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Heavy Metals And Radionuclides Particles Contamination Of Weaning Flours Marketed In Four Communes Of The District Of Abidjan

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Abstract: *The purpose of this study is to evaluate the concentration of heavy metals and radionuclides particles in industrial rice flour, a local artisanal maize flour and in weaning flours referred to as "Anagobaka" by the populations that are manufactured products and imported sold on markets in four municipalities in Abidjan District. It is necessary to ensure the safety of food for the nutritional needs of infants and children. The samples tested consisted of industrial rice cerelac flour from a commercial center and used as a reference flour, a local artisanal infant corn meal and eleven "Anagobaka" weaning flours, distributed as 4, from Adjamé, 4 from Abobo and 3 from Treichville. The contents of heavy metals and radionuclides particles from these samples were analyzed by the scanning electron microscope method. These results indicate the levels of lead, cadmium, chromium and uranium. In the reference flour and local flour, the lead and cadmium contents were 0.06 ± 00; 0.02 ± 00 mg/kg and 0.04 ± 0.01; 0.05 ± 0.01 mg/kg. Both flours contain no chromium and uranium content. In all Anagobaka flours, the respective levels of lead and cadmium ranged from 0.27 ± 0.03 to 1.32 ± 0.16 mg/kg and 0.23 ± 0.01 mg / kg to 2.52 ± 0.17 mg/kg. Only five flours contained chromium at levels ranging from 0.23 ± 0.01 mg/kg to 2.52 ± 0.17 mg/kg. The only flour containing uranium was Bolero pineapple brand flour with a content of 1.03 ± 0.1 mg/kg. Conclusion: The weaning flours contain heavy metal contents that do not comply with the regulations (EC: 1881/2006). The consumption of these flours concentrated in heavy metals could have adverse consequences for the health of infants and children*

Keywords: *Heavy metals, radionuclidesparticles, infants flours, Abidjan district.*

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I. Introduction

Heavy metals are pollutants generated for the most part by human activity. From a physical point of view, heavy metals are defined as trace metal elements (EMT) characterized by a density greater than 5 g / cm3 or an atomic number greater than twenty[1]. The issues raised by the emissions of trace metal elements are mainly sanitary and are linked to their persistence in the natural environment, their bioaccumulation in the environment and their effects on health [2]. Many contaminants of various origins and nature can contaminate soils, the environment and be captured by the food web. Once transferred to humans through the digestive tract, they combine with the organic sulfur compounds of our body to cause serious disorders, including cerebral [3], in the short or long term. In the absence of any specific source of exposure, food is the main route of exposure to many of these metals.

Contamination of the food chain by heavy metals has become a major problem in recent years due to their potential accumulation in biosystems via contaminated water, soil and irrigation water. Industrial discharges, chemical fertilizers, combustible fossils, sewage sludge and municipal waste are the main sources of heavy metal contamination in soils and their uptake by crops[4]. Also natural radionuclide entering the food chain are mainly derived from the soil and ingestion of contaminated food is also one of the important pathways for long-term health problems [5].

Infants are the population group the most vulnerable to the toxic effect of heavy metals due to the higher absorption of metals by the digestive tract, rapid growth, immaturity of internal organs, an incompletely developed detoxification system [6] [7]. In addition, harmful elements for infant health can accumulate in the undeveloped brain causing dysfunction of the central nervous system[8]. Exposure to heavy metals during growth and development can have long-term effects on children's health[9]. Market-available infant foods have become an important part of the diet of many infants and young children because of their mineral and vitamin content that meets the dietary needs of these target groups [10] [11].

