Original Research Article

HEAVY METALS AND HEALTH RISK BURDEN, HOW SAFE IS THE CONSUMER POPULATION?: A STUDY ON THE HEAVY METAL CONTENT OF SOYBEANS CULTIVATED IN KATSINA STATE, NORTH WEST NIGERIA

ABSTRACT

This work contributes to the monitoring of heavy metals in agricultural produce in Katsina State, Northwest Nigeria, and possible health risk to the consumer population. Evaluation of some selected heavy metals in Soybean samples from the three senatorial zones that constitute to make up Katsina state in the North West of Nigeria was conducted by atomic absorption spectrometry. Using methods developed by the United States Environmental Protection Agency (US EPA) in assessing health risks, the possible health hazards of heavy metals in the samples on the children and adult population were investigated. The highest mean concentration (mg/kg) was observed for Zn (range: 1.204-1.432), followed by Pb (range: 0.658-0.998), Fe (range: 0.563-0.687) and Cr (range: 0.128-0.151). The lowest concentration was exhibited by Cd (range: 0.041-0.046), while the concentrations of heavy metals Mn and Ni were below detection level (BDL). The computed target hazard quotient (THQ) and the hazard index (Hi) from consumption of the samples lies within the regulatory limit. The overall cancer risk to the population lies beyond the threshold limit with the heavy metal Pb being the major contributor to the violation. It was concluded that consumption of the Soybean samples from Katsina State may add to the population cancer manifestations.

Keywords: Soybeans, Heavy metals, Katsina, Carcinogenic, Health Risk Index, Cancer Risk, Katsina

1. INTRODUCTION

Toxicities from heavy metals are of utmost concern, for their persistence in environmental components (soil, water and air) as they bioaccumulate and biomagnify and can cause deleterious effects such as carcinogenesis, mutations, and neurological problems (1; 2; 3). In recent decades, exposures to environmental toxic metals have become a global public health concern owing to their potential bioaccumulation and their deleterious health effects in humans (4; 5; 6; 7). Environmental exposure to heavy metals is a well-known risk factor for cancers (8) as chronic exposure to high levels of toxic metals has been associated with higher risk of cancers of the bladder, kidney, liver, pancreas, lung, and skin (9) and many visceral organs diseases. Because of heavy metals influence on disease systems and organs heavy metals exposure may also lead to cardiovascular, nervous, urinary and reproductive disease, as well as aggravation of pre-existing symptoms and disease (10). Evidence suggests that these toxic metals may have adverse effects on these outcomes even at lower concentrations (7), which might be prevalent in many parts of the world. This work contributes to the monitoring of heavy metal exposure in various food items cultivated in Katsina and possible carcinogenic and non-carcinogenic risk to the population.

2. MATERIAL AND METHODS

2.1 STUDY AREA

The area of study was Katsina State, North western part of Nigeria with an area spanning 24,192km^2 (9,341 m^2) and globally positioned at latitude 12^{0}15'N and longitude of 7^{0}30'E (11). The month of April heralds the beginning of the rainy season which ends in October, with the dry season starting in November and ending in March. The average annual rainfall is 1,321 mm, an average temperature of 27.3^{0}C, and a relative humidity of 50.2%. The soil is alluvial flood plain that varies base on location, having good water holding capacity and low in contaminants (11).

2.2 SAMPLING

The catchment area for sampling for this work was divided into five (5) locations, which were subdivided further into twenty (20) sampling sites. Sampling was done in each of the site and thereby combined to form bulk sample, from which a representative sample was obtained. Code named glass Bottles were used to store the samples for protection against contamination and moisture at a temperature of 4^{0}C prior to analysis.

2.3 SAMPLE PREPARATION

After cleaning of the seeds by removing all impurities and drying at room temperature 300g of the sample was grinded to a fine powder and store under the same condition as the duplicate portion prior to analysis.

