Review Article

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# Review of south sudans food safety status in relation to chemical contaminants

**Abstract**

The importance of food safety to the health of population has been subject to public health agenda for a long time. However, South Sudan still faces challenges with food safety and quality across the entire food chain. The country grapples with many health problems, especially the burden of diseases from various sources including those ecological, environmental, water and food contamination. Due to the weak national surveillance system for food-borne diseases, the magnitude and implication of food borne diseases cannot be accurately ascertained. As the demand for quality and safe food in terms of chemical and microbiology increasingly become important, this review highlights some of the major sources of food contamination. Chemical food contaminants are found to arise from unregulated and uncontrolled use of agrochemicals, environmental wastes, mycotoxins, food processing and mining. In order to address these vast food safety problems of chemical origin, food testing laboratory infrastructure, safety standards, skills and awareness among all stakeholders will be paramount.

**Keywords:** south sudan, food safety, foodborne disease, chemical contaminants

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Kuorwel Kuai Kuorwel,[1] Clara S Lumori,[1] Amegovu K Andrew[2]

[1]Department of Chemistry, College of Applied and Industrial Sciences, University of Juba, Republic of South Sudan
[2]Department of Foods and Nutrition, College of applied and Industrial Sciences, University of Juba, Republic of South Sudan

**Correspondence:** Amegovu K Andrew, Department of Foods and Nutrition, College of Applied and Industrial Sciences, University of Juba, 82, Juba, Republic of South Sudan, Email kiri_andrew@yahoo.com

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**Abbreviations:** SPLM, sudan people's liberation movement; PCBs, polychlorinated biphenyls; PAHs, polycyclic aromatic hydrocarbons; HAAs, heterocyclic aromatic amines; PP, polypropylene; PVC, polyvinyl chloride

## Introduction

South Sudan faces a myriad of challenges ranging from a struggling economy, low levels of technology to weak health care systems. It is a new country born out of a Comprehensive Peace Agreement between Sudan and the Sudan People's Liberation Movement (SPLM). Its independence on July 9th, 2011, ended one of the longest protracted civil wars in Africa. The country has a population of about 12million ethnically diverse people who rely on subsistence farming as the main source of livelihood. The several decades of civil war rendered South Sudan food industry and food safety infrastructure severely underdeveloped and in most cases dysfunctional. Today, some of the major health problems experienced by the people of South Sudan are food-borne illnesses. This situation is worsened by the absence of systems to identify, record and prevent food borne diseases yet some food borne infections are fatal. Deficiency in surveillance and case recoding infrastructure for food-borne diseases of both microbiological and chemical aetiology in the entire Republic of South Sudan means absence of reliable data on food-borne diseases. This affects the level of information available and subsequently hinders the country from appropriately diagnosing and responding to the burden of food bore diseases in terms of treatment as well as putting in place preventive mechanisms. Currently, agrochemical residues, environmental wastes, cross-contamination or food processing toxicants are presumed to be among the major food contaminants in South Sudan. This paper provides a review on chemical food contaminants of public health importance in the Republic of South Sudan.

## Agrochemicals from agricultural production process

### Residues in crops

Chemical contaminants can remain in crops from use of agrochemicals such as pesticides, herbicides and fertilizers. In South Sudan, maize, sorghum, millet, cassava are grown as a staple foods alongside small amounts of vegetables- some of which are sold for cash and domestic consumption.[1] These crops are affected by various pests and plant diseases. The most common insect pests include the elegant grasshopper "*Zonocerus* sp." that attacks cassava, boll worm and cutworms that attack vegetables, stalk borers that attack maize and sorghum and aphids that normally attack vegetables. On the other hand, most of the crops are affected by weeds such as Striga sp, *Bidens pilosa*, *Datura stramonium*, etc. The Striga can cause total crop loss in maize and sorghum.[2] Numerous other weeds that affect crops springing up every year depending on crop type, farming system, rainfall, flood intensity and cultivations. Given that the pests, weeds and plant diseases are some of the critical problems in crop production; the use of herbicides, fertilizers and pesticides such as sumicidin, sevin, dursban, pyrethroids, furadan, etc. has become an integral part of agriculture more especially in large-scale mechanized farms. Herbicides have been applied on some of the large-scale mechanized farms in Upper Nile State with access to supplies from the Sudan. Regarding pest control campaigns, prior to South Sudan's independence, there was aerial spraying of nesting sites as routine control for migratory Quelea bird populations near the mechanized areas. The aerial spraying practice was resumed in 2013 and conducted by the Desert Locust Control Organization based in Nairobi.[3] It is uncertain that care is taken by the farmers when applying pesticides; there are some circumstances when pesticides are overused because of the lack of appropriate knowledge in the application of the pesticides.

