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# Code of practice for the prevention and reduction of cadmium contamination in cocoa beans

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This African Standard was prepared by ARSO Technical Committee on Coffee, Cocoa, Tea and Related Products (ARSO/TC 06).



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## Introduction

This African standard has been developed by Technical Committee TC 06 /WG 1-Cocoa on "Cocoa and related products".

1. The objective of this Code of Practice (COP) is to provide guidance to countries and the cocoa production industry on the prevention and reduction of cadmium (Cd) contamination in cocoa beans during production and postharvest processing: fermentation, drying, storage and transportation.

2. Cd is a heavy metal that predominantly enters the environment through anthropogenic (human) activities such as processing ores, burning fuels, contamination with industrial waste, and use of phosphate fertilizers. Cd can also enter the soil naturally by volcanic activity, from marine shale soils, erosion sea-salt aerosols, and sewage-containing fertilizers.

3. Cd is toxic and persistent in soil (estimated half-life for Cd in soils varying between 15 to 1100 years). Cd is absorbed and bioaccumulated by cocoa trees (*Theobroma cacao* L), which in some cases results in unacceptably high levels in cocoa beans, so measures may be needed to reduce both Cd in the soil and Cd absorption by cocoa trees.

4. Cd is not found in nature in its pure state. Its most common oxidation state is +2 and i t is usually found associated with iron (Fe), zinc (Zn), lead (Pb), phosphorus (P), magnesium (Mg), calcium (Ca), or copper (Cu). The concentrations of Cd in soil depend mainly on soil pH, which affects Cd solubility and mobility. Most metals in the soil tend to be more available at acidic pH, which increases their bio-availability for uptake by plants.

5. Greater adsorption of Cd on the surface of soil particles is desirable, as this reduces the mobility of this contaminant in the soil profile and reduces its bioavailability to cocoa trees, and consequently, its environmental impact. The concentration of Cd in soil solution and Cd bioavailability and mobility are mainly controlled by adsorption and desorption reactions on the surface of soil colloids. Soil factors that affect the accumulation and availability of cadmium include pH, texture, organic material, Fe, and manganese (Mn) oxides and hydroxides, Zn, carbonates, chlorinity, and cation exchange capacity.

6. At alkaline pH, elevated chloride content in soils tend to enhance chloride complex formation, which decreases the adsorption of Cd on soil particles, thereby increasing Cd mobility and bioavailability.

7. Over time, the development in our understanding of how various cropping systems contribute to or alleviate Cd contamination in cocoa beans could be used to develop integrated systems for the management of cadmium levels in cocoa beans. (e.g. agricultural – forestry integration systems)

8. Grafting as a genetic strategy with low cadmium accumulation varieties may be a viable option in various soil types and at different soil Cd levels, but has only been tried experimentally for reducing Cd in cacao trees.

To mitigate Cd levels in cocoa beans it is crucial to identify cocoa-growing areas with high Cd and develop strategies to address this problem.

# Code of practice for the prevention and reduction of cadmium contamination in cocoa beans

## 1. Scope

This Code of Practice provides guidance on recommended practices to prevent and reduce Cadmium (Cd) contamination in cocoa beans before planting, for new or existing cocoa tree plantations and during the production stage through the harvest and post-harvest phases.

## 2. Normative References

**2.1** CXC 49- 2011 Code of Practice Concerning Source Directed Measures to Reduce Contamination of Food with Chemicals

## 3. Terms and Definitions:

For the purpose of this Standard, the following terms and definitions apply:

**3.1**
**biochar – biocarbon:**
byproduct of the pyrolysis of residual biomass.

**3.2**
**cocoa bean:**
Seed of the cocoa fruit composed of episperm (integument, testa or shell), embryo and cotyledon.

**3.3**
**pulp or mucilage**:
Aqueous, mucilaginous and acidic substance in which the seeds are embedded.

**3.4**
**bioavailability**:
Accessibility to normal metabolic and physiological processes as influenced by many factors including total concentration and speciation of metals, pH, redox potential, temperature, total organic content (both particulate and dissolved fractions) and suspended particulate content.

**3.5**
**adsorption**:
Attraction and retention that a body makes on its surface of ions, atoms or molecules that belong to a different body.

**3.6**
**Absorption**:
Attraction developed by a solid on a liquid with the intention that its molecules penetrate into its substance; to the ability of a tissue or a cell to receive a material that comes from its outside.