2.4 HEAVY METALS DETERMINATION

A Gallenkamp hotbox oven (CHF097XX 2.5) was used to dry 5 g of each of the powdered sample at 80^{0}C for 2 hours and then blended using an electric blender, which was followed by ashing 0.5 g of the sample in an electric muffle furnace (Thermolyne FB131DM Fisher Scientific) at 550^{0}C for 24 hours. The ash was diluted with a mixed ratio of 3:1 concentrated hydrochloric acid (HCl) and concentrated nitric acid ($HN0_3$) and allowed to stand for a while. To make up to 100 ml mark, 50 ml of distilled water was added to the diluents. Using standard methods (12), the levels of heavy (Pb, Zn, Ni, Cd, Cr, Mn and Fe) metals in the soybeans samples were determined using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA)) and the results expressed in mg/kg.

2.5 HEAVY METAL HEALTH RISK ASSESSMENT

Daily intake of metals (DIM)

The daily intake of metals was calculated using the following equation

$$\mathrm{DIM} = \frac{C_{\mathrm{metal}} * C_{\mathrm{factor}} * D_{\mathrm{intak}}}{B_{\mathrm{weight}}}$$

Where, C metal stands for heavy metal concentration sample, C factor represent the conversion factor (CF) which was taken as 0.085 used in converting the soybean samples to their dry weight, D intake represent the daily intake of the sample taken from literature as 0.527 kg person^{-1} d^{-1} (13), and B weight represent the average body weight which is also taken from the literature as 60 kg (14) for adults and 24 kg (15) for children. The same values were used to compute of HRI as well.

Non-cancer risks

The target hazard quotient (THQ), which gives an idea of the non-carcinogenic risks to the consumer population from intake of heavy metals were determined using the following equation (16).

$$THQ=CDI/RfD$$

CDI represent the chronic daily heavy metal intake expressed in mg/kg/day and RfD represent the oral reference dose (mg/kg/day) which is a quantification the maximum permissible risk to the consumer from daily exposure throughout an individual life span (17). Individual reference doses taken from literature were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe = 0.7, Ni = 0.4, Mn = 0.014, Cr = 0.3) (18; 19). In conjunction with the THQ this research also uses the chronic hazard index (HI) that evaluate the potential risk to the population from exposure from more than one heavy metal, which is the summation of all the hazard quotients (THQ) for each heavy metal for a particular exposure pathway (20), which is computed using the formula below:

$$HI=THQ1+THQ2+\cdots+THQn$$

Where the subscripts 1, 2 …. n represent each heavy metal in the sample.

It is taken that the severity of the effect is equal to the total metal exposures and that organs affected by the exposure have similar working mechanism (21). HI less than 1 infer that the consumer population is safe, while HI above 1 raise the level of concern to the consumer population (22).

Cancer risks

The cancer risks to the consumer population from intake of the soybeans samples in the study were evaluated using the Incremental Lifetime Cancer Risk (ILCR) (23).

$$ILCR = CDI \times CSF$$

Where, CDI represent the chronic daily intake of individual carcinogenic heavy metal from life time consumption of the sample expressed in mg/kg BW/day and CSF represent specific cancer factors for each heavy metal in sample comparable to the body weight (16). Adapted from literature, cancer slopes for Pb = 0.0085 mg/kg/day (24), Cd = 0.38 mg/kg/day (25) where used in this study.

ILCR value in sample represents the probability of an individual's lifetime health risks from carcinogenic heavy metals' exposure (26). The range 10−6 to 10−4 is considered safe for the consumer population (17). The CDI was computed using the equation below (23).

$$CDI = (EDI \times EFr \times EDtot)/AT$$

In which the EDI is the estimated daily intake of metal from intake of the samples; EFr represents the frequency of exposure (365 days/year); EDtot is the length of exposure which is taken as the average life time of 60 years for Nigerians; AT represent the duration of exposure for non-carcinogenic effects (EFr × EDtot), and 60 life years for carcinogenic effect (16). The Human exposure to more than one carcinogenic heavy metal through food intake may result in cumulative cancer risk is the summation of the individual heavy metal increment risks and it is computed as below (23).

$$\sum 1n = ILCR1 + ILCR2 + \cdots + ILCRn$$

With the subscripts 1, 2 …n, representing each carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

The present study investigated the presence of heavy metals in soybeans which is a major component of the diet among the population in Katsina state, Nigeria. As shown in table 1, among the heavy metals evaluated, the highest concentration (mg/kg) was observed for Zn (1.3242), followed by Pb (0.8336), Fe (0.6284) and Cr (0.1395). While Cd has the lowest concentration (range: 0.041-0.0440). The heavy metals Mn and Ni were below detection level (BDL). The heavy metal Pb mean concentration in the sample was above the permissible values for Pb in legumes, while the rest of the heavy metals evaluated exhibited mean values that were within the permissible range as set by regulatory agencies.