  

Furthermore, pesticides might accidentally end up in the food chain because of the improper disposal of remains, containers/equipment and spill over into the environment. Since there are no competent analytical laboratories that can test the level of pesticide residues in foods; the adversity of effects on health of the local population is never known. Exposure to pesticide is a public health concern due to human health risks associated. Wanwimolruk et al.[4] and Alavanja et al.[5] reported health risks associated with extensive use of pesticides in agriculture on the health of humans after consumption such crops. According to Magkos et al.[6] and Carvalh,[7] there is a possibility of these chemicals ending up as residues in food, and potentially be harmful in contrast to the benefits gained from their use. Some of the pesticides may contaminate food items during application or through bioaccumulation in the food chain as suggested by Amoah et al.[8] and Kasem et al.[9]

Pesticides residues in foodstuffs arise also arise from application of fumigants to protect crops from attack and spoilage during storage. In rural areas of South Sudan, storage facilities comprise of the above-ground granaries that are susceptible to attack by pests such as rats, weevils, etc. In order to control some of these pests; fumigants such as methyl bromide, phosphine, etc. are applied by farmers after harvest. According to Rajendran et al.[10] fumigants come into contact with insects in the gaseous, rather than the solid or liquid phase. While they are absorbed onto commodities during the course of fumigations, most of the absorbed fumigant is not lost during subsequent aeration, unless there is some form of chemical reaction with components of the commodity. Of the chemicals widely used as fumigants to treat grains, only methyl bromide reacts chemically with the commodity.[11] This reaction results in fixed residues of inorganic bromide. While residues of absorbed unreacted methyl bromide remain low, this is not the case for residues of phosphine and the other fumigant that is widely used.

### Residues in animal products

Drug residues in animals have a substantial effect on human health and have an important role to play in public health. While the appropriate use of veterinary drugs in agriculture contributes to improving the quality of life, it also raises concerns about its harmful effects on consumers. South Sudan imports livestock, fish and poultry products from neighbouring countries who also have either limited or no food drugs control system. When administered inappropriately, drugs can remain as residues in animal tissues.[12] Use of antibiotics for treatment of bacterial infections has gained attention in the media over the past years because of increased antibiotic resistance both in animals and humans.[13] According to Tajik et al.,[14] the liver and kidney are highly susceptible to residues given their biological functions. Some antibiotics like penicillin can cause severe allergic reactions in sensitive individuals. Consequently, there is need for appropriate quality control and safety management standards-particularly measures regarding the handling and application dosages to limit residues. Although most veterinary drugs are not of acute toxicological concern, some chemical substances such as nitrofurans, chloramphenicol, clenbuterol and diethylstilbestrol have been banned in most countries due to their carcinogenicity.[15] Concern about endocrine-disrupting effects has become another reason for regulation of certain veterinary drugs, such as beta-agonists and hormones.[16]

## Chemical food contaminants from the environment

This type of chemical contaminants can be present in foods as a result of contamination from environmental sources (water, air or soil pollution). Environmental chemical contaminants may originate from man-made or naturally occurring substances present in air, water or soil.[17] If entered into the food chain and bio accumulated, some of these chemical contaminants pose an acute health risk if present at high concentrations. One of the major concerns related to the presence of environmental chemical contaminants in foods is their potential endocrine disruption, carcinogenic and other chronic effects.[18,19] Some examples of environmental contaminants include heavy metals,[20] polychlorinated biphenyls (PCBs),[21] dioxins,[22] persistent chlorinated pesticides (e.g., DDT, aldrin, dieldrin), brominated flame retardants (mainly polybrominated diphenyl ethers),[23] polyfluorinated compounds, polycyclic aromatic hydrocarbons (PAHs), perchlorate, pharmaceutical and personal care products or haloacetic acids and other water disinfection by-products.[24] The discussion of environmental chemical contaminants is limited to the contaminations that might result from the oil exploration and production, mining and some effluent in the major cities.

