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Insights to support enforcement of the ban on usage of the neurotoxic chlorpyrifos in Nigeria: A review

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Abstract

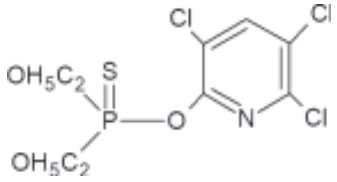
The ban on Chlorpyrifos (O, O-diethyl O-3, 5, 6-trichloro-2-pyridyl phosphorothioate) by the Federal Government of Nigeria is a laudable achievement that has been long overdue. Chlorpyrifos, a wide-ranged chlorinated organophosphate insecticide, is mainly applied for the prevention of pests on different crops as well as lawns and ornamental plants. The uncontrolled use of this pesticide and other similar chemicals by farmers has led to the contamination of natural resources with an unplanned human risk exposure. Chlorpyrifos, is a neurotoxin well known to have properties that inhibit the acetylcholinesterase, leading to prevention of the transmission of nerve signals. There are also documented negative psychological and cognitive effects in exposed infants, as well as other chronic illnesses associated with exposure to Chlorpyrifos. Several countries have led by example and have banned the use of chlorpyrifos, and more countries are reviewing its usage. A number of Studies had revealed its high usage in Nigeria but by concerted efforts, the Federal Government of Nigeria through the Federal Ministry of Agriculture and Rural Development (07 March 2022) banned the use of Chlorpyrifos. This is a commendable step and regulatory agencies must continue to consolidate the gains so far made in phasing out the chemical. The review concludes by making some recommendation to policy and other stakeholders to facilitate the journey to total compliance.

Key words: Acute effects, health hazards, organophosphates, pesticides regulation

Introduction

Food is an integral part of what sustains man on earth hence continuous effort is being made in every country throughout the globe, especially in Third World countries, to cater for the teeming population in order to overcome and combat food insecurity. Farmers have resorted to the use of herbicides, fertilisers, and pesticides for good yields, and to ensure the safety and good condition of their produce (Rahimeh *et al*., 2018). Pesticides are organic chemical which are expected to increase agricultural yield and products' quality, and to control the insect vectors thereby preventing the breakout of human and animal diseases. Pesticide usage in agriculture has increased over the years to facilitate field crops' and in-store produce protection. There are over five hundred compounds that are registered and used globally as pesticides or metabolites of pesticides. According to reports by Alliance for Action on Pesticides in Nigeria (AAPN), 65 per cent of the active ingredients used by farmers in Nigeria belong to the group of Highly Hazardous Pesticides (HHPs) of which Organophosphates form the bulk of insecticides registered for use in agriculture (YESSO, 2016).

Chlorpyrifos is moderately toxic and widely used broad spectrum organophosphate insecticide. Its chemical name is O, O-diethyl O-3, 5, 6-trichloro-2-pyridyl phosphorothioate with the formula $C_9H_{11}C_{l3}NO_3PS$. It has a relative molecular mass of 350.62, and vapor pressure of $1.8x\ 10^{-5}$mmHg at a temperature of 25 ^{0}C (Verma *et al.* (2020). Its structure is illustrated below:



Organophosphates were first developed during the Second World War as part of research into potential nerve agents such as sarin and tabun (Thacker, 2002; John and Shaike, 2015). Since then, they have become the most widely used type of pesticide, and account for approximately 38 % of all available products worldwide (Saiskala *et al.,* 2012) for control of pests on different crops as well as lawns and ornamental plants (John and Shaike, 2015). Chlorpyrifos was first produced for commercial purpose in 1965 by Dow Chemical Company and is one of the most widely used pesticides in agriculture and other sectors (Rathod and Garg, 2017). It has wide usage in non-agricultural settings like golf courses, residential buildings and lawns and in domestic settings (Hu, 2018).

Chlorpyrifos is a colourless to white crystal-like solid and has a mild mercaptan (thiol) strong smell likened to that of sulphur compounds, which can be found in onions, rotten eggs, garlic and skunks (Christensen *et al*., 2009). Chlorpyrifos is often times combined with oily liquids before its application to crops or animals because it does not mix well with water.

It has been widely sold under various trademarks including Brodan®, Dursban®, Detmol UA®, Massacre®, Empire®, Dowco 179®, Eradex®, Equity®, Lentrek®, Lock-On®, Piridane®, Lorsbanv®, Stipend® and Pageant® (ATSDR, 1997). According to data releases by Environmental Protection Agency, approximately 2.2 million litres of chlorpyrifos were applied on a wide variety of crops, ranging from vegetables, soy, maize, peaches, cotton, nut trees and apple fruit between 2014 and 2018 (Orrantia, 2022).