Table 1 Heavy Metal Concentration (mg/kg) in Cultivated Soybean Samples from Katsina State

Location	Heavy metal						
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Kafur	BDL	1.204 ± 0.0130	0.658 ± 0.0002	0.045 ± 0.0003	BDL	0.687 ± 0.0010	BDL
M/Fashi	BDL	1.347 ± 0.0002	0.998 ± 0.0003	0.046 ± 0.0001	BDL	0.563 ± 0.0002	0.151 ± 0.0006
Dabai	BDL	1.432	0.926	0.041	BDL	0.648	0.128

		± 0.0002	± 0.0008	± 0.0003		± 0.0004	± 0.0003
Funtua	BDL	1.381 ± 0.0004	0.673 ± 0.0003	0.046 ± 0.0003	BDL	0.652 ± 0.0002	0.147 ± 0.0002
Matazu	BDL	1.257 ± 0.0008	0.913 ± 0.0003	0.042 ± 0.0006	BDL	0.574 ± 0.0004	0.132 ± 0.0007

The results for the estimated daily intake (EDI) of the heavy metals on consumption of the cultivated soya beans were given in Tables 2 and 3. Compared to the estimated daily intake limit for heavy metals by USEPA (27) all the estimated metal EDIs were within the regulatory limit. The sequential order for the daily metal intake of heavy metals from the various sampling sites is represented as: Kafur (Zn>Pb>Fe>Cd); Malumfashi (Zn>Pb>Fe>Cr>Cd); Dabai (Zn>Pb>Fe>Cr>Cd); Funtua (Zn>Pb>Fe>Cr>Cd); Matazu (Zn>Pb>Fe>Cr>Cd) in both the adult and children population.

Table 2 Daily Intake of Heavy Metal in Adults from Consumption of Cultivated Soybeans from Katsina State

Location			Heavy metal				
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Kafur	BDL	0.0009	0.0005	0.00003	BDL	0.0005	BDL
M/Fashi	BDL	0.0010	0.0008	0.00003	BDL	0.0004	0.0001
Dabai	BDL	0.0011	0.0007	0.00003	BDL	0.0005	0.0001
Funtua	BDL	0.0010	0.0005	0.00003	BDL	0.0005	0.0001
Matazu	BDL	0.0009	0.0007	0.00003	BDL	0.0004	0.0001

Table 3 Daily Intake of Heavy Metal in Children from Consumption of Cultivated Soybeans from Katsina State

Location			Heavy metal				
	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Kafur	BDL	0.0023	0.0012	0.0001	BDL	0.0012	BDL
M/Fashi	BDL	0.0025	0.0019	0.0001	BDL	0.0011	0.0003
Dabai	BDL	0.0027	0.0018	0.0001	BDL	0.0012	0.0002
Funtua	BDL	0.0026	0.0013	0.0001	BDL	0.0012	0.0003
Matazu	BDL	0.0024	0.0017	0.0001	BDL	0.0011	0.0003

Tables 4 and 5 represents the THQ and HRIs in the children and adult population from consumption of the soybean samples in the study, the results have revealed that the THQ value is less than 1 with the highest being that for the heavy metal Zn of the sample from Dabai (0.0036 in adult; 0.0084 in children) and the heavy metal Cd in the sample from Dabai (0.00006 in adult; 0.00015 in children) having the least THQ value. Likewise the HRIs is less than 1 in both the children and adult population, with the sample from Dabai (0.0073 in adult; 0.0139 in children) having the highest HRI and the sample from Kafur (0.0046 in adult; 0.0115 in children) having the lowest HRI.