### Oil extraction pollutants

Food systems in South Sudan are prone to contaminations from chemicals from oil production and exploration activities. The potential environmental impacts associated with oil production activities are manifold and vary significantly. One of the primary sources of potential contamination from oil production is toxic waste water discharges. Major components of the waste water include: hydrocarbons, salts, metals, radio nuclides and production chemicals.[25,26] Furthermore, oil wells drilling affects the environment because of the toxic drilling soil mixture which, if not properly disposed can pollute surface and ground water.[27] Presently, the oil production activities take place in the Eastern Nile and Unity States of the Republic of South Sudan. There are claims of the presence of constituents of crude oil in the biophysical environment of the oil producing areas. Pragst et al.[28] confirmed the presence of lead and cadmium in human hair sampled from people living around Tharja an oil producing area in the Unity State of South Sudan. The presence of heavy metals in human hair samples might be through the consumption of contaminated foods or drinking from contaminated water. The presence of elevated level of trace metals and hydrocarbons potentially exerts acute and long-term adverse health effects to humans. The effects of oil production pollutants to communities around the oil fields include increased infertility in women and a high number of miscarriages; eye pains, eye infections and even blindness; and skin problems.[29]

There is also limited knowledge and awareness on the health risks dangers associated with the oil production among communities around the oil producing areas. The unprotected water pits and holes filled with crude oil are a serious threat to the safety of the people and their livestock. When pits around the oil wells fill with water during the rain, toxic soil mixes with this rainwater, making it dangerous for livestock of the nearby villages. There are claims of livestock deaths following consumption of intoxicated water. Such products are consumed predispose humans to health risks. Another source of oil related pollution is the discharge of effluents into the surrounding

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environment, sometimes into the water. The disposal of wastes into the water bodies from oil facilities has direct effects on fish stocks.

### Gold mining contaminants

Food contaminations may also arise from the chemicals released into the environment from the mining gold activities. On the one hand gold contributes significantly to economic development and employment, on the other hand, there are potential health risks of trace metals to local communities. Mining activities can lead to the generation of large quantities of heavy metal that contaminate of the ecosystem.[30] The metallic salts formed during recovery and refining processes can escape as waste products into surface and ground water. If these mining wastes are not controlled and which is the case for South Sudan it can contaminate agricultural food crops and water. Therefore the contaminated food crops and water with chemical residues of gold mining presents hazards to humans.[31]

### Industrial effluents

Currently, the Republic of South Sudan is attracting significant investment opportunities from neighbouring countries and/or around the world in term of trade. Due to this flourishing trade with neighbouring countries; the country is importing a very large volume of commercial commodities. These commercial commodities include a great deal of consumer products such as food items, drugs and veterinary products, petrochemicals, clothes, toys, water and beverages as well as building materials. Although, these commodities are desperately needed in the Republic of South Sudan; there is however, a consumer safety and environmental health issues that might arise from this influx of consumer products. Some of these products contain various toxic chemicals such as heavy metals in lead-acid batteries, paints, printing inks and the concern is the inability of South Sudan to assess and monitor the risks associated with such products that contains chemicals. Recycling could have been an important environmental management strategy; however, many items most notably batteries, printing inks, used engine oils that contains extensive concentrated cocktail of toxic compounds and other toxic chemicals are disposed in the environment leading to their accumulation in the environment. As it rains, these pollutants are washed into the water system, hence, increasing the human exposure through food and water consumption. For instance, soil and water contamination with the heavy metal such as cadmium can lead to the presence of this toxicant in vegetables grown in the swamp area known as 'Touch' or 'Gezira'. It is important to note that lots of vegetable are eaten raw or half-cooked while the level of chemical residue is not known due to the absence of competent laboratory where analytical testing is made so the citizens are informed of the chemical levels on the products. Furthermore, when these chemicals are washed into water systems, people have the potential of being exposed to mercury through the consumption of fish that might have elevated level of mercury. Mercury accumulates in fish in form of methyl mercury that, when consumed, poses a range of health risks.[32]