The European Commission has defined a specific maximum limit for toxic elements in designated foods, only for lead in infant formulas and ready-to-use follow-up preparations at 0.02 mg / kg, cadmium in cereals, baby food for infants and young children at 0.02 mg / kg (Commission Regulation 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs, as amended; amendment 12 May 2014). Although these toxic elements are sometimes added intentionally with additives to the formula resulting in excess toxicity ([12], [13]). It is therefore necessary to obtain better information on the levels of trace metals in the ill-labeled flours manufactured, imported and referred to as Anagobaka by local populations, flours and industrial flours made from cereals, vegetables and fruit for infants. marketed in the district of Abidjan in Ivory Coast. It is obvious that baby food products sold on the markets have not been fully studied to determine the content of metallic trace elements and radionuclide. Nevertheless, the need for routine monitoring of these infant food products can not be overstated.

The objectives of this work are to evaluate the concentration of heavy metals in weaning flours and their exposure to radionuclides particles.

II. Material And Methods

2.1Biological Material

The biological material used consists of flour marketed on the markets of four communes of the District of Abidjan and coded as follows: 1st letter = name of the commune / 1st digit = No. of the sample and 2nd digit = the year of the sample(Table 1). These are the industrial flour used as reference flour came from a shopping center. Local artisanal flour and imported Anagobaka weaning flours came from markets in four communes of Abidjan District.

N°	Trade name of the analyzed products	Codification of products	Type of products
01	Bolero pineapple	ADJ/001/18	Anagobaka flour
02	Fincap	ADJ/003/18	
03	Jone Family	ADJ/004/18	
04	Tollex	ADJ/006/18	
05	Bolero strawberry	ABO/001/18	
06	Egg Banana	ABO/003/18	
07	Queen Royale	ABO/005/18	
08	Prime	ABO/006/18	
09	Family Milk	TREICH/001/18	
10	Lady B	TREICH/002/18	
11	Glad Family	TREICH/003/18	
12	Corn flour	COCO/001/18	Artisan flour
13	Rice Cerelac	COCO/002/18	Industrial flour

Table 1.Description and codification of the weaning flours analyzed

ABO; ADJ ;TREICH; COCO: commune 001 : Number of the sample, 18 : year of taking away 2018

2.2 Technical equipment

The equipment used is essentially a hood laminar flow, a Muffle Furnace (Jouan, Type MSC 12BSDUCTED), a Desiccator, Crucibles, Spatulas, a Precision Analytical Balance 10^{-4} g (Sartorius AG, Germany Goettingen, TE 124S), a bunsen burner, a hot plate (Schott Instruments No. 3000203), a pad (Agar Scientific, CM24.8, DA, England), a Model FEG supra 40 VP scanning electron microscope (SEM) of Zeiss coupled to an X-ray microanalyzer EDS. This SEM is equipped with an X-ray detector (OXFORD Instruments) X-MAX SDD connected to an EDS (Inca Dry Cool) microanalyzer platform and a desktop computer.

2.3 Reagents

Double-sided adhesive carbon (Agar Scientific, G3939A, 12mm x 20m)

2.4 Criteria for the selection of communes
The communes were selected according to the way of life of the inhabitants, the density of the population and the accessibility of the markets.
2.5 Criteria for selecting samples
The selection was made on industrially-produced rice weaning flour, home-made local weaning flour, and manufactured, mislabeled, imported weaning flours known as Anagobaka and marketed in the district markets. Abidjan
2.6 Determination of heavy metals by electronic scanning microscopy (SEM)
2.6.1 Sample preparation
Under a hood, 65 g aliquots were made for each box of flours in several copies for the research of heavy metals and subsequent microbiological analyzes.

2.6.2 Operating mode
Using an analytical balance of precision 10^{-4} g, 2 g was taken on each aliquot of 65 g per box of flours. The flour is put to the benzene beak. The ash obtained is baked at 750 ° C for half a day. It is then removed and cooled in a desiccator. The ash residue is then recovered. The binocular loupe is turned on. 10 mg of ash residue are removed and placed on a slide. A double-sided adhesive carbon tape is attached to a pad. Then, the ash residue is spread on the pad. The pad is put on a plate, then observe with the magnifying glass to see if the ash residue is homogeneous. The pad is removed from the plate and put in a box to prevent air contaminations. In a cold room, the SEM / EDS is put on 30 minutes before the analysis to allow the barrel vacuum to stabilize. The pad is attached to the slide holder of the SEM / EDS. Finally, the object holder containing the sample is placed on the vacuum plate of the SEM chamber. Identify the area of interest of the sample for microanalysis-RX (EDS) and begin the ash residue analysis that lasts 90 min for each sample. The results are digitized by using a Smart Sem system.

