Chapter 21
Total Diet Study in Cameroon—A Sub-Saharan African Perspective

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Introduction

Little is known about the acute or chronic dietary exposure to toxic chemicals in sub-Saharan Africa. In these countries, except for some high-value exported products, few foods are regularly monitored for toxic chemicals, and no country has an operational monitoring program for chemicals in food. There is an obvious interest of the authorities to protect consumers faced with various food hazards. However, the means and mechanisms of implementation are not very efficient and do not always meet international requirements for exportation of foodstuffs. The following difficulties are often encountered: (i) inadequacy of the legislative authority which do not meet current international recommendations, (ii) absence of a disease alert

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and surveillance system, (iii) absence of a communication and promotion system, (iv) little or no application of good practices such as Good Manufacturing Practices and Good Agricultural Practices, (v) weak technical and analytical capabilities and capacities of laboratories, and (vi) absence of risk analysis-based approaches for food safety issues for the national population. All these difficulties contribute to ineffective coordination of food safety management actions. Moreover, rapid urbanization, industrialization and development in Africa have contributed to the emergence of man-made environmental hazards with harmful effects on the environment, food and health. These critical contributors to the continent's disease burden have to be addressed.

According to United Nations Environmental Programme (UNEP) and World Health Organization (WHO), the main sources in Africa of such persistent hazards are agriculture, artisanal or industrial mining, manufacturing, electricity and electronic production, certain imported products, vector-control purposes, stockpiles of obsolete pesticides, and uncontrolled combustion processes. These new and emerging environmental threats, including persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), dioxins and furans, as well as heavy metals, need to be better managed [1, 2].

Nweke et al. in 2009 [3] reviewed published data related to heavy metals (mercury and lead), pesticides, and industrial air pollutants, and pointed out the serious implication of these environmental health hazard releases for Africa's disease burden.

Large quantities of electrical devices and other electronic waste (e-waste) end up dumped in developing countries. According to Frazzoli et al. in 2010, [4] e-waste scenarios such as illicit dumping may impact on the environment and the food chain, thus eliciting a widespread and repeated exposure of the general population to mixtures of toxicants, mainly POPs, heavy metals, brominated flame retardants, and polycyclic aromatic hydrocarbons. The authors conducted a diagnostic risk assessment, which demonstrated how e-waste exposure poses an actual public health emergency for present and future generations to come.

Some sub-Saharan Africa countries, such as Senegal, Burkina Faso and Cameroon, have undertaken identification and quantification of their dioxins and furans releases. The results obtained showed the need to assess human exposure to these POPs and also to take necessary measures to reduce and eliminate these pollutants through a monitoring program. The level of dioxins, PCBs and hexachlorobenzene (HCB) was assessed in egg samples collected from free-ranging chickens in the neighborhood of the waste discharge, suspected as a potential source of POPs in Senegal. The results showed a dioxin content 11 times higher and PCB content 1.7 times higher than the European normal background values [5]. This raises the question of the level of exposure of people living in such an environment.

Several African countries have undertaken actions to eliminate and/or manage obsolete pesticides and POPs, according to recommendations of UNEP [6–8]. The major problems that arise include the identification of stockpiles, their safe storage and transport and their destruction in accordance with environmental and human health protection requirements.

Another potential source of human exposure to toxic chemicals is the use of DDT in malaria vector control, notably in Africa where use has doubled between 2000 and 2006. The Conference of the Parties to the Stockholm Convention on POPs continues to allow the use of this persistent organic pesticide. However, in areas where DDT and related pesticides have been used for disease vector control in Africa, high residue levels of these pesticides have been found in human milk. Considering the potential risks to infants through breastfeeding, the incorporation of such a risk assessment into the WHO Pesticide Evaluation Scheme has been suggested [9].

The WHO, through its Global Environmental Monitoring System/Food Contamination Monitoring and Assessment Programme (GEMS/Food), collects information on levels of POPs in foods, including human milk. According to their report, biomonitoring of human milk data can provide important information on the exposure of mothers through food as only traces of POPs appear in air and water [10]. Moreover, it has been reported in some African countries that mosquitoes have developed resistance to DDT. Considering the above reasons, it is important to develop alternatives to DDT that can effectively control vector disease [11].