Literature summary of health hazards associated with exposure to chlorpyrifos

The supposed role of a pesticide administered to an agricultural field is toxicity to the target pest organisms with minimum disruption to the environment (Rosell *et al.,* 2008), unfortunately this is not the case as most pesticides are non-specific and kill harmless organisms that are useful to the environment. Researches have shown Chlorpyrifos neurotoxicity effects on non-target species such as mammals, birds, fish and bees (Jabeen *et al.*, 2015; John and Shaike, 2015; Jaiswal *et al.*, 2017). Chlorpyrifos is absorbed into the body via the nose, mouth, and skin (Yurumez *et al.,* 2007). Highest levels of chlorpyrifos have been reported in human urine for 6-7 hours after oral dosing and 17-24 hours after skin contact (Alizadeh *et al.,* 2018).

Once in the body, the mechanisms of its toxicity include inhibition of acetylcholinesterase and disruption of the transmission of nerve signals (Koshlukova and Reed, 2014). The pesticide combines with acetylcholinesterase at nerve endings in the brain and nervous system and with other types of cholinesterase found in the blood. This allows acetylcholine to build up thus decreasing protective level of the cholinesterase enzyme (Koshlukova and Reed, 2014). Many unspecific signs and symptoms have been reported to appear within minutes to hours after exposure. Exposure to low concentrations can cause runny nose, tears, and increased salivation, increased sweating, headache, nausea, and dizziness. Exposure at high concentrations can cause vomiting, abdominal muscle cramps, muscle twitching, tremors and weakness, loss of coordination and blurriness or darkened vision. In severe cases, exposure can lead to unconsciousness, loss of bladder and bowel control, convulsions, difficulty in breathing, and paralysis even death (Eaton, 2008; Tan *et. al.,* 2009; Rush *et. al.,* 2010; Yu *et al.,* 2019, Ubaid ur Rahman *et al.,* 2021). Also, continuous exposure can cause skin and eye irritation and chronic kidney disease (Xu *et al.,* 2018, Yu *et al*., 2019). Studies have also revealed the exposure to chlorpyrifos as a

key factor in the delay of mental development in young children (US EPA, 2017); and a great hindrance to neuro-endocrine development in fetus and infants (Mascarelli, 2013, Grandjean and Landrigan, 2014, Burke *et al.,* 2017). Studies have indeed reported that prenatal and early childhood exposure to Chlorpyrifos, among others, is associated with indicators of delayed neurodevelopment (Lizardi *et al.,* 2008) and results from a longitudinal birth cohort study demonstrated that prenatal exposure to organophosphate insecticides such as Chlorpyrifos is negatively associated with cognitive development at 7-years of age (Rauh *et al.,* 2011). They reported evidence of deficits in 7-year working memory and full scale IQ scores as a function of prenatal Chlorpyrifos exposure. Working memory is one of the core processes of executive function. It encompasses the ability to memorize new information, hold it in short-term memory, concentrate, and manipulate information to produce results (Baddeley and Logie, 1999). Insufficient development of executive functioning during early childhood has been associated with an array of adverse outcomes including psychological issues (Tremblay, *et al.,* 2005) and a lack of school readiness (Blair, 2002). Other chronic health issues associated with Chlorpyrifos are summarised in Figure 1.