2.7 Statistical analysis
The different results obtained are the average of triplicates and are expressed as mean ± standard deviations. The data were subjected to one-way analysis of variance (ANOVA) using the Graph Pad Prism7 software. The Dunnet test with a statistical significance threshold of $p < 0.05$ was used for the comparison of means when the analysis of variance reveals significant differences.

III. Results and Discussion
3.1 Concentration of heavy metals from weaning flours
The heavy metal concentrations in the weaning flours in mg/kg analyzed were shown in Table 2. The data show a significant difference ($P < 0.05$) between the heavy metal concentrations of the weaning flours analyzed. The results indicate that the lead concentration of the weaning flour used as reference is 0.06 ± 00 mg/kg. That of the local flour is 0.02 ± 00 mg/kg. The lead concentration of Anagobaka flours ranged from 0.27 ± 0.03 mg / kg to 1.32 ± 0.16 mg/kg.

The cadmium concentration of the weaning flour used as a reference is 0.04 ± 0.01 mg/kg. That of the local flour is 0.05 ± 0.01 mg/kg. The cadmium concentration of Anagobaka flours ranged from 0.23 ± 0.01 mg/kg to 2.52 ± 0.17 mg/kg.

The weaning flour used as a reference, the local infant flour and six Anagobaka weaning flours are free of chromium. The chromium concentration of other Anagobaka flours ranged from 0.23 ± 0.01 mg/kg to 2.52 ± 0.17 mg/kg.

Lead and cadmium were detected in all the weaning flours tested and chromium was detected in five types of Anagobaka weaning flours. Heavy Metals Found More Concentrated in Bolero Strawberry brand Anagobaka Flour.

Table 2. Concentration of heavy metals from weaning flours (mg/kg)

Flours	Heavy Metal Concentration (mg/kg)					
	Lead		Cadmium		Chromium	
	Mean±SD	P Value	Mean±SD	P Value	Mean±SD	P Value
Bolero. P	0,66± 0,05	0,001	0,37± 0,01	0,1913	ND	0,999
Fincap	0,86± 0,10	0,0001	0,23± 0,01	0,7839	ND	0,999
Jone Family	1,02± 0,13	0,0001	1,56± 0,10	0,0001	ND	0,999
Tollex	0,9± 0,17	0,0001	0,59± 0,07	0,004	ND	0,999
Bolero.Straw	1,32± 0,16	0,0001	2,52± 0,17	0,0001	2,57± 0,09	0,0001
Egg Banana	0,94± 0,01	0,0001	0,35± 0,01	0,2371	2,5± 0,12	0,0001
Q. Royale	0,36± 0,02	0,2088	0,23± 0,01	0,7839	2,87± 0,15	0,0001
Prime	0,75± 0,08	0,0001	0,38± 0,04	0,1599	ND	0,999
Family Milk	1,24± 0,08	0,0001	0,3± 0,04	0,4343	1,47± 0,20	0,0001

Lady B	0,44± 0,03	0,0688	0,24± 0,02	0,7058	ND	0,999
Glad Family	0,27± 0,03	0,5581	0,74± 0,01	0,0002	0,47± 0,03	0,1527
Corn flour	0,02± 0,01	0,9999	0,05± 0,01	0,9998	ND	0,999
Rice Cerelac	0,06± 0,01	0,9997	0,04± 0,01	0,9998	ND	0,999
Max Limit	0,02		0,02		0,1	

3.2Concentration of radionuclides particles in weaning flours

The radionuclide concentrations in the weaning flours analyzed were reported in Figure 1. The results indicate that the weaning flour used as a reference, that of the local flour and ten of the Anagobaka flours are free of uranium. Only Bolero pineapple Anagobaka weaning flour contains uranium with a concentration of 1.03 ± 0.1 mg/kg.

