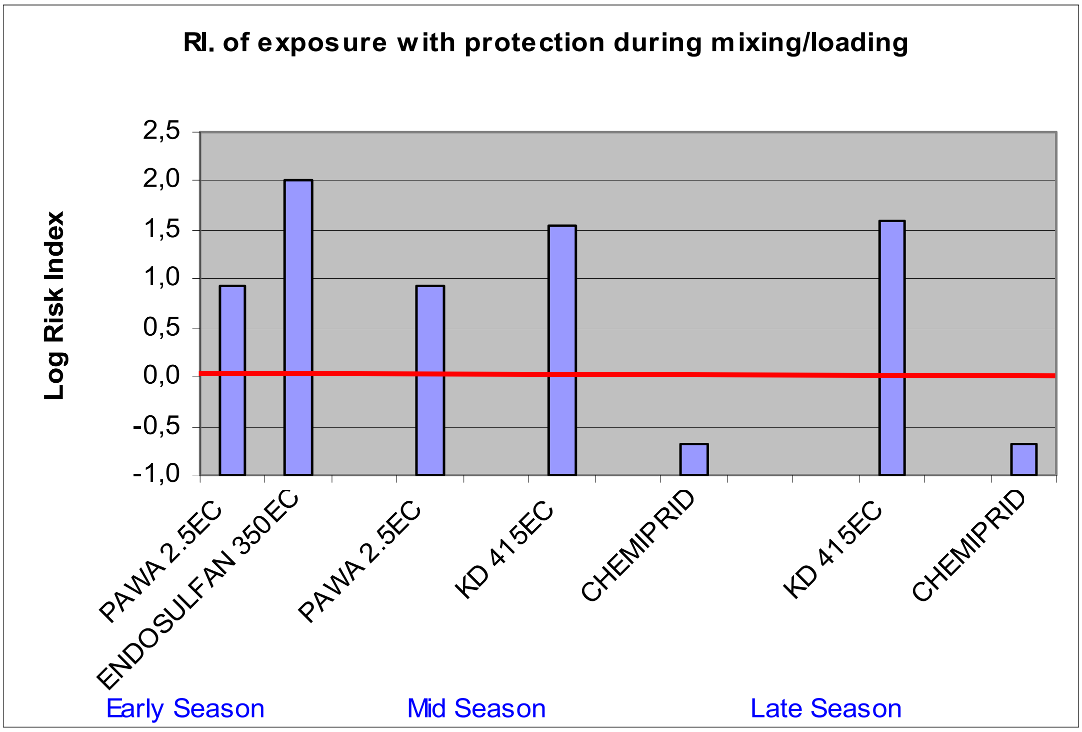

Figure 9: Risk index of operator exposure to pesticides with protection during mixing/loading, but without protection during application, by using data of the German model (The red line represents TPE/AOEL=1 where TPE is total potential exposure and AOEL is acceptable operator exposure level).

From Figures 8 and 9, it is observed that the use of pesticides on cotton farms in Ghana with protection during only the mixing/loading operation pose significant risk to farmers when endosulfan, chlorpyrifos and lambdacyhalothrin are used. There is no risk as indicated on the two figures when Chemiprid (acetamiprid and cypermethrin) is used. Also, like for the no protection scenario, the risk associated with the use of the endosulfan and chlorpyrifos is higher than that for λ-cyhalothrin. Just like for the exposure, there has been a decrease in risk with the introduction of PPE at the mixing/loading phase. For the UK-POEM, there has been a decrease in risk from 1.9 to 1.8 for endosulfan and from 1.8 to 1.7 for chlorpyrifos. For the German model there is a decrease in risk from 2.5 to 2.0 for endosulfan and from 2.1 to 1.6 for chlorpyrifos.

4.1.3 Exposure with protection during only application

The results for operator exposure with protection during application, but without protection during mixing/loading for both the UK-POEM and the German models can be seen in figures 10, 11, 12 and 13.

