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*Full Length Research Paper*

# Assessment of pesticide residues and trace element contamination in market gardens of Togo

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**All intensive agriculture, like periurban agriculture, uses massive inputs such as agrochemicals. This study aims to assess the environmental impacts of agrochemical use in periurban agriculture in Togo. It was based on the chemical analyses of soil, water and vegetable samples. These analyses were carried out by gas chromatography on extracts from soil, water and vegetable samples. In soil samples, the concentrations of pesticide residues are lower than 20 µg/kg of dry material. For water samples, contamination levels vary from 0.02 to 1.1 µg/L of dry material with the highest levels for metalaxyl M (1.1 µg/L) and for dimethoate (1 µg/L). In vegetables, the concentrations measured are between 0.01 and 0.1 mg/kg of dry material. All these concentrations are affected by a positive factor of the maximum limits of residues. These agrochemicals, coupled with periurban environmental management led to the high concentrations of trace elements. Lead and cadmium concentrations in water are 10 and 21 times respectively higher than the maximum concentration allowable for drinking water by the WHO. The study showed that inappropriate use of agrochemicals in Togolese periurban agriculture creates ecological disturbances that could affect produce quality.**

**Key words:** Togo, periurban agriculture, agrochemicals, pesticide residues, trace element.

## INTRODUCTION

Periurban agriculture has known very rapid growth in West Africa since Independence and allows meeting the supply of urban centres with fresh vegetables (Delamarche, 2007; Mougeot, 2005; Bouzid et al., 2005; Pélissier, 2000). It is also a catalyst for job creation and generates substantial income for different stakeholders. Nevertheless it uses many inputs (such as agrochemicals) that can have negative effects on the environment and the quality of the product as noted by Delamarche (2007), Koc et al. (2006), Dièye (2006), Bouzid et al. (2005), Midmore and Jansen (2003), Agunwamba (2001), Bahri (2001) and Gerstl (2001).

In Togo, studies carried out to the present only deal with agricultural production and its commercial implications (Kanda, 2003; Talaki, 2002; Schilter, 1991a, b). These studies have also tackled the use of pesticides, substances which have become indispensable to most agricultural practices, without assessing their environmental implications.

This study aims to deepen knowledge on the eventual drawbacks of the use of agrochemicals in the gardening agriculture in Togo on the environment and the quality of vegetable products.

## MATERIALS AND METHODS

### Research on pesticide residues

#### *Vegetable, soil and water sampling*

Vegetable, soil and water samples were taken in market garden

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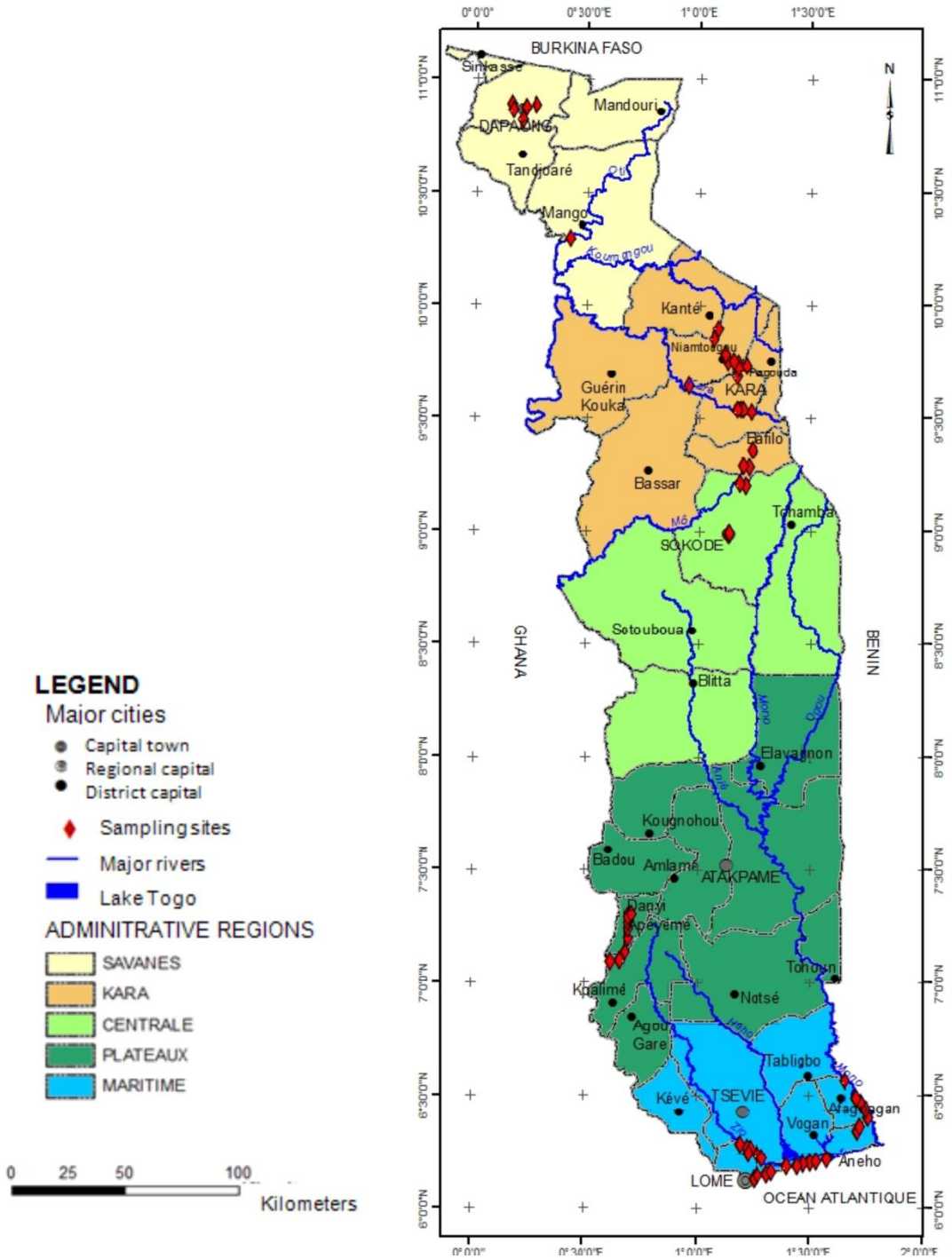