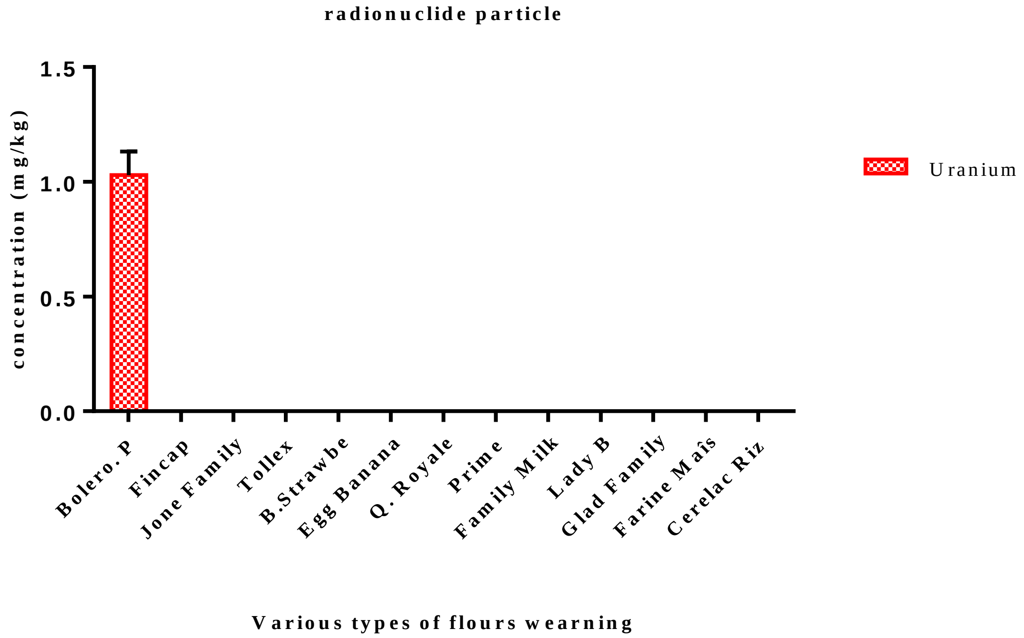

Figure1. Concentration of uranium from weaning flours (mg/kg)

3.3Maximum concentrations for certainheavy metalsand radionuclides particlesin weaning flours

The regulations set, taking intoaccount several parameters, the maximum levels for certain contaminants including cadmium, lead and chromium in infant formula containing cereals. Regulation (EC: 1881/2006) fixes 0.02 mg/kg in infant formula for lead and cadmium and 0.1 mg / kg for chromium; 0.2 mg/kg in cereals for lead and 0.1 mg/kg in cereals for cadmium). In France the General Direction of the Food (DGAL) has chosen to use as threshold of alert for uranium the indicative limits fixed by the Codex Alimentarius of 100 Bq / kg for uranium [14], knowing that 1 µg / kg corresponds to 12 mBq / kg [15].

3.3.1Concentration of lead from weaning flours

In view of the texts in force, it is deduced that the concentration of lead found in corn flour (0.02 mg/kg) complies with the regulation set of (0.02 mg/kg), that of the reference flour (0,06 mg/kg) is 3 times higher than the recommended standard. The lead concentration of Anagobaka weaning flours ranging from 0.27 mg / kg to 1.32 mg / kg are more than 10 times higher than the regulation. The highest concentrations were found in Bolero Strawberry brand Anagobaka flours, Family Milk and Jone Family with values of 1.32 mg/kg; 1.24 mg/ kg and 1.02 mg/kg. Our results show above average levels of lead in infant flours and significant in Anagobaka flours. Our results corroborate those of Mohamed et al. (2017) [16] who showed that lead content was high in infant flours above the limit for most. On the other hand, some results are different from ours. It is the studies of Muntean et al., 2013[17] that found concentrations of 0.0031 mg / kg of lead in infant formulas, lower than the regulation set. Those of Ojo et al., (2013) [18]have shown that lead contamination in infant formulas may be due to its presence in raw materials, industrial production or leakage of packaging materials. Some foods may be contaminated with lead when made by hand, such as contaminated infant flour during grinding, distillation and / or fermentation processes in containers containing lead solder ([19]; [20]).