In sub-Saharan Africa, pesticides are mostly used in plantations for export crops. Formal or informal agriculture has increased in urban and peri-urban areas with a growing use of chemical inputs, which could have harmful effects for human health and environment [12]. According to the agricultural experts, risks linked to the use of pesticides could be attributed to: (a) not following correct applications procedures, (b) off-label use of pesticides to treat food others than those registered for use for that product, (c) the use of pesticides for hunting or fishing, (d) the reuse of pesticide packages, (e) disregard for withholding periods prior to harvesting of crops, and (f) the circulation of fraudulent imitations of approved pesticides. They also argued that the half-lives of almost all approved pesticides are short, approximately 2 months; therefore, these compounds should not be easily found in food as consumed. Furthermore, the experts suggest that acute exposure to pesticides is most probably due to cases of dermal uptake and/or inhalation during application because of poor agricultural practices. It may also be due to accidental, intentional or criminal ingestion.

In a concrete way, studies on commonly consumed beverages were conducted in Nigeria to investigate their concentration of heavy metals. The results showed high concentrations (in mg/L) of copper (0.04–3.55), selenium (0.07–1.67), arsenic (0.002–0.261), total chromium (0.01–0.59), cadmium (0.003–0.081), and lead (0.001–0.092). The resulting mean and median concentration values of copper, selenium, cadmium, and lead, exceeded the Maximum Contaminant Level set by the United States Environmental Protection Agency (USEPA) [13–15]. This finding highlights the need to estimate the dietary exposure of the population and to implement a monitoring system to reduce and eliminate such contaminants in beverages.

Natural occurring food toxins are other threats to human health. An outbreak of Konzo Disease, which causes paralysis in both legs, has been attributed to dietary exposure from insufficiently processed cassava, containing high concentrations of cyanogenic compounds. Such outbreaks have been reported in some regions of

Cameroon and the Central African Republic [16]. The extent of chronic dietary exposure of the population has been raised and needs to be studied, especially in African regions where the dietary staple is cassava tubers.

In addition, concerning trade of food products originating from Africa, some of them have caused economic losses as a result of rejected food exports due to shortcomings in food safety [17]. Groundnuts coming from Africa were frequently rejected at the European border due to their contamination with mycotoxins. The World Trade Organization (WTO) framework for international trade, under its Agreement on the Application of Sanitary and Phytosanitary Measures, now requires that health and food safety decisions be based on sound scientific risk assessments, including food products exported from African countries or from other regions of the world.

These few examples collected in various sub-Saharan Africa reveal that food may contain toxic substances, which have potential adverse health effects. Given these concerns, the African countries have to implement means and necessary mechanisms to assess these potential risks, manage such risks, and effectively communicate any risk; the main purpose being to prevent and reduce it, both nationally and internationally.

A total diet study (TDS) is a key risk assessment tool, enabling estimates of chronic dietary human exposure to chemicals in a most cost-effective way. The WHO recommends the implementation of a TDS in developing countries and encourages it via inter-country collaborations to ensure a safe food supply and a nutritionally adequate diet [18]. A TDS can also include the intake assessment of selected nutrients, especially micronutrients like iodine, iron, and zinc, which may be deficient in the diet and are known to cause numerous health disorders in African countries. The results thus obtained would provide pertinent information for various programs, notably in food fortification and supplementation.

Yaoundé-Cameroonian Experience on TDS

The Third International TDS Training Course and Workshop in Paris in 2004 targeted French-speaking participants from sub-Saharan Africa [19]. Following this training course, a TDS was initiated in 2006 by the Centre Pasteur du Cameroun in Yaoundé, Cameroon, with the support of the Food and Agriculture Organization of the United Nations (FAO) and the French Food Safety Agency (Agence Française de Sécurité Sanitaire des Aliments, AFSSA) [20]. The objective of the Cameroonian TDS was to assess the chronic dietary exposure of the inhabitants of Yaoundé to residues of the main pesticides used in the country. Yaoundé, the capital, is supplied with foods coming from all regions of the country and thus offers good sampling facilities representing the country's food supply. In addition, it is characterized by a heterogeneous population with a very high diversity in terms of food origin and habits.