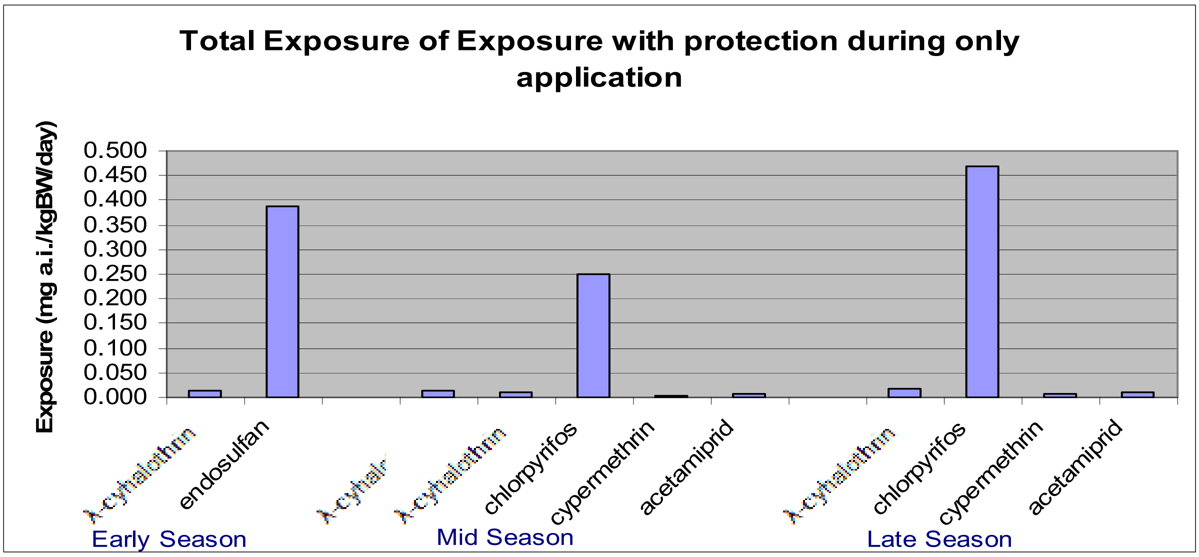

Figure 10: Total operator exposure to pesticides with protection during application but without protection during mixing/loading, by using UK-POEM.

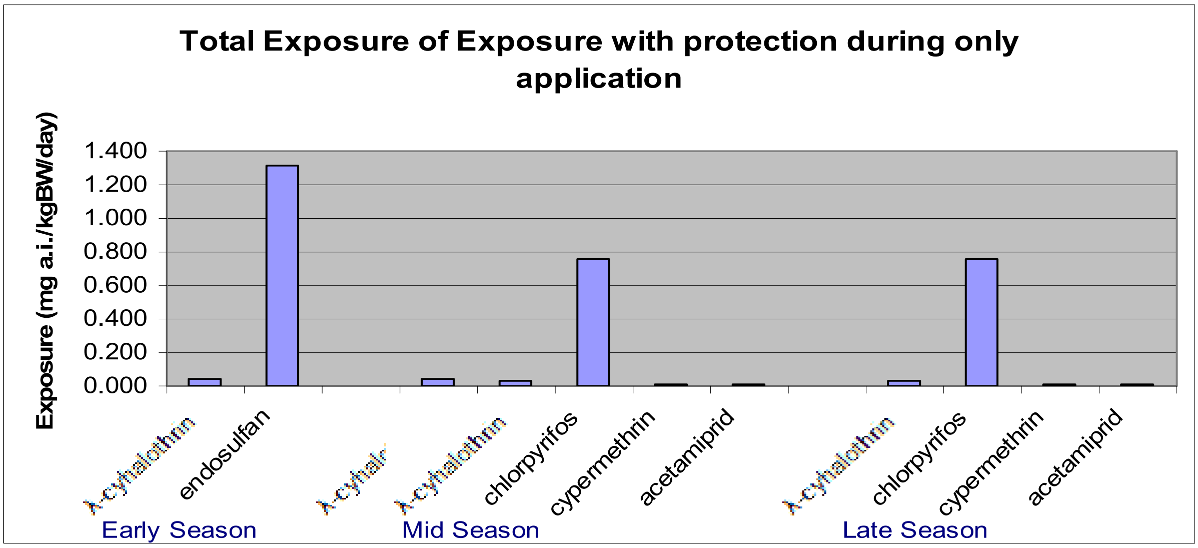

Figure 11: Total operator exposure to pesticides with protection during application, but without protection during mixing/loading, by using German model.