Infants are the target population for lead poisoning. Digestive absorption in children is greater than that of adults (50% of the ingested lead goes into the blood in children and 10% in adults). Once in the body, lead is distributed in the blood, tissues and especially the bone in which it accumulates, can be stored for a long time and be gradually rejected. The health effects of lead vary with the severity of the poisoning, but are essentially neurological. Exposure to lead can cause serious adverse health effects, and can even be fatal at high doses. Lead can accumulate in the body, and exposure, even at very low doses, can be dangerous. The toxicity caused by this metal in the long term is called "lead poisoning". Lead poisoning refers to all manifestations of lead poisoning whose target organs are the nervous system, blood and kidney.

A plumbing below 1000 µg /L would cause neurological disorders in adults and children: Irritability, sleep disturbance, anxiety, memory loss, confusion and fatigue in workers whose plumbing is between 260 and 660 µg /L, disturbances in reaction time and manual lability [21]**.** Behavioral disorders, particularly those related to hyperactivity, inattention and impulsivity, are also often associated with 110 µg/L blood-fungi [22]. In humans, studies suggest that a long-term lead exposure of several years, in the order of 6 to 10 years (plumbing greater than 400µg /L), causes a reduction in sperm production and therefore, a risk of hypofertility [23]. The results of Konan et al. (2017) also showed a significant decrease in sperm count and germ cell mobility in the epididymis of treated rats. This hormonal reduction in exposed rats is thought to be due to the concentration of lead in the blood. In his study he showed that lead accumulation in the blood affects male fertility by disrupting the biosynthesis of gonadotropins and testosterone as well as the process of spermatogenesis [24]. Lead blocks several enzymes necessary for the synthesis of hemoglobin. These blood effects lead to a decrease in the number of red blood cells and anemia. In high doses, lead also induces renal tumors in the rat.

3.3.2 Concentration of cadmium from weaning flours

The cadmium concentration found in the reference flour is 0.04 mg/kg, that of the local flour is 0.05 mg/kg and the concentration of the Anagobaka weaning flours varies from 0.23 mg/kg to 2,52mg / kg. The highest concentrations were found in Bolero Strawberry 2.52 mg/kg and Jone Family 1.24 mg / kg flours. All these weaning flours do not comply with the fixed regulation of 0.02 mg/kg. Our work has shown that Anagobaka weaning flours have high concentrations of cadmium. This work corroborates that of Mohamed et al., (2017) [16] who showed that some infant formulas had concentrations above the maximum limit. In contrast, Muntean et al., (2013) [17] in their studies found cadmium concentrations of 0.0035mg/kg in infant formulas inferior to the set regulation and Ojo et al., (2013) [18] showed that in their study that infant flours were free of cadmium.