Overview of Chlorpyrifos usage and issues arising in Nigeria

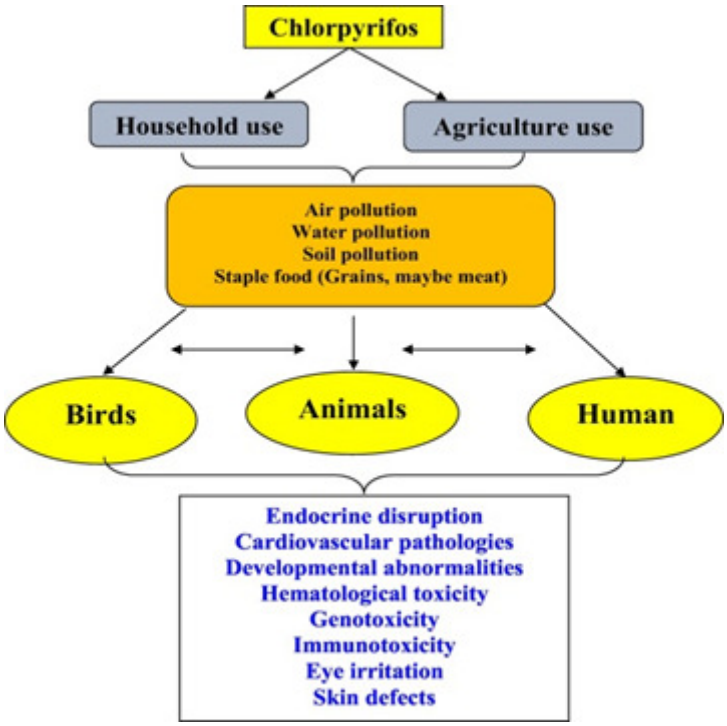


Figure 1. Hazardous impact of chlorpyrifos in animals (Source: Ubaid Ur Rahman *et al.*, 2021).

This synthesis is of information obtained from local newspaper publications, and online publications and journals (international and local) indexed in Google Scholar, Medlib, PubMed and Scopus. A total of fifty four (54) articles were reviewed for this narrative.

Isaa *et al*. (2016) investigated the perceptiveness of the properties and usability of pesticides in Kaduna and Ondo States of Nigeria. They reported that chlorpyrifos had the highest percentage usage by farmers of the studied insecticides, more popular than Cypermethrin, Dichlorvos, Carbofuran, Dimethoate, Cypermethrin+Dimethoate, and Aluminum phosphide, in that order. This was in line with a comprehensive study carried out in four states (Benue, Kano, Ebonyi and Oyo) in Nigeria reported in the book "Time for a detox" (Bollmohr, 2020). The findings of which indicate that chlorpyrifos was the most widely used pesticides of all forty sampled pesticides.

Isegbe (2016) also reported that dried beans exported to Europe were rejected due to high Maximum Residue Levels (MRLs) of cypermethrin, dichlorvos, dimethoate, chlorpyrifos, and diazinon. A couple of years later, Osesua *et al*. (2018) reported residues of chlorpyrifos in watermelon fruits grown in Birnin Kebbi, Nigeria. The unwashed watermelon fruits, detergent-washed, and tap water washed had mean concentrations of $0.114\pm0.006\ \mu g\ g^{-1}$, $0.006\pm0.002\ \mu g\ g^{-1}$ and $0.009\pm0.003\ \mu g\ g^{-1}$, respectively. The chlorpyrifos residue levels in the unwashed fruit exceeded the MRLs established by FAO/WHO. Nigeria has now adopted the European Union's standard of maximum residue levels (MRLs) tolerated in or on food. However, it is widely recognised that the country has trouble adhering to these, which directly impacts its export opportunities.

There are a number of worrying reports on acute poisoning due to pesticide contaminated food in Nigeria, a case in point being in Cross River State where ingestion of moi-moi and beans that were later confirmed to have with outrageously high levels of organophosphates (fenithrothion, chlorpyrifos) caused massive hospitalisations and deaths (Hopkins, 2008).

Of great concern is the fact that 40% of all the pesticide products registered in Nigeria have either been recalled or banned from the European market or are heavily restricted due to potential chronic health effects; environmental persistence; high toxicity for fish or bees; or insufficient data to uphold the principle of preventing harm. This 40% represents 57 active ingredients in 402 products that are still in use in Nigeria (Bollmohr, 2020; Abdulkareem. 2021).

Status of pesticide regulations enforcement in Nigeria and the ban of Chlorpyrifos

In Nigeria, the pesticide registration has been covered by among others the Drugs and Related Products Act (1996), the Pesticide Registration Regulations (2019), and the National Agency for Food, Drug Administration and Control (NAFDAC). NAFDAC and now the National Agency for Food and Drug Administration and Control Act Cap N1 Laws of the Federation of Nigeria (LFN) 2004 is mandated to regulate and control the manufacture, importation, exportation, distribution, advertisement, sale and use of Food, Drugs, Cosmetics, Medical Devices, Packaged Water, Chemicals and Detergents (collectively known as regulated products).

Due to outcries as a result of hospitalisations and deaths, in 2008, NAFDAC banned the sales and supply of thirty (30) pesticides, but not Chlorpyrifos. However, on March 7, 2022, receded its decision based on current global trends on application of harmful organic agricultural chemicals; continuous sensitisation by regulatory agencies like United State Environmental Protection Agency, Pesticide Action Network International, Alliance for Action on Pesticides in Nigeria (AAPN) and Non-governmental organisations (VON, 2022).