From figure 10 and 11 which show exposure scenario of pesticides use on cotton farms in Ghana with protection during only the application operation, it is observed that there are unacceptable exposure levels to endosulfan, chlorpyrifos and λ-cyhalothrin as each of them has their exposure levels significantly higher than their respective acceptable operator exposure level (AOEL) values. The exposure values estimated by the German model are as usual, significantly higher than that of the UK-POEM. Though, there are still higher exposures to operators under this scenario, the exposure levels are lower compared to the levels recorded under the no protection scenario. As a result of the use of PPE during application, there is reduction in the level of exposure. For the UK-POEM there has been a decrease in exposure from a no protection scenario value of 0.55mg/kg/d to 0.353mg/kg/d for endosulfan and from 0.7mg/kg/d to 0.452mg/kg/d for chlorpyrifos. For the German model, there has been a decrease of exposure from 1.8mg/kg/d to 1.34mg/kg/d for endosulfan and from 1.1mg/kg/d to 0.75mg/kg/d for chlorpyrifos. The use of PPE during the spraying phase has resulted in significant decrease in exposure than the use of PPE during the mixing/loading phase. Whereas the use of PPE during mixing/loading resulted in a decrease in exposure of 0.05mg/kg/d to endosulfan with the UK-POEM, the use of PPE during application resulted in a decrease in exposure of 0.197mg/kg/d to endosulfan by the same model. This is an indication of the importance of the application phase in the use of pesticides as far as exposure is concerned, hence the need to emphasize the use of PPE at that stage. This has been confirmed by many studies (Durham and Wolfe 1962, Fenske and Elkner 1990).

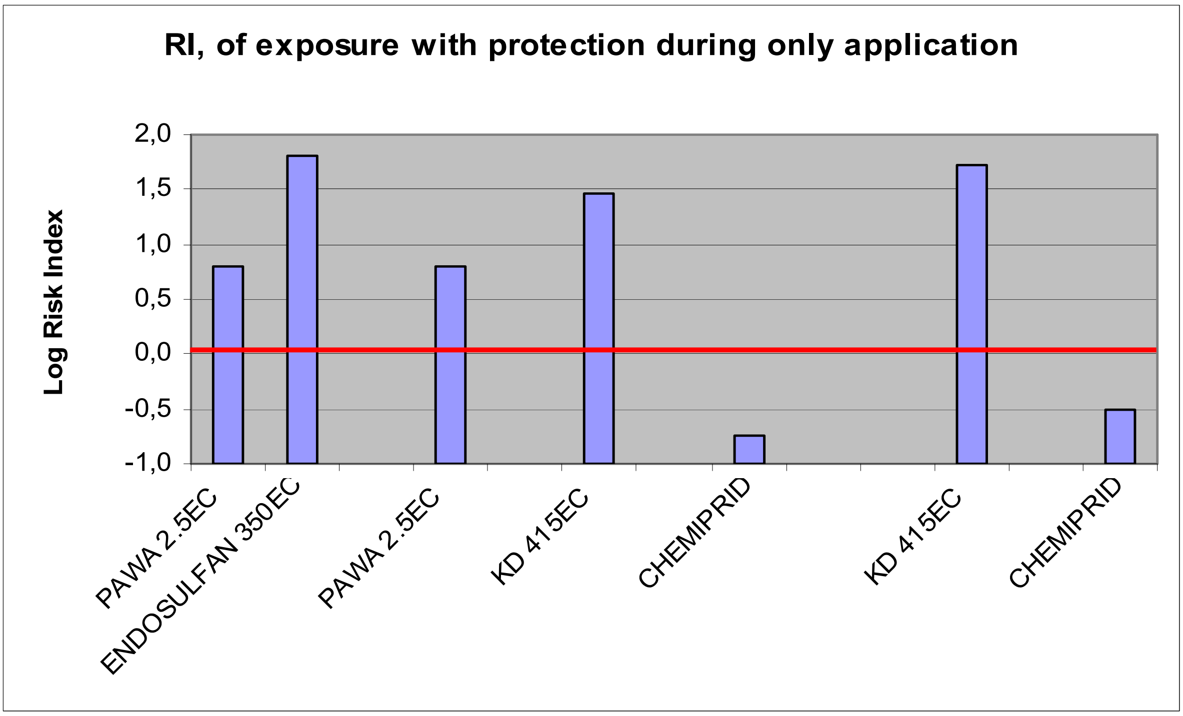

Figure 12: Risk index of operator exposure to pesticides with protection during application but without protection during mixing/loading, by using data of the UK-POEM (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