Infants are the most exposed population to intoxication due to cadmium ingestion. Several studies have been carried out on this metal discovering that it is a mutagenic element that can alter the structure of DNA [25]**.** Cadmium compounds (chloride, oxide and chromate) are Category 2 carcinogens and sulfate is classified as a Class 3 carcinogen. Short-term exposure to high concentrations of cadmium dust or smoke is irritating to the cells of the respiratory system and causes severe pulmonary disorder. The results obtained during the work of Diaby et al. (2016) [26] showed a decrease in red blood cells, hemoglobin and hematocrits both in female rats and in males significantly compared with controls. Similarly, Fawzia et al. (2014) [27] found in pregnant female rats contaminated with cadmium chloride. This decrease is considered anemia reported by Horiguchi, (2007) [28]. Anemia is an important expression of cadmium toxicity. It could therefore be explained by an increase in the destruction of red blood cells and at the same time a decrease in their syntheses. Indeed, metals, accumulating in the spleen, liver and kidneys, inhibit erythropoietic activity by damaging the synthesis of erythropoietin which is a hormone secreted by the kidneys whose role is the stimulation of red blood cells [29]. Cadmium therefore disrupts the hematopoietic system ([30]; [31]). Thus, for Hounkpatin et al. (2013) [32]**,** cadmium causes blood disorders. Oral ingestion of a single 10 mg dose of metal leads to intestinal disorders and renal failure. If the ingested dose is greater, death can occur within 24 hours [33]. Chronic exposure to cadmium by inhalation or ingestion results in severe kidney, lung and bone disorders including osteoporosis and osteomalacia (adult rickets) ([34] [35]). These negative effects on human health are due to a slow rate of excretion (half-life of 15 to 20 years) and its accumulation in the body [36]. The other consequences of chronic cadmium exposure are arterial hypertension [37], reproductive tract disruption [38]; [39] and liver dysfunction [35]**.** An increased case of some cancers, particularly lungs, are observed in populations exposed to cadmium [40].

3.3.3Concentration of chromium from weaning flours

The reference flour, local flour and six Anagobaka weaning flours are free of chromium while the other five Anagobaka weaning flours have chromium levels ranging from 0.47 mg/kg to 2.87 mg/kg. These Anagobaka flours do not comply with the fixed regulation of 0.1 mg/kg. The highest concentrations were found in Queen Royale, Bolero Strawberry and Egg Banana flours with values of 2.87 mg/kg; 2.57 mg/kg and 2.50 mg/kg. Our study showed a high chromium content in only five Anagobaka flours. This work does not support the studies of Ojo et al. (2013) [18] who found low chromium concentrations below the recommended standard and those of de Mohamed et al. (2017) [16] found that infant flours had concentrations below the maximum limit.

Our work is contrary to the results of Olu-Owolabi et al., (2007) [41] who reported the zero level of chromium in certain infantile formulations in Nigeria.

Chromium plays some important roles in the body, it is essential for the metabolism of glucose, lipids and proteins and insulin. The recommended daily intake of chromium for adults by the US National Academy of Sciences is 50-200 µg. Very little chromium in the diet can lead to insulin resistance. However, there is no standard against which chromium deficiency can be established ([42] [43]). The toxic effects of chromium intake include skin rashes, allergies, nose irritation, bleeding, stomach ache, liver and kidney damage, insulin resistance and lung cancer [44]. Chromium III is a natural compound of the low-toxicity organism. Its derivatives can behave as allergens if the concentration is very high, hence the onset of asthma and dermatitis. Chromium VI is highly toxic and can be accumulated in the liver, kidneys, thyroid gland and bone marrow. It causes respiratory disorders, inflammation of the mucous membranes and ulcers. Gastrointestinal disorders have also been observed during occupational inhalation exposures (stomach pains, cramps, peptic ulcers and gastritis). If ingested at a high dose, chromium VI may cause inflammation of the digestive tract and necrosis (abdominal pain, vomiting, diarrhea, hematemesis). In 1990, IARC classified chromium VI in group 1: "carcinogenic to humans" and chromium III in group 3: "agent that can not be classified for its carcinogenicity to humans".