**Figure 1.** Sample sites in the country (red lozenges).

fields all over the country (Figure 1). In the field, a sample site measuring 20 cm × 20 cm (Figure 2) was individualised (Savadogo et al., 2006) and its geographic coordinates taken by a GPS™. Only edible parts of vegetables that are available all year round and were ready for market were sampled (Table 1). For every species, samples were taken at five (5) random points in the square areas and mixed to constitute a composite 1 kg sample. The samples were washed with tap water and packed in aluminium paper prior to treatment with purified petroleum ether. They were then labelled and conserved in a refrigerator.

In each square, elementary soil samples were taken between a 0 and 20 cm depth and mixed to constitute a composite sample of 2 kg each. The samples were dried at 25 to 30°C and sieved. 250 g of the fine fraction (under 2 mm) were conserved away from light for later analysis. One litre of water was sampled using washed and decontaminated amber glass bottles (Keith, 1990; Saliot et al., 1992).

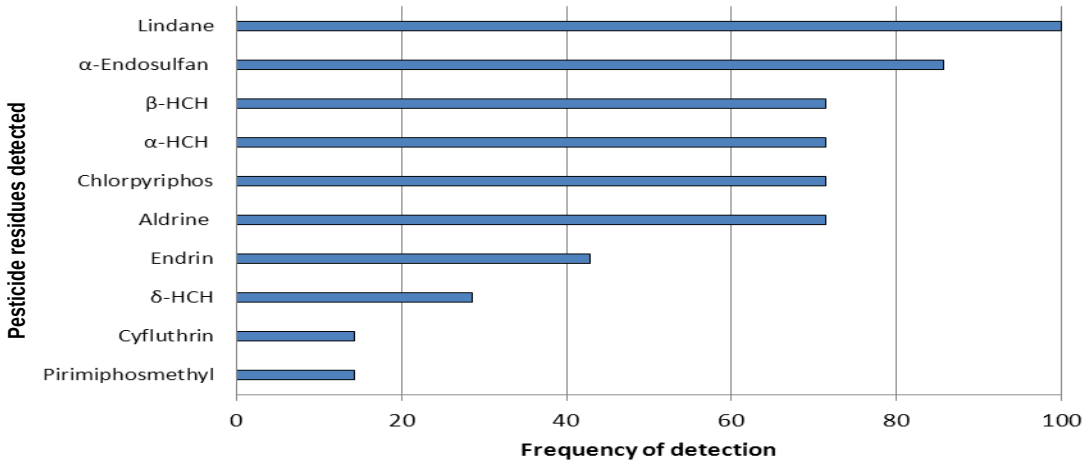


**Figure 2.** Presence of pesticide molecules in vegetable samples.

***Pesticide residue analysis***

Pesticide residue extraction and analysis concern active molecules (such as organochlorines, organophosphorines, carbamates and pyrethrinoids) most used in Togo (Kanda, 2011). Analytical grade reagents and solvents supplied by BDH Laboratory Supplies (England) were used.

20 ± 0.1 g of prepared matrix was weighed and introduced in a 100 ml centrifuge tube. 40 ± 0.2 ml of ethyl acetate was added and macerated for 30 seconds. Anhydrous sodium sulphate (20 ± 0.1 g) and sodium bicarbonate (5 ± 0.1 g) were added and the mixture was macerated for 90 s. The resulting solution is centrifuged at 2500 rpm for 5 min. A 10 ml aliquot is placed in a 100 ml round-bottomed flask and evaporated to 2 ml. The residue obtained is dissolved in 2 ml of ethyl acetate before analysis. The extract was kept frozen until the end of the quantitative study.