Methods

Consumption Data

In Cameroon, as in some other sub-Saharan countries, data from household budget surveys are available. The Second Cameroonian Household Budget Survey [21] was used to derive the food consumption data needed for the TDS. Expenditures for 223 food products of households from Yaoundé (1,095 households) were extracted and transformed to 'foods as purchased' per adult equivalent (ae) using a price database and age and sex specific ae factors [22]. The amount of 'foods as consumed' expressed in g/day/ae was obtained by applying additionally edible and yield factors, which were obtained either from literature data or from measurements obtained during the study. In order to eliminate biases caused by an under- or over-reporting, only households for which the energy intake per ae was estimated as being within 1,200–3,500 kcal/day were included in the study population. When taking into account the sampling weights from the original database, 557 households remained in the analysis which corresponded to the 142,185 households of Yaoundé.

Food Selection

The foods for the TDS were selected if the food was consumed in amounts over 1 g/day/ae in the overall population or by 15 % of the household consuming this food; or if it was consumed only seasonally; or if it represented a high potential risk regarding pesticide contamination due to known local practices. For examples, fishing with pesticides or preservation of Kola nuts or dried fish with pesticides have been reported. Initially, a food list of 86 food products was selected, which were further clustered into 63 food items by grouping similar agricultural practices or processing methods in respect to pesticide usage.

Sample Collection and Preparation of Foods 'As Consumed'

A specific sampling plan for food was elaborated, which was refined after pretesting and peer review. For fresh and semi-processed foods, representativeness of food samples was ensured by considering the origin of production, the markets and the usual form for consumption. Seven wholesale or intermediate markets distributed all over Yaoundé, representing the city's major food outlets, were selected to obtain fresh, processed or frozen foods from all origins, including local, provincial and foreign sources. Peri-urban and urban farming products were purchased directly from producers in and around Yaoundé. Manufactured products and bakery products were purchased in the main supermarkets and bakeries of the city. A composite sample of tap drinking water from 12 districts distributed over the city was prepared. The same was done with drinking water collected from 12 underground sources. An individual food approach method was used to prepare food samples 'as consumed' using local habits and recipes, but without added salt and spices. Due to budgetary constraints, some foods were combined into one composited sample. Stainless steel tools were mainly used, except for large aluminum cooking pots for leafy vegetables preparation. Vegetables and fruits were not systematically washed, as this is the observed norm in the vast majority of households where tap water is not available. Tap water was used for cooking. Samples were homogenized, and then stored at −20 °C in plastic containers for solid foods or in glass bottle for liquids, until their transport at low temperature to the laboratory for chemical analysis.

Purchased food samples were put together in several steps to obtain the final composite sample for analysis. They were grouped according to purchase site, market share and variety distribution before preparation. In most cases, another composite mixture was prepared based on the proportion of consumption of each preparation type. In the absence of information about market share or ratio of consumption data, equal portions of samples were combined within a composite sample.

Pesticides Selection

The pesticides for the TDS were selected if they were part of the GEMS/Food comprehensive list, including banned pesticides and other organochlorine compounds [23]; or on the list of approved and marketed pesticides in Cameroon in 2002, 2003 or 2004 (Ministère de l'Agriculture et du Développement Rural, MINADER); or on the list of approved pesticides of 2005 (MINADER); or if they have a low Acceptable Daily Intake (ADI). In all, 46 pesticides were selected for the TDS. Most of the selected pesticide residues were analyzed in all composite samples. Dithiocarbamates (DTC) (= mancozeb, maneb, ethylenethiourea, etc.) were analyzed only in vegetables and fruit consumed raw, such as tomatoes, cabbages, carrots, lettuces, cucumbers, aromatic herbs, bananas, mangoes, papaws, oranges, tangerines and pineapples. Glyphosate was analyzed only in the composite samples of rice, cassava tubers, cassava flour, and desiccated cassavas, unripe plantains, potatoes, cocoyam, yam, tomato, pineapple, and aromatic herbs. Chlordecone was analyzed in nine composite samples, i.e. tomato, carrot, cassava tubers, sweet potato, cocoyam, yam, taro tuber, and dried shelled groundnuts, all of which have been known to be potentially contaminated with this pesticide.