Table 4 Heavy Metal Target Hazard Quotient and Health Risk Index in Adults from Consumption of Cultivated Soybeans from Katsina State

	Target Hazard Quotient	Health Risk Index (HRIs)

Location			Heavy metal					
	Mn	Zn	Pb	Cd	Ni	Fe	Cr	
Kafur	BDL	0.0030	0.0008	0.0001	BDL	0.0007	BDL	0.0046
M/Fashi	BDL	0.0034	0.0012	0.0001	BDL	0.0006	0.0004	0.0056
Dabai	BDL	0.0036	0.0012	0.0001	BDL	0.0007	0.0019	0.0073
Funtua	BDL	0.0034	0.0008	0.0001	BDL	0.0007	0.0004	0,0057
Matazu	BDL	0.0031	0.0011	0.0001	BDL	0.0006	0.0003	0.0053

The population is assumed to be safe when HI < 1 and in a level of concern when 1 < HI < 5.
THQ is interpreted as either greater than 1 (>1) or less than 1 (<1), where THQ >1 shows human health risk concern.

Table 5 Heavy Metal Target Hazard Quotient and Health Risk Index in Children from Consumption of Cultivated Soybeans from Katsina State

			Target Hazard Quotient					Health Risk Index (HRIs)
Location			Heavy metal					
	Mn	Zn	Pb	Cd	Ni	Fe	Cr	
Kafur	BDL	0.0075	0.0021	0.0002	BDL	0.0018	BDL	0.0115
M/Fashi	BDL	0.0075	0.0031	0.0002	BDL	0.0015	0.0010	0.0132
Dabai	BDL	0.0084	0.0029	0.0002	BDL	0.0017	0.0010	0.0139
Funtua	BDL	0.0089	0.0021	0.0002	BDL	0.0017	0.0009	0,0138
Matazu	BDL	0.0086	0.0028	0.0002	BDL	0.0015	0.0008	0.0119

The population is assumed to be safe when HI < 1 and in a level of concern when 1 < HI < 5.
THQ is interpreted as either greater than 1 (>1) or less than 1 (<1), where THQ >1 shows human health risk concern

Tables 4 and 5 represents the THQ and HRIs in the children and adult population from consumption of the soybean samples in the study, the results have revealed that the THQ value is less than 1 with the highest being that for the heavy metal Zn of the sample from Dabai (0.0036 in adult; 0.0084 in children) and the heavy metal Cd in the sample from Dabai (0.00006 in adult; 0.00015 in children) having the least THQ value. Likewise the HRIs is less than 1 in both the children and adult population, with the sample from Dabai (0.0073 in adult; 0.0139 in children) having the highest HRI and the sample from Kafur (0.0046 in adult; 0.0115 in children) having the lowest HRI.

The computed ILCR and cumulative incremental lifetime cancer risk (∑ILCR) for Cd, and Pb through the cultivated Soybeans samples are presented in Tables 6 and 7. From the results in the Soybeans samples in adults, the ILCR for Cd has reached the safety threshold risk limit ($>10^{-4}$) in all the studied samples, while the ILCR for Pb lies within the moderate risk limit ($>10^{-3}$). In children population, the calculated cancer risk for Pb and Cd has reached the moderate risk limit ($>10^{-3}$). The trend of risk for developing cancer as a result of consuming the studied soybeans samples exhibit the sampling location sequence: Malumfashi> Dabai > Matazu> Funtua > Kafur.
All the studied soybeans samples have a calculated cumulative cancer risk (∑ILCR) that has reached the moderate risk limit ($>10^{-3}$). The Soybeans sample from Malunfashi has the highest chances of cancer risks to the consumer population (ILCR 5.2×10^{-3} in adults, 1.3×10^{-2} in children) and the studied soybean from Kafur has the lowest chances of cancer risk (ILCR 3.5×10^{-3} in adults, 8.9×10^{-3}in children). The above values implies that an excess of 52 cancer cases in 10,000 of the adult population and 13 cancer cases in 1000 of the children population may likely result from the consumption of the sample from Malunfashi. While consumption of the sample from Kafur would likely result in an excess of 35 cancer case in adults and 89 cancer case in children per 10,000 people exposure.