The analyses of residues of pesticides were carried out using a Varian CP 380 GC chromatograph equipped with a capillary column (30 m × 0.25 mm). Columns VF-5 ms and VF-1701 respectively were used for the quantification of organochlorinated and of organophosphorus compounds.

The identification of pesticides was done by calibration with standard solutions and comparison of retention indices of the standard solution peaks with those of the samples (vegetable, soil and water). The determination of pesticide residue concentrations was made from standard calibration curve solutions. These curves were established by tracing peak areas in accordance with the concentration of analysed pesticide. A correlation coefficient superior to 0.99 was obtained.

**Trace element investigation**

***Vegetable and water sampling***

Vegetable samples were taken under the conditions mentioned above. To assess the migration and accumulation of trace elements in the plants, the roots, stems and leaves of some species were sampled, packed in plastic bags and labelled. For each species, five (5) random samples were combined to form a composite sample. After, all samples were immediately transported to the laboratory. In addition, eight (8) composite water samples were collected in the coastal market garden fields (piezometers) or in the Zio river at Agoènyivé in polystyrene bottles that were previously cleaned with 10% nitric acid and thoroughly rinsed with distilled water (de Mora and Harrison, 1983).

***Pre-treatment of samples***

The vegetable samples were washed with tap water, rinsed with distilled water, weighed and dried in an oven at 70°C for 72 h. The resulting dry material is weighed and then ground to a fine powder in a porcelain mortar. 2 g of the fine powder were introduced in a Teflon box, moistened with a little distilled water and then subjected to acid hydrolysis using a mixture of 10 ml of hydrogen peroxide (9%) and 6 ml of concentrated nitric acid. The Teflon box containing the dissolved sample is closed with a watch glass and heated on a sand bath for about 1 h 30 min at about 150°C. The pellet obtained after heating was dissolved in 2 ml of 10% $HNO_3$ and reheated. After cooling, the solution obtained after acid digestion is transferred to a 50 ml flask which was then filled with deionized water to the mark. After homogenization, the solution was filtered through a Whatman filter paper. The filtrate is collected in a 125 ml bottle which was then tightly closed. The blank is prepared from 6 ml of concentrated nitric acid.

For the water samples, three drops of 1% $HNO_3$ were added to dissolve complex metals and analyzed without further treatment. The water was measured directly without treatment.

***Preparation of standard solutions***

The determination of a metal ion concentration by spectrophotometry is carried out after calibration of standard solutions. The concentrations of chosen standard solutions must lie within the ranges of the solutions to be analyzed. Standard solutions are obtained by diluting stock solutions supplied by Merck K Ga A.

***Determination of trace elements***

Trace element analysis was performed by atomic absorption spectrophotometry using a Thermo Electron Corporation S Series AA Spectrometer. The operating principle is based on the absorption of a beam of monochromatic light of given wavelength by a chemical when the latter is sent into an atomic vapour obtained by spraying into a flame. An aqueous solution containing metallic ions is vaporized into the flame to give neutral atoms. These atoms, by absorption of light rays of specific wavelength attain a higher

**Table 1.** Analysed vegetable species.

| Species | Families | Samplings | Samplings for pesticide residues research | Samplings for trace elements research |
|---|---|---|---|---|
| *Beta vulgaris* L. | Chenopodiaceae | Tuber | + | |
| *Allium cepa* L. | Alliaceae | Bulb | + | |
| *Brassica oleracea* L. var. *botrytis* | Brassicaceae | Inflorescence | | + |
| *B. oleracea* L. var. *capitata* | Brassicaceae | Leaf (stem, root) | | + |
| *Capsicum annuum* L. | Solanaceae | Fruit | + | |
| *Capsicum annuum* L. | Solanaceae | Fruit | | + |
| *Corchorus olitorius* L. | Tiliaceae | Leaf (stem, root) | + | + |
| *Daucus carota* L. | Umbelliferae | Tuber | + | + |
| *Lactuca sativa* L. | Asteraceae | Leaf | + | + |
| *Phaseolus vulgaris* L. | Papilionaceae | Fruit | | + |
| *Lycopersicum esculentum* L. | Solanaceae | Fruit | + | |
| *Solanum macrocarpum* L. | Solanaceae | Leaf (stem, root) | | + |

+: Concerned species and samplings.

energy level. By measuring the light intensity before and after its passage through the atomic vapour, the concentration of the solution under study is determined. To attain this objective, the beam of incident light must be sufficiently intense.

Concentrations of trace elements were determined and expressed in mg/kg for vegetable samples and in mg/L for water samples.

#### Statistical analysis and calibration

The different results were processed using Microsoft Excel Software™. Descriptive statistics (number of observations, percentage detection, maximum, average and median values) were calculated.

Significant tests were carried out using the analysis of variance (ANOVA) of the statistical package for social sciences (SPSS Version 17) computer program.