## Natural contaminants by mycotoxins

Mycotoxins are toxic secondary metabolites of fungal origin mainly produced by *Aspergillus, Penicillium* and *Fusarium genera*.[33] These mycotoxins are often found as contaminants in agricultural products before or after harvest as well as during transportation or storage.[34,35] Fungal growth and mycotoxin production in cereals is influenced by various climatic conditions, especially temperature and humidity, moisture, water activity, etc. are among the predisposing factors that facilitate the proliferation and production of mycotoxins.[36,37] South Sudan is situated in a temperate climatic region where hot sunny weather changes into colder weather during the harvest period. These climatic variances support the growth of several kinds of fungi such as *Genera Aspergillus* and *Penicillium* in foods such as maize, peanuts, millets, sorghum and wheat. The *Genera Aspergillus* and *Penicillium* for instance, aflatoxins are typical storage fungi and however, their occurrence in cereals during harvest is also possible. Fusarium species such as fumonisins are representatives of field fungi and their higher amounts in cereals are connected with a higher humidity and colder weather. Therefore, in the context of South Sudan, the mycotoxins of public health concern include, deoxynivalenol, fumonisins, aflatoxins especially *Aflatoxin* $B_1$. *Aflatoxin* $B_1$, fumonisins and deoxynivalenol are found mainly in foods such as maize, peanuts, sorghum and wheat which are staple foods in many States of South Sudan. It is important to mention that the storage facilities in South Sudan are very poor which can support the proliferation and production of *Genera Aspergillus* and *Genera Aspergillus*. When ingested, inhaled or absorbed through the skin, mycotoxins will cause lowered performance, sickness or death on humans and animals. Mycotoxins are among the most potent mutagenic and carcinogenic substances known.[35,38] They pose chronic health risks: prolonged exposure through diet has been linked to cancer and kidney, liver, and immune-system disease.[36] Several studies have claimed that the consumption of mycotoxin-contaminated foods has been linked to the occurrence of human diseases in populations in other parts of Africa,[39,40] China[41] and India.[42] The humanitarian and relief foods imported to South Sudan are tested for mycotoxins unlike foods imported by private sector. Some mycotoxins compounds can find their way from livestock feed into milk or meat;[43] however the food safety hazard of mycotoxins in animal products might not be a serious issue in South Sudan.

## Food processing contaminants

Cooking and processing in general can inactivate many chemicals like protease inhibitors and lectins that are either directly toxic or inhibit digestion or absorption of nutrients. However, some undesirable chemicals have become associated with food processing techniques developed in the last decades. These chemicals can be formed in certain foods during processing as a result of reactions between compounds that are natural components of the food.[44,45] In some cases, undesirable chemicals may be formed as a result of a food additives reacting with other compounds in the food and result in the decrease of nutrient levels.[46,47] The latter is consistent with the works of Rupp et al.[48] who found that some processing techniques decreases nutrient levels, bioavailability and produce chemical and physical changes that may render a food hazardous. Thermal processing is a common process for generating flavour and/or ensuring microbiological safety in food.[49] Thermal processing practices such as baking, deep frying, etc. of foods are a very widespread practice in the Republic of South Sudan. Recently, eating habits have evolved towards increased consumption of fast foods It is also important to note that there is multiplicity of unregulated restaurants with the people involved having no knowledge of food processing and the environmental requirements in which foods are vended. As a result, some food venders in the informal markets keep recycling the cooking oil for considerable number of hours a day, hence, exposing people to processing toxicants such as acrylamide, furan, etc. As mentioned by Lineback et al.[50] and Gökmen,[51] when foods are heat-processed, there are reactions that occur between components of the food,