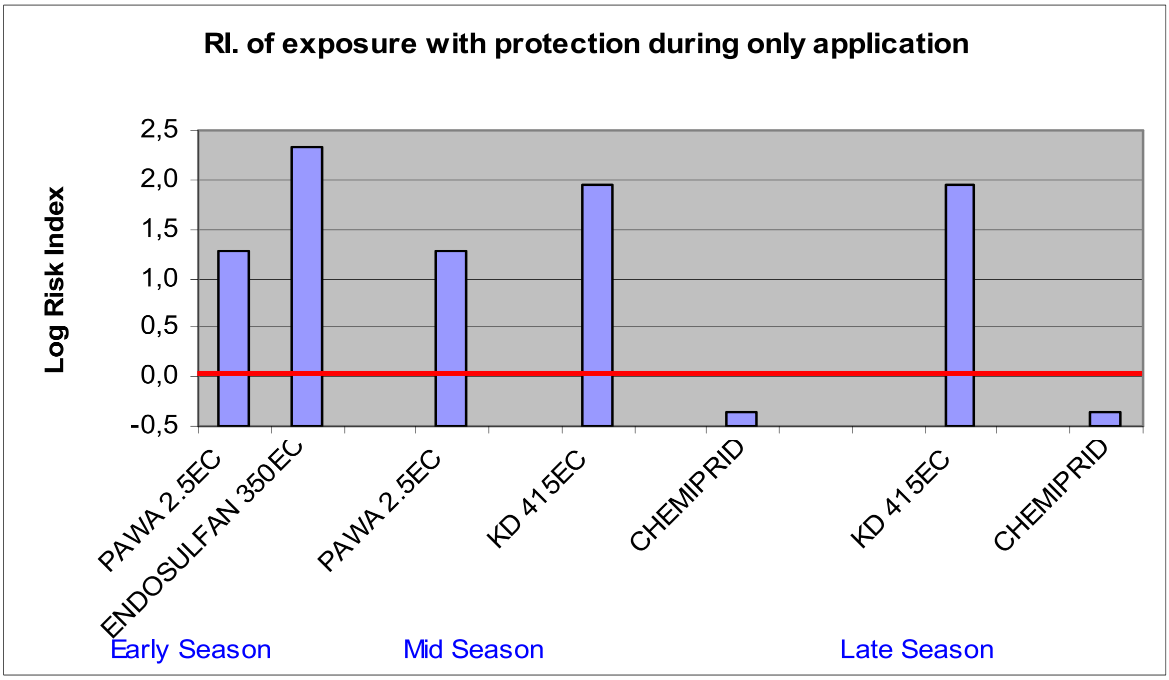

Figure 13: Risk index of operator exposure to pesticides with protection during application but without protection during mixing/loading, by using data of the German model. (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

From figures 12 and 13 which show the risk to pesticides operators on cotton farms in Ghana in a scenario where they use PPE during only the application activity, it is observed that there is significant risk when applying endosulfan, lambdacyhalothrin and chlorpyrifos, but with no risk when applying acetamiprid and cypermethrin. Again, the results show that there is higher risk in using endosulfan and chlorpyrifos than using lambdacyhalothrin. If one compares the risk observed under the scenario of no protection to the risk observed under the scenario of protection during application, it is observed that the risk level for the respective pesticides has decreased with the use of PPE. For instance, with the UK-POEM there is decrease in risk from 1.9 to 1.6 for endosulfan and from 1.8 to 1.4 for chlorpyrifos. In the same vein, with the German model, there is risk reduction from 2.5 to 2.3 for endosulfan and 2.1 to 1.9 for chlorpyrifos. From the above results, it is also observed that the use of PPE during application results in greater decrease in risk to farmers than the use of PPE during mixing/loading. Whereas the use of PPE during application results in as high as 0.3 and 0.4 for endosulfan and chlorpyrifos respectively, the use of PPE during mixing/loading results in only marginal reduction in risk of about 0.1 for endosulfan and chlorpyrifos. It is important therefore, that, pest control operators take the use of PPE during the application activity serious as they are prone to a lot of exposure and risk during this activity.

4.1.4 Exposure with total protection

The results for operator exposure with complete protection (protection during both mixing/loading and application) for both the UK-POEM and the German models can be seen in figures 14, 15, 16 and 17.