The results marked as "traces" or "not detected" were replaced by zero. The objective was to determine whether the pesticide residues and trace elements in vegetables, soil and water samples could be risky to human health. The benchmark references used are those of the WHO (1993, 1998) for pesticide residues in drinking water and vegetables, and for trace elements Public Health Council of France (1996), FAO and WHO (2001), and European Commission (2001) standards were used for cadmium and lead. For copper and nickel, data from Kabata-Pendias and Pendias (2001) were used.

Certified standards (Perkin, 1999) of 100 ppm were used to build calibration curves for each metal. Detection limit was established for each element as estimated from the variance of the zero ordinate for the calibration data of each metal.

## RESULTS

### Pesticide residue contamination

Analyses of vegetable samples reveal contamination by different groups of pesticides. These are mostly organochlorines (Figure 2) such as lindane (100% detection), α-endosulfan (85.71%), α-HCH, β-HCH, chlorpyriphos and aldrin. These molecules are found in at least five (5) vegetable species (Table 2).

Some examples of the mean concentration coefficient and the maximum allowed residue limits are shown in Table 3. The concentrations of α-endosulfan, lindane, chlorpyriphos, aldrin, α-HCH and β-HCH were analysed with coefficient 1.5 to 10 in *Lactuca sativa*. In *Daucus carota* and *Corchorus olitorius*, α-endosulfan was analysed with coefficient of 2. *Capsicum annuum* contains α-HCH and β-HCH with coefficient of 5.

For all pesticide molecules investigated, the concentrations are less than 20 mg/kg of dry material. These molecules were herbicides (56.76%), insecticides (32.43%) and fungicides (10.81%) (Table 4).

The analyses revealed that water in the market garden fields is contaminated by pesticides (Table 5). Different molecules of pesticides were detected but all were under 0.05 µg/L. Some pesticides such as metalaxyl M (0.06 µg/L and 1.1 µg/L) and dimethoate (1 µg/L) were detected in larger concentrations.

### Trace element contamination

Trace element accumulations vary with vegetable species (Figure 3). Of all trace elements investigated, copper content is highest in all species. Its average concentration ranges from 1.86 to 9.32 mg/kg of dry matter. Nickel and lead are noted in some species such as *C. olitorius*, *Brassica oleracea* var. *capitata*, *C. annuum*, *Phaseolus vulgaris* and *Brassica oleracea* var. *botrytis*. Nickel concentrations range from 0.238 to 1.509 mg/kg. Lead is detected in doses from 0.171 to 4.006 mg/kg.

The mean levels of trace elements in different Vegetable species and the over-concentration factors (CF) where appropriate are presented in Table 6.

**Table 2.** Mean concentrations of pesticide residues in vegetable species.

| Vegetable species | Mean concentration and Maximum residues Limits | Pesticides residues mean concentration (mg/kg) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | α-Endosulfan | Lindane | Chlorpyriphos | Aldrin | Endrin | α-HCH | β-HCH | δ-HCH | Cyfluthrin | Pyrimiphos-methyl |
| *A. cepa* | TM | 0.06 | 0.05 | 0.05 | 0.055 | 0.01 | 0.1 | 0.1 | 0.01 | - | - |
| | LMR | 0.1 | - | 0.2 | - | 0.1 | - | - | - | 0.2 | - |
| *L. sativa* | TM | 0.075 | 0.05 | 0.075 | 0.05 | 0.01 | 0.1 | 0.1 | 0.01 | - | 0.05 |
| | LMR | 0.05 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | - | 0.05 |
| *C. annuum* | TM | 0.05 | 0.05 | 0.05 | 0.05 | - | 0.1 | 0.1 | - | - | - |
| | LMR | 0.05 | 0.5 | 0.05 | 0.1 | - | <0.02 | <0.02 | - | - | - |
| *D. carota* | TM | 0.1 | 0.1 | 0.1 | 0.1 | - | 0.1 | 0.1 | - | - | - |
| | LMR | 0.05 | - | 0.1 | - | - | - | - | - | - | - |
| *C. olitorius* | TM | 0.1 | 0.1 | 0.1 | 0.1 | - | 0.1 | 0.1 | - | - | - |
| | LMR | 0.05 | - | - | - | - | - | - | - | - | - |
| *L. esculentum* | TM | 0.01 | 0.01 | - | - | 0.01 | - | - | - | - | - |
| | LMR | 0.05 | 0.01 | - | - | 0.01 | - | - | - | - | - |
| *B. vulgaris* | TM | - | 0.01 | - | - | - | - | - | - | <0.02 | - |
| | LMR | - | 0.01 | - | - | - | - | - | - | <0.02 | - |