3.3.4Concentration of uranium in weaning flours

All flours tested are free of radionuclides particles except Bolero pineapple flour with a uranium concentration of 1.03 mg/kg that is 12.36 Bq / kg. The presence of uranium in this brand of Anagobaka flour can be explained by the transfer of uranium in cereals from the soil probably contaminated. In fact, according to the Institute of Radioprotection and Nuclear Safety (IRSN), four main sources of industrial activity enrich certain compartments of the biosphere, such as soils, with uranium. These are the nuclear fuel cycle from the exploitation of uranium mines to the treatment of waste, the military use of depleted uranium; not to mention the last two sources that are most commonly used by people in developing countries: the use of coal (combustion leads to the atmospheric emission of uranium) and the agricultural use of phosphate fertilizers particularly rich Uranium 238 (concentrations of 150 mg/kg may also contribute to the uranium content of groundwater). Because of its presence in all soils in partially available form and by means of root transfer factors of uranium ranging between 10^{-3} and 10^{-2} Bq/kg of dry plant per Bq /kg of dry soil, the highest values are measured in root vegetables, particularly in potato tubers. On the other hand, uranium is found in greater proportion in the stems and leaves of plants than in seeds or fruits [45].According to the Independent Research and Information Commission on Radioactivity. (CRIRRAD), uranium detection thresholds remain high, he recommends that the measurement of a single becquerel of plutonium 239 or uranium 235 in a liter of milk should be sufficient to launch the warning [14].However, it should be noted There is no data on the transfer of uranium during agro-food processing [45].Some authors such as Mlwilo et al, (2006) [46] reported in maize samples concentrations of 16.38 Bq/kg in the Dar es Salaam region of Tanzania.Also Mohamed, (2008) [47] reported in maize samples concentrations of 1.3Bq/kg in Tanzania.The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has determined that low doses of ionizing radiation are 100 mSv and below or 0.1 mSv / Min. The UNSCEAR report explains that low dose ionizing radiation can cause increased cataracts and circulatory disturbances in people who have been exposed to radiation. On the other hand, it is difficult to determine the degree of responsibility of low-dose radiation in these diseases, since they take a long time to manifest themselves and a part of the population is naturally subject to them. The same report states that the risk of cancer increases even when the doses received are between 100 mSv and 200 mSv and that children are particularly vulnerable [48]. Moreover, it is interesting to note that this exposure limit can be cumulated every year. Indeed, the addition of the few mSv received each year accumulates to become a dose of 100 mSv and more [49]. Man exposes himself to uranium in many ways, since this metal is present in small quantities in the environment. This is why humans naturally have a small amount of uranium in their body, 0.1 mg. UNSCEAR has estimated the annual quantity of uranium entering the human body at 460 µg / year by ingestion (food and water) and at 0.59 µg / year by inhalation (values given for an adult) [15]. Thedanger forhuman health is mainly related to internal contamination due to ingestion or inhalation of dust [50]. Uranium ingestion is by water, contaminated food consumption and injury in the case of nuclear workers. About half of the absorbed dose is excreted in the urine within 24 hours, the rest will be accumulated in the kidneys, where it will be eliminated in 3 months and in the bone system, where it will remain for several years. As a heavy metal, uranium has a chemical toxicity, called chemotoxicity, affecting the renal system. The radiological toxicity of uranium is based on its long presence in the bones from which gamma and alpha radiation are released, which damage the various biological tissues [51]. The International Commission on Radiological Protection has set the safe concentration of uranium in the kidney at 3 mg/kg. Uranium would contribute to osteoporosis and have neurotoxic, hepatotoxic and endocrine disrupting effects [51].

IV. Conclusion

This work permited to determine the composition of heavy metals and radionuclide particles of the various infant flours subjected to our study. The analyzes show that the cadmium and lead concentration of these infant meals used as weaning foods in infants and young children in Côte d'Ivoire are for the most part superior to the regulations laid down (EC: 1881/2006), the Chromium concentration is higher in five Anagobaka weaning flours and uranium in Anagobaka flour. The consumption of these flours containing heavy metals could have adverse consequences on the health of infants. Thus, it appears appropriate to control the concentration of heavy metals in these infant flours from harvesting cereals to processing and ensure that it is below the maximum limit. Competent authorities should decontaminate soils polluted by heavy metals and radionuclides in agricultural areas. This will reduce health risks and allow them to be true complementary foods.

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Abbreviations

SD: Standard deviation;EMT: trace metal elements, SEM:electronic scanning microscopy, ND: not determined

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