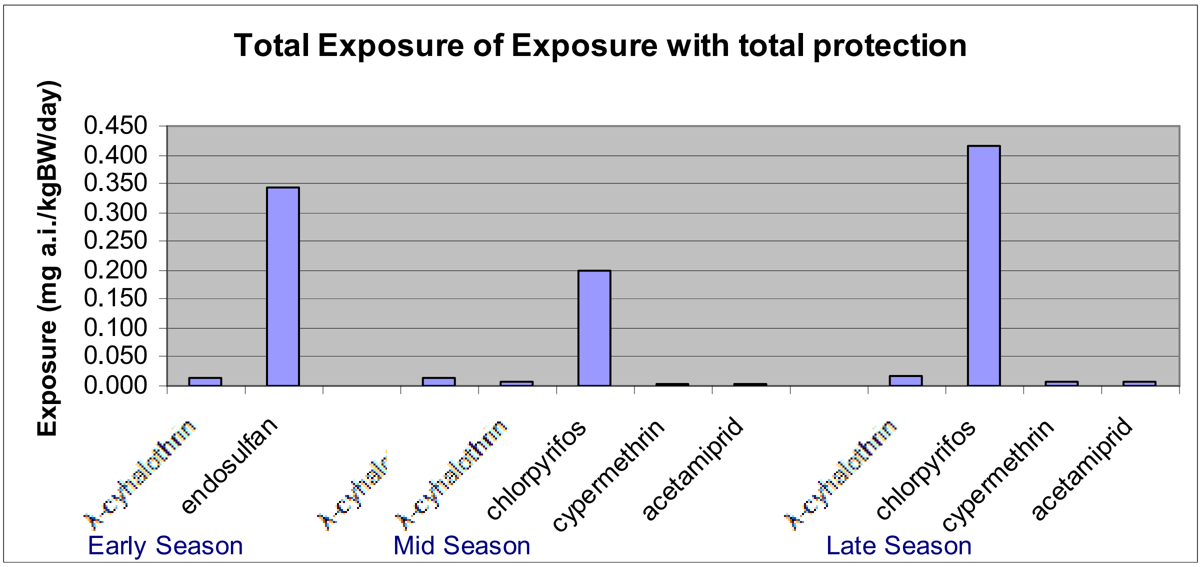

Figure 14: Total operator exposure to pesticides with protection during both mixing/loading and application, by using POEM.

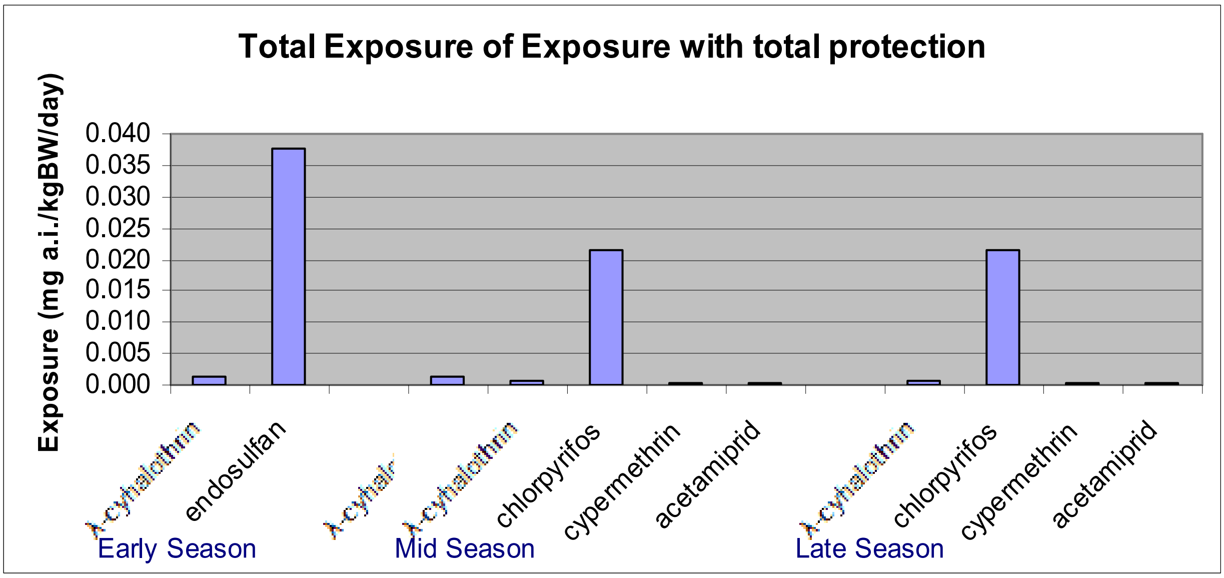

Figure 15: Total operator exposure to pesticides with protection during both mixing/loading and application, by using German model.