**Table 3.** Mean concentration of pesticide residues in vegetable species and over-concentration factors (CF).

| Vegetable species | Mean concentration and maximum residues limits | Pesticides residues mean concentration (mg/kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | α-Endosulfan | CF | Lindane | CF | Chlorpyriphos | CF | Aldrine | CF | αHCH | CF | βHCH | CF |
| *L. sativa* | TM | 0.075 | 1.5 | 0.05 | 5 | 0.075 | 1.5 | 0.05 | 5 | 0.1 | 10 | 0.1 | 10 |
| | LMR | 0.05 | | 0.01 | | 0.05 | | 0.01 | | 0.01 | | 0.01 | |
| *C. annuum* | TM | 0.05 | 1 | 0.05 | 0.1 | 0.05 | | 0.05 | | 0.1 | 5 | 0.1 | 5 |
| | LMR | 0.05 | | 0.5 | | 0.05 | | 0.1 | | 0.02 | | 0.02 | |
| *D. carota* | TM | 0.1 | 2 | 0.1 | | 0.1 | | 0.1 | | 0.1 | | 0.1 | |
| | LMR | 0.05 | | - | | 0.1 | | - | | - | | - | |
| *C. olitorius* | TM | 0.1 | 2 | 0.1 | | 0.1 | | 0.1 | | 0.1 | | 0.1 | |
| | LMR | 0.05 | | - | | - | | - | | - | | - | |

**Table 4.** Soil content of pesticide residues.

| Pesticide detected | Class | Chemical family | Average content( µg/kg) |
|---|---|---|---|
| Cyprodinil | F | Anilinopyrimidins | < 20 |
| Kresoxim-methyl | F | Strobulirins | < 20 |
| Flusilazol | F | Triazols | < 20 |
| Tebuconazol | F | Triazols | < 20 |
| Alachlor | H | Chloroacetamid | < 20 |
| Metazachlor | H | Chloroacetamid | < 20 |
| Metolachlor | H | Chloroacetamid | < 20 |
| Clodinofop-Propargyl | H | Aryloxyphenoxy-propionates | < 20 |
| Tebutam | H | Benzamid | < 20 |
| Ethofumesate | H | Benzofuran | < 20 |
| Aclonifen | H | Diphenulethers | < 20 |
| Bromoxynil octanoate | H | Hydroxybenzonitrils | < 20 |
| Oxadiazon | H | Oxadiazols | < 20 |
| Diflufenican | H | Pyridinecarboximids | < 20 |
| Triallat | H | Thiocarbamate | < 20 |
| Trifluralin | H | Toluidin | < 20 |
| Atrazine | H | Triazene | < 20 |
| Desmetryn | H | Triazene | < 20 |
| Prometryne | H | Triazene | < 20 |
| Propazin | H | Triazene | < 20 |
| Simazine | H | Triazene | < 20 |
| Terbuthylazine | H | Triazene | < 20 |
| Terbutryn | H | Triazene | < 20 |
| Metribuzin | H | Triazene | < 20 |
| Epoxiconazol | H | Triazoles | < 20 |
| Aldrin | I | OC | < 20 |
| Alfa HCH | I | OC | < 20 |
| Alpha endosulfan | I | OC | < 20 |
| Beta endosulfan | I | OC | < 20 |
| Beta HCH | I | OC | < 20 |
| Dieldrin | I | OC | < 20 |
| Gama HCH (Lindane) | I | OC | < 20 |
| (Hexachlorobenzen) | I | OC | < 20 |
| Heptachlor | I | OC | < 20 |
| Heptachlorepoxyd | I | OC | < 20 |
| Chlorpyriphos ethyl | I | OP | < 20 |
| Lambda-cyhalothrin | I | PS | < 20 |

F: fungicide, I: insecticide, H: herbicide, OC: Organochlorinated compound, OP: organophosphorus compound, PS: pyrethrinoid

**Table 5.** Significant concentrations of pesticide residues detected in water (µg/L).

| Pesticides detected | Well 1 | Well 3 |
|---|---|---|
| Métalaxyl M | 1.10 | 0.06 |
| Diméthoate | - | 1.00 |

Trace element over-concentration was observed in all species except *B. oleracea var. botrytis*. It reaches 3 times the maximum acceptable value for copper in *D. carota* and *Solanum macrocarpum*. This contamination in trace metals is especially observed for nickel and lead for which over-concentration can reach 30 (in *S. macrocarpum* for nickel) to 40 times (in *P. vulgaris* for