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resulting in the desired flavour, appearance and texture of the food. Thermal processing can lead to the formation of process toxicants, usually present in foods at very low levels, such as acrylamide, furan, 3-MCPD and glycidol esters.[49] Thermal processing causes free amino acids and sugars to react via the Maillard reaction to form a wide variety of chemical compounds.[52] The Maillard reaction products are important for the sensory properties of foods such as flavour, colour, and texture, but some are toxic.[52,53] The examples of these toxic compounds include various mutagens and carcinogenic products like heterocyclic aromatic amines (HAAs),[51,54,55] polycyclic aromatic hydrocarbons (PAHs),[56] furan,[57,58] acrylamide,[49,59] and N-nitrosamines.[60] Other detrimental changes in food that occur as a result of processing include the formation of trans fatty acids during the hydrogenation of fats and the creation of chloropropanols and their fatty acid esters during the production of hydrolysed vegetable protein.[61] Carcinogens from heated foods have been a health concern over the last three decades, when it was discovered that HAAs were formed in over heated meats, PAHs were produced in barbequed meats, and N-nitrosamines were created in fried bacon.[60] Although many of the processing toxicants are produced during thermal processing of foods; there are also several that are formed through non-thermal processes. Some of these chemical reactions involve naturally-occurring components in the food, while other reactions may involve food additives, ingredients, or food packaging materials that were intentionally used. According to Esselen et al.,[62] ethyl carbonate, 3-monochloropropane-1,2-diol, glycidol, biogenic amines, trans fatty acids and fatty acid peroxides are some of the toxicants in foods generated by non-thermal processes. For instance, benzene and/or benzoic acids have been reported in soft drinks.[63,64] In many cases, the presence of processing-induced chemicals in food cannot be avoided; however, understanding the processes by which these products are formed can allow the consumers to optimise and/or adjust food preparation methods, formulae or processes, thereby reducing or eliminating the formation of such chemicals. It is worth mentioning that there are poor storage facilities and preservation techniques in the country. Currently, foods and beverages are stored at very elevated temperatures at the open markets such as in the Konyo Market in Juba, South Sudan. Consequently, there are high chances of processing induced chemicals such as benzene in soft drinks during the temperature abuse storage conditions.

## Food packaging contaminants

A further area of concern is the migration of chemicals from packaging materials into foods especially among food manufacturers. Packaging is an essential element of the food value chain that allows the efficient handling, transport and storage of food as well as preventing food spoilage.[65,66] In South Sudan, there are many different forms of food packaging made of various synthetic polymers such as polystyrene, polycarbonate and polyvinyl chloride. These materials are the preferential materials used for packaging foods because they have properties that prevent detrimental changes to food during storage.[65] According to Aurela et al.,[67] many chemicals such as slip agents, antioxidants, plasticizers, stabilizers, and pigments are used during the preparation of food packaging materials. However, several studies have highlighted the potential migration of additives from the packaging onto food products from where ingestion occurs.[68–73] Examples of potentially toxic packaging chemicals include bisphenol A (BPA).[74] melamine[75] and phthalates.[76] It is recommended that use of these materials into the food system be regulated.[77]

In recent years, phthalates, which are widely used as plasticizers have been found to contain endocrine-disrupting chemicals that may cause cancer.[78] Bisphenol A as an industrial chemicals used in the production of polycarbonate plastics and synthetic resins has also attracted public attention for its ability to migrate out of the packaging materials into foods.[79,80] As a result, the migration of BPA from packaging materials such as PE, LDPE, polypropylene (PP), polyvinyl chloride (PVC), and PLA films has been the subject of several studies. In particular, these studies have investigated the release of the BPA from polymeric films into food; principally into food stimulants.[69,81] In one example, Cao[69] reported that BPA was detected in all of the corresponding soft drink products in cans. He detected BPA at low concentrations ranging from 0.081 to 0.54µg/liter in all beer samples in cans, indicating that migration from can coatings is the likely source for BPA in canned products. BPA Alin et al.[81] on the other hand studied the migration of 9,9-dimethylxanthene and m-tert-butyl-phenol from polycarbonate packaging into aqueous, alcoholic and fatty food simulants. They also found that dimethyl benzaldehyde, 4-ethoxy-ethyl benzoate, benzophenone, m-tert-butyl phenol and 1-methylnaphthalene have migrated out of the PC. Polycarbonate is used in food storage containers such as water and baby bottles, and epoxy resins are used to coat the interior of metal food and beverage containers.[82] Moreover, many food packaging materials coming in contact with food such as foils, cans, pans, storage containers continuously release mixtures of synthetic substances into food at low levels, which are then ingested by the consumer on a daily basis. Many chemical containers most notably paint containers and solvent drums that are supposed to be properly recycled are used for food and water handling by many people in Juba and other major cities. The major problem is the improper cleaning of the container leaving the chemicals leaching into water or food, thus, exposing people to the chemical leachates. Majority of South Sudanese especially in Juba keep their drinking and cooking water in drums once used for chemical solvents. Another food safety concern for South Sudanese is nanoparticles in food packaging. Nanotechnology which involves the use of polymeric nanoparticles is a rapidly growing area in the food industry. It has potential benefits like improving food safety and quality, the delivery of micronutrients and bio-actives in food processing and packaging.[83,84] Also, nanomaterials promise to expand the use of edible and biodegradable films and this technology has been related to improvements in the overall performance of biopolymers, enhancing their mechanical, thermal and barrier properties.[85–87] Although there are many potential benefits of nanoparticles in food packaging, there are also some risks due to the possibility of these particles migrating out of the packaging material into the foodstuff hence posing a potential risk to human health.[88–90] Indeed, the migration of nanoparticles from the packaging material might cause organoleptic changes in foodstuffs.[88,91] A number of recent research papers have highlighted the fact that potential migration of nanoparticles from packaging to foodstuffs has not been fully investigated nor has it been appropriately characterised in many cases.[88,89,92–94] Various studies have investigated the release of nanoparticles from polymeric films into food simulants and/or onto a variety of food products. Huang et al.,[95] determined the migration of nanosilver in commercial polyethylene containers and reported that nanosilver was released into food simulants from one of the plastic containers. Farhoodi et al.,[96] investigated the migration of nanoclay (Cloisite 20A) incorporated into PET films and found that the migration of Cloisite 20A (aluminium and silicon) from PET films into food simulants is dependent on storage time and temperature. In their studies, Avella et al.,[97] detected low-levels of MMT constituents (magnesium, iron and silicon) that migrated out of starch/clay nanocomposite films into vegetables (lettuce and spinach). They also reported low level migration of these elements from packaging to distilled water used as a food simulant and/or food products.