From figures 14 and 15, which show the exposure of operators to pesticides on cotton farms under the condition of complete protection, it is observed that though, operator exposure has not been eliminated, there has been a significant reduction in operator exposure. Like in the previous scenarios, the main culprits of higher exposures are endosulfan and chlorpyrifos. The exposure to λ-cyhalothrin, though higher than that of cypermethrin and acetamiprid is insignificant. From figure 14 it can be observed that exposure to chlorpyrifos was higher during the late season application than during the mid season application. This can be explained by the different spraying methods adopted in the two seasons. With the German model (figure 15) no such difference in exposure to chlorpyrifos is observed, because the model maintained the same method of spraying (hand held to high crops) for both seasons. From the two figures it can be observed that the German model estimates far lesser exposures than the UK-POEM. For instance, while the UK-POEM estimates exposure level of 0.34mg/kg/d for endosulfan, the German model estimates as low as 0.038mg/kg/d for the same pesticide. This is in conformity with the study by Machera K. *et al* (2001) in which it was indicated that the measured dermal exposure values were consistently greater than values predicted by the German model. This may seem contradictory to the three previous scenarios where the German model was overestimating exposure and risk, but there should be no contradiction at all, as there was no complete protection in the previous scenarios. The underestimation associated with the German model could be attributed to the nature of the PPE adopted in the model.

The use of PPE during both mixing/loading and application has brought about more decrease in operator exposure than when PPE are used during only mixing/loading or during only application. For the UK-POEM, there is a reduction from an initial value of 0.55mg/kg/d to 0.34mg/kg/d for endosulfan. This gives a total exposure reduction of 0.21mg/kg/d for endosulfan as against a slim reduction of 0.05mg/kg/d and 0.197mg/kg/d for use of PPE during mixing/loading and during application respectively.

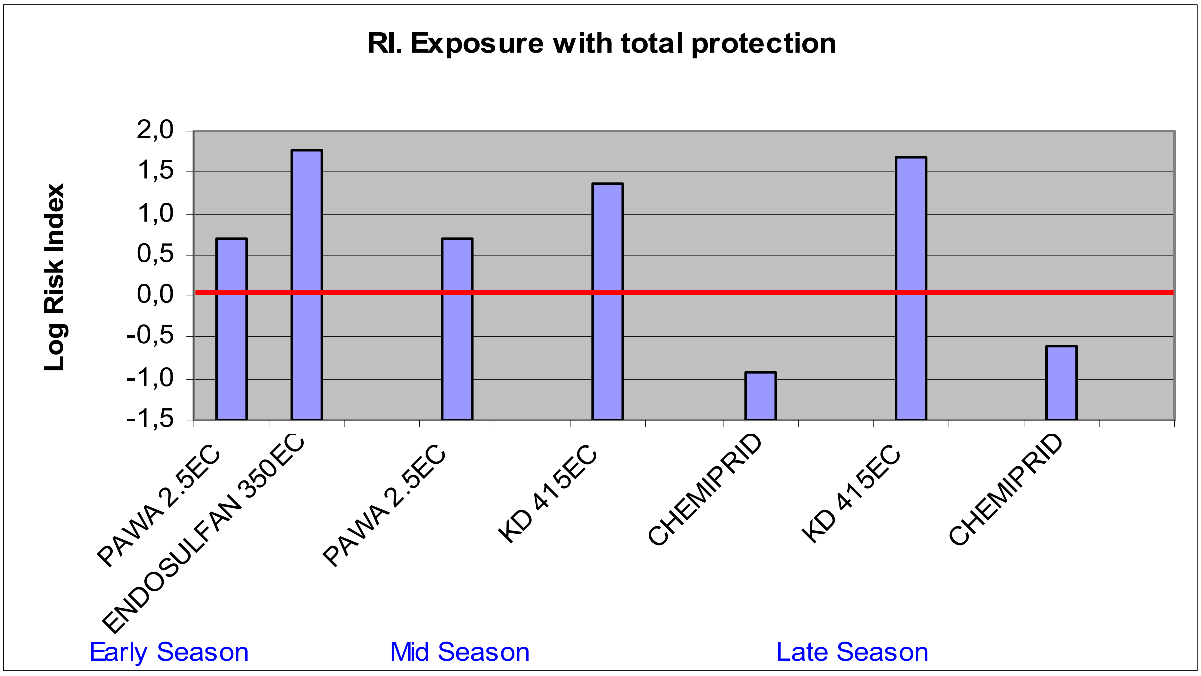

Figure 16: Risk index of operator exposure to pesticides with protection during both mixing/loading and application, by using data of the UK-POEM. (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