Table 6 Incremental Life Time Cancer Risk in Adults from Consumption of Cultivated Soybeans from Katsina State

Location	ILCR		∑ILCR
	Pb	Cd	
Kafur	3.0952E-03	5.0400E-04	3.5992E-03
M/Fashi	4.6941E-03	5.1450E-04	5.2086E-03
Dabai	4.3533E-03	4.5900E-04	4.8123E-03

Funtua	3.1689E-03	5.1450E-04	3.6834E-03
Matazu	4.3004E-03	4.7100E-04	4.7714E-03

The safe limit for cancer risk is below about 1 chance in 1,000,000 lifetime exposure (ILCR < 10^{-6}) and threshold risk limit (ILCR > 10^{-4}) for chance of cancer is above 1 in 10,000 exposure where remedial measures are considerable and moderate risk level (ILCR > 10^{-3}) is above 1 in 1,000 where public health safety consideration is more important

Table 7 Incremental Life Time Cancer Risk in Children from Consumption of Cultivated Soybeans from Katsina State

Location	ILCR		∑ILCR
	Pb	Cd	
Kafur	7.7372E-03	1.2599E-03	8.9971E-03
M/Fashi	1.1735E-02	1.2879E-03	1.3023E-02
Dabai	1.0889E-02	1.1479E-03	1.2036E-02
Funtua	7.9136E-03	1.2879E-03	9.2015E-03
Matazu	1.0736E-02	1.1759E-03	1.1912E-02

The safe limit for cancer risk is below about 1 chance in 1,000,000 lifetime exposure (ILCR < 10^{-6}) and threshold risk limit (ILCR > 10^{-4}) for chance of cancer is above 1 in 10,000 exposure where remedial measures are considerable and moderate risk level (ILCR > 10^{-3}) is above 1 in 1,000 where public health safety consideration is more important

Discussion

Lead was seen in all the samples at a higher concentration than the 0.01mg/kg, 0.02mg/kg and 0.05mg/kg safety limits set by the WHO/FAO, EU and USEPA respectively, raises a level of concern. Compared to the reported Pb concentration range for leafy vegetables from Kaduna state Nigeria (28) and that reported for beans samples from Italy, Mexico, India, Japan, Ghana and Ivory Coast (29), the values in the current study are lower These values are also lower than the WHO safe limit for Pb in Cereals reported in literature (30). But the results are higher when compared to results reported for the concentration of Pb from Kano and Kaduna states, Nigeria, the result of a study conducted in Southeast Nigeria and in Zhejiang, China (31; 32; 33; 34). A possible explanation for the difference may be due to disparities in anthropogenic contribution to heavy metal pollution in the various sites were the studies were conducted or contamination production or handling process and industrial and vehicular exhaust (35).

Studies conducted in Zhejiang China that evaluate heavy metals in Romaine lettuce and cabbage (34) and in Katsina state, Nigeria that evaluate heavy metals in unprocessed and processed bean samples (36) and for locust beans from Odo-Ori market Iwo, Nigeria (37) reported Cd concentrations similar to the present study. But the reported Cd concentrations are above the concentrations of Cd reported for wheat flours (38). Likewise the reported Cd values in the present study are lower than that reported for various beans samples, cereals, and cereal products (29; 30; 31, 33; 39). These differences could be due to differences in the concentration of the metal in the soils where these various food produce were grown.

The Fe concentration in this study are above the concentration recorded in Calabar, Nigeria (38), but still fall within the FAO/WHO 40.7 mg/kg Fe permissible limit in legumes (40). These values are also too low to provide for the Recommended Daily allowance for Fe in both adult male (10mg/day) and female (15mg/day) from a nutritional point of view (32). The concentrations recorded are higher than that for millet from Kaduna, Nigeria (32). The result is similar to that reported for market sold beans from Katsina, Nigeria (36), but is lower to that reported in a study in eastern Nigeria (33) and that recorded by Zahir et al. (41) in a study conducted in Pakistan and the results for the study conducted by Di Bella et al. (29).

The heavy metal Zn values obtain in this study is similar to that reported in some studies (31; 42), but are higher than the range (0.04 to 0.19mg/kg) reported by Edem et al. (38) but far below the range reported by Ahmed and Mohammed (30) and that reported in a study conducted by Sulyman et al. (43).These values also falls below the WHO permissible limit for Zn as reported by Umar et al. (44) and can also not provide for the required daily allowance for Zn which is 11mg/day for men and 8mg/day for women (32).