Chemical Analysis

The pesticides analyses were carried out by the French laboratory Qualtech accredited by the French Accreditation Committee (COFRAC) for the 99.2 'pesticides residues' program according to the standards NF EN ISO/CEI 17025. In-house methods were based on French and European standard (NF EN 12,393; NF EN 12,396–3). These operating conditions allowed a limit of detection (LOD) of 0.005 mg/kg and a limit of quantification (LOQ) of 0.010 mg/kg for the multiresidue method; for glyphosate and its metabolite (AMPA), LOD and LOQ were 0.005 and 0.010 mg/kg, respectively; for dithiocarbamate residues, LOD and LOQ were 0.050 and 0.100 mg/kg, respectively; for chlordecone, the LOD was 0.0008 mg/kg and the LOQ was 0.0020 mg/kg. Samples were analyzed in duplicate.

Dietary Exposure Estimation

For the exposure assessment, it is necessary to assign a numerical value to contamination data that are less than the LOD (i.e. non-detectable) and to 'trace' contamination data between the LOD and the LOQ. Two estimates are provided according to international recommendations [24], the first resulting in a lower bound exposure and the second in the more conservative estimate of exposure. The lower bound estimate assigns for each sample a zero value if below the LOD and the LOD value if between LOD and LOQ. The upper bound estimate assigns each sample the LOD value if below the LOD and the LOQ value if between LOD and LOQ. Dietary exposures were calculated by multiplying the TDS food consumption data (including ready-to-eat foods and light meal consumption) obtained from the 557 adult-equivalents with the TDS food concentration data (including the estimated concentrations of ready-to-eat foods and light meals), leading to 557 data of exposure to the 46 tested residues. The mean and quantiles were calculated for each pesticide residue using the sampling weight of each household from the original database. The estimates were finally reported in μg/kg bw/day assuming a 60 kg body weight basis.

Results

Food Consumption

The amount of foods 'as consumed' without drinks is estimated on average to be 863 g/day/ae. Cooked rice is by far the most consumed food with 201 g/day/ae, followed by boiled fresh cassava tubers (73 g/day/ae), boiled unripe plantain (47 g/day/ae), bread (47 g/day/ae) and others foods.

Pesticide Residue Data

Of the 46 pesticides analyzed, only nine pesticides were detected, namely atrazine, chlorothalonil, cypermethrin, deltamethrin, endosulfan, malathion, pirimiphos-methyl, DTC and chlordecone. These pesticides were detected in nine

Table 21.1 Estimated exposure to pesticide residues of the Yaoundé population based on the 2006 Cameroon total diet study (lower and upper bound estimates in μg/kg bw/day)

Pesticides residues	Mean	95th percentiles	Acceptable daily intake
Atrazine	0.001–0.098	0.002–0.163	35[a]
Chlorothalonil	0.001–0.098	0.004–0.165	15[b]
Cypermethrin	0.027–0.121	0.074–0.211	50[c]
Deltamethrin	0.006–0.103	0.018–0.170	10[c]
Endosulfan	0.011–0.105	0.031–0.174	6[c]
Malathion	0.008–0.169	0.228–0.346	30[d]
Pirimiphos methyl	0.031–0.121	0.086–0.206	4[e]
Chlordecone[f]	0.002–0.005	0.006–0.012	0.5[g]
Other residues[h]	0.000–0.097	0.000–0.163	–
Dithiocarbamates[f] (DTC)	0.298–0.342	0.941–0.973	50[b]