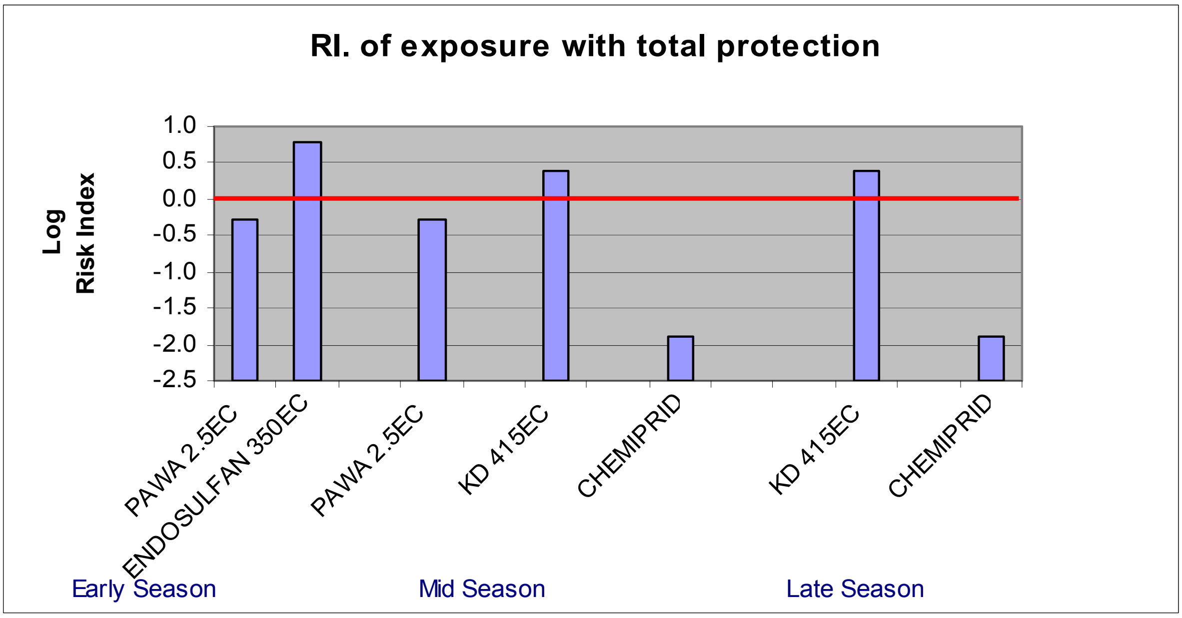

Figure 17: Risk index of operator exposure to pesticides with protection during both mixing/loading and application, by using data of the German model. (The red line represents TPE/AOEL=1, where TPE is total potential exposure and AOEL is acceptable operator exposure level).

From figures 16 and 17, which depict the risk of pest control operators on cotton farms in Ghana under the scenario of complete protection, it is observed that, though the risk is not eliminated there has been significant decrease in risk. The risk levels as observed in the two graphs are consistent with the exposure levels in figures 14 and 15. For the UK-POEM, it is indicated that workers are faced with risk when applying endosulfan, λ-cyhalothrin and chlorpyrifos, but no risk when applying cypermethrin and acetamiprid under the condition of complete protection. The German model, however, indicates that there is no risk in using λ-cyhalothrin, cypermethrin and acetamiprid.

Like with the exposure scenarios in figures 14 and 15, the use of PPE during mixing/loading as well as during application has resulted in significant decrease in risk to pest control operators (figure 16 and 17). From the two figures it can be observed that for the UK-POEM there has been decrease in risk from a no protection scenario value of 1.9 to 1.53 for endosulfan and from 1.8 to 1.52 for chlorpyrifos. For the German model, it is observed that the risk to pest control operator decreased from 2.5 to 0.53 for endosulfan and from 2.1 to 0.4 for chlorpyrifos.

From the above results it can be observed that the use of PPE for both mixing/loading and application operations brings about more risk reduction than when PPE are used during only mixing/loading or during only application. For instance, the UK-POEM recorded a total risk reduction of 0.37 for endosulfan under the condition of complete protection against a reduction of only 0.1 and 0.3 for the condition of protection during mixing/loading and application respectively.

Again, from the above results it is observed that the German model estimates lesser risk for the use of the respective pesticides than the UK-POEM. For instance while the UK-POEM estimates a risk level of 1.53 for endosulfan, the German model estimates a risk level of 0.53 for the same pesticide. The differences in exposure and risk estimation as observed between the two models used in this study could be attributed to the differences in the type of protection used in the models. Whereas the UK-POEM uses only gloves as means of protection, the German model goes a step further to include half mask, hood + visor and coverall + boots.