In the Soybeans samples risk level of Target Hazard Quotient (THQ < 1) was observed for all the evaluated heavy metals for both adults and children. It indicates that intake of these heavy metals through consumption of the Soya beans will not pose a considerable non-cancer risk to the population. The THQ for the samples was in the decreasing order Zn>Pb>Fe>Cr>Cd, for both the samples respectively. The sequence of risk was the same for both adults and children although the children had higher THQ values in all cases compared to the adults. Further, the non-cancer risks for each sample were expressed as the cumulative HI, which is the sum of individual metal THQ. All the studied samples showed the risk level (HI < 1) with highest in the sample from Dabai and lowest in the sample from Kafur. It suggests that the inhabitants of Katsina state might not be exposed to non-carcinogenic health risk through the intake of heavy metals from soya beans.

The THQ of less than 1 reported for all the samples analyzed differ from the results of THQ for cabbage and tomato in a study conducted by Gebeyehu and Bayissa (45) in Mojo, Ethiopia that reported a THQ of more than 1and that of a study conducted by Yi et al., (46), that reported a THQ of more than 1 in fish samples from upper Yangtze river, China, and in a study conducted in Enyigba, south eastern Nigeria for Pb in lemon grass and Mn in leafy vegetables (47), the value is also lower than the THQ values above 1 reported by Bhalkhair and Ashraf (13) in a study conducted in the western region of Saudi Arabia on Okra vegetable, they are also lower than the THQ values for cereals, green leafy vegetables, roots and tubers from Vadodara (48) and the values reported by Mahfuza et al. (49) for vegetables and fruits from Bangladesh. But the results are similar to the THQ of less than 1 reported for Shrimp samples from Selangor, Malaysia (50) and in tea leaves from Puan County, Guizhou province China (51).

The samples evaluated in the study showed the risk level (HI < 1) in both adults and children. The HI in the samples differ from the HI values reported for vegetables from Tamale metropolis, Ghana that showed that the hazard index (HI) for both adult and children exceeded 1 (52), the value is also lower than the HI values of more than 1 for cabbage and tomato from Mojo, Ethiopia (45), the report of Obiora et al. (47) in a study conducted in Enyigba, south eastern Nigeria for Pb in lemon grass and Mn in leafy vegetables, the HRI values above 1 reported by Bhalkhair and Ashraf (13) in a study conducted in the western region of Saudi Arabia on Okra vegetable, the values for cereals, green leafy vegetables, roots and tubers from Vadodara (48) and the values reported by Mahfuza et al. (49) for vegetables and fruits from Bangladesh. But the HRI values are similar to what was reported for Clarias gariepinus from Imo River, Nigeria (53) and the report studies conducted in Katsina State, Nigeria on leafy and fruit Vegetables, and on cereals (54; 55; 56).

The range of ILCR and ∑ILCR from consumption of all the evaluated samples as highlighted above, which raises the level of health concern for the consumer population as they may contribute to the population cancer burden is similar to what was reported by Gebeyehu and Bayissa (45), in vegetables from Mojo Ethiopia, the ILCR and ∑ILCR reported from consumption meat and sea food samples from Xiamen, China (57), the ILCR and ∑ILCR in Vegetables from Pearl River Delta South China (58), in fruits and vegetables from Jamaica (59), in vegetables from a Pb/Zn smelter in Central China (60) in vegetables grown in Patuakhali province Bangladesh (61) and in fruit, root and leafy vegetables, and fruits in a study conducted in a sub urban industrial area of Bangladesh (47) But the results differ from the results for vegetables from some selected communities from ONELGA Rivers State, Nigeria that reported non carcinogenic cancer risks from the vegetable samples in the study (62).

CONCLUSION

This work contributes to the monitoring of heavy metal exposure in various food items cultivated in Katsina and possible carcinogenic and non-carcinogenic risk to the population. The target hazard quotient (THQ) and the hazard index (Hi) for the heavy metals evaluated falls within the safety limit. The overall cancer risk to the adults based on pseudo-total metal concentrations exceeded the target value, mainly contributed by the heavy metal Pb. Zn is the primary heavy metal posing non cancer risks while Pb caused the greatest cancer risk. The study has revealed that low non-carcinogenic risks exist for the population on consumption of the samples but the cancer risk is a cause for public health concern.

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