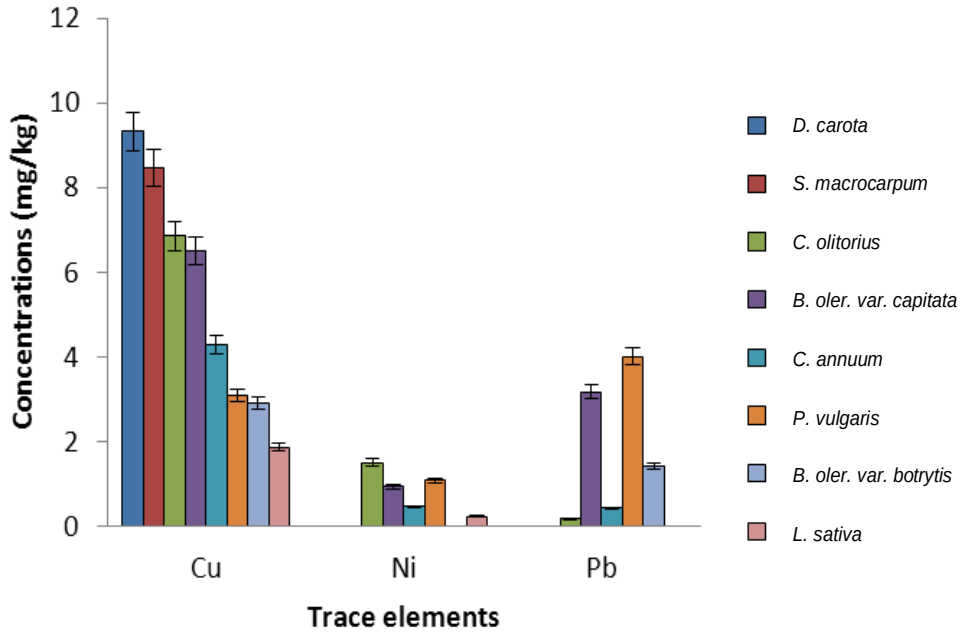


**Figure 3.** Content of trace elements in the vegetable species.

**Table 6.** Mean concentrations of trace element (MC) in vegetables and over-concentration factors (CF).

| Vegetable species | Copper | | Nickel | | Lead | |
|---|---|---|---|---|---|---|
| | MC | CF | MC | CF | MC | CF |
| *D. carota* | 9.32 ± 2.98 | 3 | - | - | - | - |
| *S. macrocarpum* | 8.46 ± 0.581 | 3 | 1.51 ± 0.045 | 30 | 0.17 ± 0.024 | 1.5 |
| *C. olitorius* | 6.86 ± 2.68 | 2 | 0.48 ± 0.052 | 5 | - | - |
| *B. oleracea var. capitata* | 6.52 ± 1.53 | 2 | 0.93 ± 0.012 | 19 | 3.18 ± 0.53 | 32 |
| *C. annuum* | 4.28 ± 1.096 | 1 | 0 | 0 | 1.41 ± 1.032 | 14 |
| *P. vulgaris* | 3.10 ± 1.082 | 1 | 1.09 ± 0.235 | 22 | 4.01 ± 1.752 | 40 |
| *B. oleracea var. botrytis* | 2.93 ± 0.085 | 1 | - | - | - | - |
| *L. sativa* | 1.86 ± 0.354 | 0.5 | 0.47 ± 0.01 | 9 | 0.42 ± 0.021 | 4 |
| FAO/WHO (2001) | 3 ± 0.861 | - | 0.05 ± 0.012 | | 0.1 ± 0.02 | |

lead).

Trace element concentrations vary according to organs (leaf, root, stem, inflorescence, fruit and tuber) of vegetable species (Table 7). The leaves of *S. macrocarpum*, *C. olitorius*, *B. oleracea* var. *oleracea*, *B. oleracea* var. *botrytis* and D. carota accumulate copper in concentrations of 14.13 mg/kg to 1.82 mg/kg. Leaves of *B. oleracea* var. *botrytis* also contain nickel at 0.16 mg/kg. Inflorescences of *B. oleracea* var. *botrytis* can accumulate copper at 2.92 mg/kg and lead at 1.42 mg/kg. Fruits of *C. olitorius* could contain 1.23 mg/kg of copper and the tubers of *D. carota* accumulate copper at a concentration of 9.32 mg/kg.

The species that accumulate the most trace elements are *B. oleracea* var. *capitata*, *C. annuum*, *C. olitorius* and *L. sativa*. They are vegetables that are much appreciated by city dwellers (Table 8). They accumulate copper, nickel and lead. Their presence in city surroundings can be explained by the fact that these areas were used as rubbish dumps. High levels of copper at Kara (4.46 mg/kg for *C. olitorius*, 13.15 for *B. oleracea* var. *capitata* and 22.62 mg/kg for *S. macrocarpum*) could be explained by the closeness of market garden fields on the banks of the Kara River to an electric power plant whose waste oils are dumped in the river. The accumulation of lead (9.53 mg/kg for *B. oleracea* var. *capitata*) at the high altitude of Danyi may be explained by a probable geological origin. This contamination could also be due to the application of agrochemicals to cocoa and coffee fields located in this part of the country.

Water samples from the coast and the Zio River contain lead at levels ranging from 0.018 to 0.194 mg/L of