5. CONCLUSIONS

The study evaluated the level of operator exposure to pesticides used on cotton farms in Ghana and the risks associated with the levels of exposures. Five pesticides and three seasons of applications were considered in this study. Two well recognized exposure models, the UK-POEM and the German model were used and through the results obtained these conclusions are reached:

Operator exposure to pesticides on cotton farms in Ghana are generally high thereby putting the lives of farmers involved at great risk. Two of the pesticides investigated in this study have operator exposure levels exceeding their respective acceptable operator exposure level (AOEL), hence resulting in greater risk. The two most important pesticides with these high exposures and risks were the cylodien based endosulfan and organophosphate based chlorpyrifos. The other three pesticides in this study, two of which belong to the pyrethroids group (λ-cyhalothrin and cypamethrin) and the other one, a neonicotinoid insecticide (acetamiprid) did not pose significant risk to farmers.

The use of personal protection equipment (PPE) though seldom practiced much in Ghana at the moment, has significant impact on exposure and risk reduction. Use of PPE in either during mixing/loading or during application does not help much as far as exposure and risk reductions are concerned. Therefore, if the use of PPE is to be encouraged, complete protection should be emphasized.
The method of spraying adopted during pesticides application and the season of application are very important in determining exposure. Exposures are usually high during the late season applications when spraying is upwards than during early season applications when spraying is downwards. Endosulfan has a positive temperature coefficient and could pose greater risk if applied in the late season. However, since endosulfan was not applied in the late season, one is hesitant to conclude on it.

Pesticides exposure models in general, have in some cases the tendency to underestimate exposure. However, among the models some are more accurate in estimating exposure than others. In this study, the UK-POEM was better in accurate exposure estimation than the German model. Both models appear to perform better under low crop application conditions than under high crop application conditions.

Exposure modeling as observed in this study and through other literature, holds the key to the future of Ghana's pesticides management and control decisions as these models are very fast in predicting exposures and less expensive compared to laboratory based pesticides exposure and risk assessment. However, the particular conditions of pesticides spraying in Ghana have to be checked for compliance with the conditions used as input for the development of these models.

6. RECOMMENDATIONS

Following the results obtained and the conclusions reached in this study the following could be considered for implementation in order to reduce operator exposure to pesticides and risk on cotton farms in Ghana:

- Since there are already policies in place in Ghana to regulate the use of pesticides, it is advised that the regulatory authorities should step up efforts to enforce the necessary laws on the proper use of pesticides. In this regard, risk management measures must be taken to reduce operators' exposure to pesticides. The EPA in collaboration with the ministry of food and agriculture could liaise with the cotton companies to offer training to farmers on the proper use of pesticides to ensure that farmers apply the right quantities of pesticides at the right time while adhering strictly to safety precautions.

- As a matter of policy, the cotton companies in Ghana should be made to provide personal protective equipment (PPE) to farmers as part of the inputs they usually provide to farmers on credit during the cause of every farming season, as it is observed that most farmers do not use protective clothing because of lack of means to acquire them.

- Having personal protective equipment is one thing and using them properly is another thing. Hence, as much as possible, if the government is able to succeed to get the cotton companies to provide PPE to their farmers, efforts should be made to educate the farmers on the proper use of the PPE so as to derive the maximum benefits that go with the use of PPE.

- Ghana, as a tropical country is generally warm, but the cotton growing areas of the country (northern Ghana) are even warmer, making the use of PPE unattractive due to the discomfort that goes with it. To reduce the need for the use of PPE, the Ghana government through the ministry of food and agriculture could focus on engineering controls to reduce operator exposure to pesticides. In this regard, air injector nozzles could be adopted for the knapsack sprayers commonly used by the cotton farmers, since it has the advantage of minimizing drift and consequently reducing operator contamination.

- A critical study combining monitoring of the real exposure with model evaluation of pesticide exposure can generate much information about the efficiency of some PPE (gloves, masks, coverall etc.) under the Ghanaian conditions.

- Safety of pesticide applicators on cotton farms can be improved by switching from a spraying method where spray nozzles are held in front of the applicator to a method where the nozzles are held behind the applicator. The latter method is known to have little operator contamination since at the time the solution is sprayed the applicator is no longer in direct contact with the plants.

- As a matter of policy, while efforts should be made in the long term to adopt biological and other benign pest control methods, the cotton companies as well as other farming groups in Ghana should be encouraged to use more of the less toxic pesticides such as the pyrethroids and neonicotionids and less of the more toxic and dangerous pesticides such as the cyclodiens and the organophosphates.

- To have a comprehensive and a holistic view on the extent of operator/applicator exposure to pesticides in Ghana, a similar study should be conducted in the other sectors of Ghana's agriculture, especially the cocoa sector, since pesticides are used more heavily in that sector than any other sector.

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