[a] US Environmental Protection Agency, 2007
[b] Agence Française de Sécurité Sanitaire des Aliments, 2006
[c] International Programme on Chemical Safety (IPCS) (2007)
[d] European Food Safety Agency, 2006
[e] European Food Safety Agency, 2005
[f] Analyses performed on selected composite samples
[g] Agence Française de Sécurité Sanitaire des Aliments, 2003
[h] Aldrin, azoxyistrobine, bitertanol, cadusafos, carbofuran, chlorpyrifos ethyl, chlorpyrifos methyl, cyproconazole, DDT complex, diazinon, dieldrin, dimethoate, ethoprophos, fenamiphos, fipronil, HCH, heptachlor, heptachlor epoxide, hexachlorobenzene HCB, lambda-cyhalothrin, metalaxyl, methyl-parathion, monocrotophos, parathion, pendimethalin, permethrin, profenofos, propiconazole, pyrimethanil, spiroxamine, tebuconazole, terbufos, triadimefon, tridemorph, trifloxystrobine

of the 63 composite samples. These were the raw or cooked aromatic herbs, a composite of basil, parsley and celery (atrazine 0.02 mg/kg and DTC 8.66 mg/kg), boiled Ndole/Keleng Keleng which are local leaves (chlorothalonil 0.02 mg/kg and endosulfan < LOQ), raw and cooked fresh tomatoes (cypermethrin 0.05 mg/kg, endosulfan 0.02 mg/kg and Chlordecone 0.004 mg/kg), bread (deltamethrin < LOQ, malathion 0.05 mg/kg and pirimiphos-methyl 0.02 mg/kg), wheat doughnut (malathion 0.04 mg/kg and pirimiphos-methyl 0.02 mg/kg), cakes and pastries (malathion 0.05 mg/kg and pirimiphos-methyl < LOQ), boiled wheat pasta (pirimiphos-methyl < LOQ), pineapple (DTC < LOQ), papaya (DTC 0.14 mg/kg). No tested pesticide residue was detectable in drinking water.

Dietary Exposure Assessment

Multiplying the TDS food consumption with the TDS food concentration data provides the estimates of the dietary exposure to pesticide residues in the population of Yaoundé. The results are shown in Table 21.1.

Risk Characterization

The highest dietary exposure estimate was 0.941–0.973 µg/kg bw/day at the 95th percentile of exposure to DTC, which is well below the ADI of 30 µg/kg bw/day, [25] equivalent to 3.24 % of the ADI. For the pesticides for which at least one analysis was > LOD, the mean exposures using the 'upper bound estimate represent from 0.24 % (cypermethrin) to 3.03 % (pirimiphos methyl) of their respective ADIs. Using the 95th percentile ('upper bound' estimates), these relative proportions reached 0.42 and 5.1 % of their ADIs, respectively.

Discussion

While the study conclusions are limited to the population of Yaoundé, this city is a melting pot of the numerous ethnic groups of the country and is supplied with food sourced from the whole country. It can, therefore, be regarded as an indicator of the likely mean level of pesticide residue exposure of Cameroon in general. For this TDS, there was no valid individual food consumption survey available. Therefore, a household budget survey database with expenditure data was used to estimate individual food consumption, after several assumptions and transformations. However, because of the very low level of contamination observed, these approximations have little significance on the final conclusions of the study.

Pesticide residues were generally undetectable with the analytical methods used in this study. Only 9 samples out of 63 showed a result greater than the LOD for at least one pesticide residue. Among these nine composite foods, four were wheat-based (bread, wheat doughnuts, cakes and pastries, and pasta) and gave quantified levels of pirimiphos methyl or malathion. Wheat is not cultivated in Cameroon, and thus the contamination occurred probably abroad (agricultural crops or post-harvest grain treatment) or during storage after importation. The five other foods for which at least one result was greater than LOD (i.e. Ndole/Keleng Keleng, fresh tomatoes, papayas, pineapples, and aromatics herbs) were produced locally, notably in urban and peri-urban areas.

In the present TDS, no systematic bias was observed that could explain the low levels of pesticide residues (e.g. the destruction of pesticides residues due to an improper preservation before analysis). The rare residue levels found in the present study could also be explained by the overall low pesticide use in agriculture in Cameroon, in particular because of the lack of awareness and/or probably high price of these substances according to users. The observed low level of contamination levels resulted in an estimated exposure far below most ADIs, even for the highly consumed foods and using the most conservative 'upper bound' residue assumption. In conclusion, the chronic dietary exposure to the various pesticides evaluated within the framework of this TDS is low for the inhabitants of Yaoundé. These results are reassuring and seem to be in concordance with the opinions of the experts of the agricultural sector in Cameroon.

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