**Table 7.** Trace element accumulation in different parts of vegetable species.

| Element | Vegetable species | Leaf | Root | Stem | Flowers | Fruit | Tuber |
|---|---|---|---|---|---|---|---|
| Cu | *S. macrocarpum* | 14.13 ± 1.72 | 4.16 ± 2.001 | 6.92 ± 1.01 | 0 | 0 | 0 |
| | *C. olitorius* | 4.46 ± 0.85 | 2.21 ± 1.96 | 0 | 0 | 1.23 ± 0.356 | 0 |
| | *B. oleracea* var. *capitata* | 13.15 ± 4.289 | 8.8 ± 1.847 | 3.57 ± 0.92 | 0 | 0 | 0 |
| | *B. oleracea* var. *botrytis* | 13.55 ± 2.87 | 0 | 0 | 2.92 ± 0.86 | 0 | 0 |
| | *D. carota* | 1.82 ± 0.28 | 0 | 0 | 0 | 0 | 9.32 ± 2.834 |
| Ni | *B. oleracea* var. *capitata* | 0.16 ± 0.12 | 0 | 0 | 0 | 0 | 0 |
| Pb | *S. macrocarpum* | 0 | 0 | 0.69 ± 0.071 | 0 | 0 | 0 |
| | *B. oleracea* var. *botrytis* | 0 | 0 | 0 | 1.41 ± 0.487 | 0 | 0 |

**Table 8.** Mean concentration in trace element in vegetable species from different provenances.

| Element | Provenance | *B. oleracea* var. *capitata* | *C. annuum* | *C. olitorius* | *L. sativa* | *S. macrocarpum* |
|---|---|---|---|---|---|---|
| Cu | Lomé | 2.67 ± 1.81 | 4.89 ± 1.253 | 7.54 ± 0.59 | 0 | 5.63 ± 1.001 |
| | Kara | 13.15 ± 1.94 | 0 | 4.46 ± 1.81 | 0 | 22.62 ± 1.84 |
| | Dapaong | 0.17 ± 0.011 | 4.5 ± 0.965 | 0 | 1.93 ± 0.61 | 0 |
| | Agoè | 0 | 0 | 7.13 ± 1.42 | 0 | 0 |
| | Aného | 0 | 3.78 ± 2.83 | 0 | 0 | 0 |
| | Danyi | 1.09 ± 0.81 | 0 | 0 | 0 | 0 |
| | Kouméa | 0 | 0 | 0 | 1.57 ± 0.87 | 0 |
| | Kpissidè | 0 | 3.87 ± 0.62 | 0 | 0 | 0 |
| Ni | Dapaong | 0.28 ± 0.04 | 1.94 ± 0.016 | 0 | 0.16 ± 0.01 | 0 |
| | Lomé | 3.62 ± 1.028 | 0 | 0 | 0 | 0 |
| | Agoè | 0 | 0 | 2.64 ± 0.67 | 0 | 0 |
| | Danyi | 1.33 ± 0.441 | 0 | 0 | 0 | 0 |
| | Kara | 0.16 ± 0.012 | 0 | 0 | 0 | 0 |
| | Kouméa | 0 | 0 | 0 | 0.57 ± 0.05 | 0 |
| | Kpissidè | 0 | 0.86 ± 0.95 | 0 | 0 | 0 |
| Pb | Lomé | 0 | 0 | 0.30 ± 0.02 | 0 | 0 |
| | Danyi | 9.53 ± 2.865 | 0 | 0 | 0 | 0 |
| | Kpissidè | 0 | 2.54 ± 1.54 | 0 | 0 | 0 |

water (Table 9). The highest concentrations (0.025 to 0.032 mg/L) are found in the Zio. However, nickel has been detected only in samples from the Zio and cadmium levels of 0.077 to 0.084 mg/L. Under our operating conditions, copper was not detected in any water sample. Lead pollution in drinking water was 2 to 19 times the maximum value allowed by the WHO. The concentrations of cadmium are 26 to 28 times higher than the maximum value allowed by the WHO.

## DISCUSSION

### Pesticide contamination

Molecules detected in vegetable samples are mainly organochlorines. Studies carried out in Togo (Djaneye-Boundjou et al., 2000), Ghana (Ntow, 2001), Senegal, Gambia (Cissé et al., 2003; Manirakiza et al., 2003) and Benin (Assogba-Komlan et al., 2007) showed contamination of tubers, fruits and vegetables by various pesticide residues in which organochlorines are the major components.

It was shown that pesticide residues are accumulated in the soil and then pass to the plant through the roots (Fismes et al., 2002; Otani et al., 2007). Apart from *A. cepa*, *B. oleracea* and *C. annuum* (white pepper), the levels of contamination of other vegetables (such as *D. carota*, *C. olitorius*, *L. esculentus* and *B. vulgaris*) do not seem to present a danger to human health according to EU/UNIDO/UEMOA (2005) standards. However, the study shows contaminations of vegetables, water and soil but it was not possible to determine long-term effects