Elsewhere, Chlorpyrifos has been banned in Morocco, Saudi Arabia, Sri Lanka, Indonesia, Switzerland, United Kingdom, and China (ONSSA, 2020; PIC Database, 2021; UNEP, 2022; Switzerland, 2019). Other countries are restricting its usage and/or are in the process of phasing it out (Table 1).

Banning the use of the product is a good step but total compliance to its ban is a challenge that needs concerted effort to surmount. Federal government, regulatory agencies and Non-governmental organisations should work together to ensure total compliance. This review is in support of the ban and is aimed at creating awareness on the hazards of Chlorpyrifos and discussing ways to ensure compliance.

Discussion and recommendations to policy

The above synthesis has shown some of the serious health issues associated with the use of chlorpyrifos. The phasing out of chlorpyrifos in Nigeria and compliance to the ban will certainly not come easy, especially given its popularity among farmers. There is a big need to create awareness of chlorpyrifos' health hazards and its consequential ban amongst farmers. Most farmers especially those in the rural areas are not informed that the toxic organophosphate pesticide has been banned. Enlightenment campaigns and appropriately packaged messages to media houses to sensitize farmers and marketers of the product should be in the ban implementation programs. Also, there is need for recruitments of agriculture extension workers in different localities of the

Table 1. Progress made towards phasing out Chlorpyrifos elsewhere in the world (Source: UNEP, 2022; India, 2020)

Countries	Status
Canada	Inability of registrants to update and produce health risk assessment data
Egypt	Chlorpyrifos ban will take effect at the close of 2022 with a restriction on its usage for cotton
New Zealand	Chlorpyrifos and Chlorpyrifos- ethyl are currently under reassessment for use as PPPs. Approvals for use in non-plant based protection, such as veterinary care and in urban pest management approvals were revoked in 2016
Australia	Chlorpyrifos and Chlorpyrifos- ethyl is currently under review on toxicology related concerns, work health and safety, chemistry, residues and environment.
Thailand	Chlorpyrifos is controlled under the Hazardous Substance Act. Public Health and Household pesticides that have chlorpyrifos as active ingredient are classified as type 4 hazardous substances (under the authority of Thai FDA) and their production, importation, exportation or possession is forbidden.
India	In India, chlorpyrifos' registration is with strict scrutiny and regulatory data requirement under the scheduled act for safety is highly adhered to.

country to give trainings to farmers and monitor them from time to time to see if they are complying to laid out rules and regulations.

Other draw-backs that may lead to non-compliance to the phasing out of the pesticide are its illegal import into the Nigerian market through porous land borders. Porosity of land borders are enabled by corrupt security official who place financial gains above service to their country. It is recommended that proper border checks and management be instituted to ensure that banned pesticides are not smuggled into the country through concerted efforts by the government and Head of security outfits concerned (such as the Nigerian Custom Services) (Agency report, 2021). Also, there should be series of trainings and regular consultations with operating officers. This will enable them to know their challenges and fix them. The security personnel should also be equipped with sophisticated weapons, man power and monitoring equipment like vehicles for routine check purposes.

The implementation of the ban of chlorpyrifos in Nigeria may also be retarded in practice due to lack of transparency and availability of effective and safe alternative pesticide in the market. If a pesticide is phased out of the market, the decision makers may offer a grace period of 6-12 months to consumers for the complete removal of the remaining stock, within this period, there is need to introduce farmer and marketers to alternatives that are as effective but safe and environmentally friendly. In the absence of such alternative, the banned chemical(s) will always stay in clandestine circulation (APC, 2021). The use of low toxicity or low-risk pesticides should especially be encouraged. Low risk pesticides are pesticides with the signal word of "CAUTION" instead of "DANGER" or "WARNING" (NPIC, 2021). Farmers need to be educated on the need to look out for these signs inscribed on the packs of these chemicals. Pesticides with the sign "CAUTION" are usually considered safer to use. The relevant authorities including NAFDAC, National Environmental Standards and Regulations Enforcement Agency (NESREA), and the Federal Ministry of Agriculture and Rural Development (FMARD) should work together to enforce the ban and liaise with their counterparts from neighboring countries to tighten their border security. They should also expedite the scrutiny of lists of prohibited pesticides ingredients and ensure that such toxins are not used in the preparation of any other agricultural chemical. Lastly, agro-allied chemical sales agents in open markets across Nigeria should be registered with appropriate regulating agents and a database of such individuals generated for ease of monitoring.

Conclusion

The ban on Chlorpyrifos in Nigeria is a prudent decision and should be given the needed support by the public, governmental and government institutions, and the private sector to make enforcement feasible and permanent.

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