## Unapproved food additives and adulterants

In South Sudan, food items and drinks are prone for adulteration includes dairy products, cereals grains, fats and oils, and others like honey, juice, peppers. Unconventional contaminants can be introduced into foods through accidental or intentional means.[98] This type of contamination may occur during the production, preparation and packaging of foods.[99] Typically, this type of contamination occurs during the production of raw food commodities, in the way they are grown (fertilizers and pesticides used during agricultural production) or, in the case of animal products, how they are raised or produced (veterinary drugs such as antibiotics and hormones).[100] It becomes of public health importance when foods are adulterated intentionally for economic reasons to sell lower-value products as the original product, mask products that are already past their prime or add a cheaper compound to a food or ingredient and sell it for a higher value. This type of contamination is perhaps the most difficult to handle since adulteration is unexpected and difficult to anticipate. Over the past few years, considerable attention has been given to the presence of chemical contaminants in imported foods around the world. Of these contaminants, the presence of melamine in human foods and animal feeds has caused considerable consumer anxiety and desire to control the presence of these compounds.[101] Other examples include the use of toxic Sudan dyes in adulterated chili powders,[102] adding high fructose corn syrup to honey[103] and adulteration of virgin olive oil with hazelnut oil, which can cause unexpected allergic reactions in sensitive individuals.[104,105] Another source of contaminants may be the interactions of cleaning and sanitizing agents with other naturally occurring compounds.[106] For example, the carcinogen bromate forms in water when naturally occurring bromide reacts with ozone used for disinfection; haloacetic acids form when chlorine disinfectants react with organic acids.[107] Furthermore, it is important to mention that South Sudan is importing huge quantity of chicken from around the world. Although the major concern in these chicken consignments is microbial contaminations; there are claims of chemicals contamination especially antibiotic residues and formalin contaminations.

## Conclusion and recommendations

In South Sudan, chemical contamination of foods is believed to be as result of the use of agrochemicals, such as pesticides residues, veterinary drugs, contamination from environmental sources (water, air or soil pollution), cross contamination or food processing toxicants. In the oil producing areas chemicals contamination is as a result of the waste water, drilling muds and oil spills which are present in the environment and around the oil fields. Food contamination is probably among some of the major causes of food borne illnesses. While health risks associated with food contamination are multiple, at present, the food safety laboratories in South Sudan only perform specific tests for microbiological and physical contamination. In some cases, only proximate analyses are conducted locally and other samples for chemical contaminants are sent abroad. There is no laboratory equipped for determination of food chemical contaminants such as food adulterants. The existing infrastructure shortfalls are compounded by deficiency requisite skills among the population and in government regulatory and scientific agencies such as South Sudan national Bureau of Standards (SSNBS). The need to strengthen and build upon on a country-wide network of public and private laboratories is still underexplored. In addition to providing equipment and skills, it will be critical for the government regulatory and scientific agencies to set science-based standards in line with regional and international accreditations for easy of identification and testing of the chemical contaminants.

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## Conflict of interest

The author declares no conflict of interest.

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