**Table 9.** Mean concentration (MC) in trace element (mg/L) in water and over-concentration factors (CF).

| Element | Concentration and factor | River Zio 1 | River Zio 3 | River Zio 2 | Well 3 | Well 4 | Well 5 | Well 1 | Well 2 |
|---|---|---|---|---|---|---|---|---|---|
| Ni | MC | 0.025 ± 0.01 | 0.029 ± 0.001 | 0.032 ± 0.012 | 0 | 0 | 0 | 0 | 0 |
| | CF | 0.4 | 0.5 | 0.5 | 0 | 0 | 0 | 0 | 0 |
| Pb | MC | 0.194 ± 0.023 | 0.187 ± 0.047 | 0.152 ± 0.02 | 0.135 ± 0.02 | 0.093 ± 0.032 | 0.081 ± 0.04 | 0.036 ± 0.021 | 0.018 ± 0.01 |
| | CF | 19 | 18 | 15 | 14 | 9 | 8 | 4 | 2 |
| Cd | MC | 0 | 0 | 0 | 0.079 ± 0.034 | 0.084 ± 0.011 | 0.077 ± 0.02 | 0.081 ± 0.012 | 0.082 ± 0.011 |
| | CF | 0 | 0 | 0 | 26 | 28 | 26 | 27 | 27 |

on living organisms and ecosystem function. It is clear that the absorption of pesticide residues present in market garden produce may present a risk of poisoning when consumption is associated with a regular intake in small doses (Kamdem and Fofiri, 2008).

This study is comparable to those of Cissé et al. (2003) and Traoré et al. (2006) who have also detected in wells, vegetables and in banana and pineapple plantations, higher concentrations of pesticides such as endosulfan, chlorpyrifos-ethyl and HCH than those obtained in this study. Mawussi (2008) and Gamboa-Rodríguez et al. (2012) noted organochlorines in river water and wells at levels exceeding the maximum recommended by the FAO, WHO and European Union. This kind of water contamination is mentioned throughout Africa (Ntow, 2001; Ntow, 2005; Mwevura et al., 2002; Cissé et al., 2003; Kishimba et al., 2004). Indeed, Richard and Giroux (2004) demonstrated that the presence of pesticides in water could be responsible for stream degradation and could also affect human health (Hayat et al., 2010).

## Trace element contamination

These results compared to WHO standards on vegetables and drinking water, show values exceeding the maximum allowable concentrations for copper, nickel, lead and cadmium whatever the sample point (Public Health Council of France, 1996; Commission européenne, 2001). The contamination could be due to the use of pesticides and chemical fertilizers (Derwich et al., 2008; Adam et al., 2010). The highest and most frequent concentrations were those of copper and lead in vegetables and cadmium in water. Copper comes from copper fungicides (Delas, 1963; Shtangeeva, 2005; SOGREAH, 2007). Organic fertilizers also contain high concentrations of copper and zinc (Jondreville et al., 2002; Levasseur, 2002; Marcato, 2007); while phosphatic fertilizers were rich in cadmium (Nicholson et al., 2003; Shtangeeva, 2005; SOGREAH, 2007). Trace elements are often concentrated in animal manures because they are not assimilated by animals. Kouakou et al. (2008) and Boukhari and Rada (2000) showed that poultry manures are a source of trace metal enrichment of soils and their bioavailability could be enhanced by soil acidity. These manures are used in Togolese market gardens (Kanda, 2011). The banks of the Zio River are dumpsites for household and factory waste, a factor that could also facilitate contamination. Coastal soils have low cation exchange capacity which could also facilitate trace element transfer to the environment (Denaix, 2007). According to Tremella-Schaub and Feix (2005), soil-plant transfer of lead is negligible compared to the direct deposition of dust containing lead on the aerial parts of plants especially in urban areas or along roads with heavy traffic. In Nigeria, Atayese et al. (2008) have shown that vegetables grown along highways contain lead (68 to 152 mg/kg) and cadmium (0.5 to 4.9 mg/kg).

The study showed that the aerial parts of vegetables contain more copper. Cadmium was only detected in water as also noted by Niang (1996). Cadmium is very soluble in water and can migrate in its soluble form from the surface to the phreatic layer (Camobreco et al., 1996; Ablain, 2002). However, even if these recorded concentrations can cause acute toxicity, it is important to point out that the ecotoxicological risks reside in their bioaccumulation (Tarras-Wahlberg et al., 2001; Ramade 1992; Cheggour et al., 1999).

## Conclusion

This study allows us to state that agrochemical

application could pollute agro products like vegetables, and could be present in the soil and groundwater. In vegetables, the notable molecules are lindane, α-endosulfan, α-HCH, β-HCH, chlorpyriphos and aldrin. In soils, contaminations are below 20 mg/kg. Water contamination is significant in coastal wells where metalaxyl M at 0.06 µg/L and 1.1 µg/L and dimethoate at 1 µg/L are detected.

Trace element levels vary according to vegetable species from 1.86 to 9.32 mg/kg of dry matter. *B. oleracea* var. *botrytis* inflorescences accumulate copper and lead; the fruits *C. olitorius* could contain copper and *D. carota* tubers, copper. These results also depend on sample origin. Water samples could be contaminated by trace elements and this kind of pollution could reach 28 times higher considering WHO recommendations.

All kinds of pollution in garden market fields could be reduced if some precautions were taken. Amongst them, best practices in commercialization and application of agrochemicals could be noted. Market gardeners may be advised on ways of applying agrochemicals that are suited to this kind of agriculture. In this way, they could contribute positively to the implementation of the National Program for Agricultural Investment and Food Security (NPAIFS).

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