**3.7**
**cachaza**:
By-product of sugar cane.

**3.8**
**cation Exchange Capacity (CEC)**:
A measure of the soil's ability to hold positively charged ions. The clay mineral and organic matter components

of soil have negatively charged sites on their surfaces which adsorb and hold positively charged ions (cations). This electrical charge is critical to the supply of nutrients to plants because many nutrients exist as Magnesium (Mg), Potassium (K) and Calcium (Ca) cations by electrostatic force.

**3.9**
**drying**:
Cocoa beans are dried either under sunlight or in mechanical/solar dryers (or a combination of both) to reduce the moisture content (to less than 8 %) to make them stable for storage.

**3.10**
**fermentation**:
process designed to degrade the pulp or mucilage and initiate biochemical changes in the cotyledon by enzymes and microorganisms in the farm environment.

**3.11**
**humus:**
The organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms.

**3.12**
**soil Amendments**:
Any material added to the soil to improve its physical and chemical properties. The application of amendment depends on the characteristics of the soils, and may include compost, livestock manure, magnesium sulfate, vinasse, zeolite (minerals or adsorbents that hydrate and dehydrate reversibly); charcoal or biochar; calcium sulphate, lime, cachaza , zinc sulphate, dolomite (calcium magnesium carbonate), vermicompost, sugar cane, palm kernel cake, phosphate rock, and other organic matter.

**3.13**
**pruning**:
Annual removal of branches that are dry, diseased, or unbalanced from shade trees and cocoa plants.

**3.14**
**shading**:
Growing cocoa plants with shade trees to reduce the amount of solar radiation and wind that reaches the crop. Shading is usually more or less 50% during the first 4 years of plant life after which the percentage of shade can be reduced to 25 or 30%.

**3.15**
**vinasse:**
A byproduct of the production of alcohol from sugarcane.

# 4. Recommended Practices to Prevent and Reduce Cadmium (Cd) Contamination in Cocoa Beans

## 4.1 Contamination before planting – new plantations

1. The prevention and reduction of Cd in cocoa should begin with the physico-chemical analysis of the soil and be an integral part of the practices before planting a new plantation. Soil analysis is not limited to Cd measurement, but should also consider percent organic matter, cation exchange capacity, soluble zinc, and chlorinity. Physical analysis parameters are: sand %, clay %, silt %, textural class. Chemical analysis should consider: pH, organic matter %, Total Nitrogen (N) %; Available ppm of Phosphorus (P), Potassium (K), Lead (Pb) Iron (Fe) oxides and hydroxides, Manganese (Mn) carbonates, Cd and Zinc (Zn); changeable centimoles per kilogram (cmol (+) /kg) of Calcium (Ca), Magnesium (Mg), K, Sodium (Na), Aluminium (Al) and, Hydrogen (H); CEC, Bas. Camb %, Ac. Camb. %, and Sat. Al.

2. National or relevant food control authorities should consider implementation of source directed measures in the *Code of Practice for Source Directed Measures to Reduce Contamination in Foods with Chemicals* (CXC 49- 2011).
3. In new plantations, the use of cover crops of perennial legumes should be considered. Cover crops improve soil organic matter and they can protect soil from erosion and reduce the loss of nutrients, improving soil productivity through greater availability of essential nutrients and reducing the bioavailability of metals.
4. No specific recommendation on Cd levels in cocoa growing areas has been identified. The acidity of the soil affects acceptable cadmium soil levels. When the soil pH = 7, the Cd concentration in the soil could be higher than 1.0 mg Cd/kg.
5. Irrigation waters should be monitored to determine if they are a potential source of Cd, e.g., higher than background levels due to point source contamination. As one possible guideline for higher levels, the WHO recommended level for drinking water is 0,005 mg/L.
6. Although there are known benefits to agroforestry, data on the impact of agroforestry vs. monoculture on Cd levels, are preliminary. Studies that have systematically or statistically compared agroforestry with monoculture found no statistically significant difference in Cd uptake in cacao beans.
7. In agroforestry the most commonly used shade plant species with cocoa trees are Musaceae (bananas, moles and cambures) for temporary shade in early cocoa establishment and legume trees such as the pore or bucare (Erythrina sp.) and guabas (Ingas) for permanent shade trees. Other shading plant species used that provide greater economic benefits include timber species (e.g. laurel, cedar, Colombian mahogany (*Cariniana pyriformis*), cenizaro or rain tree and terminalia) and / or fruit trees (e.g. citrus, avocado, sapote, breadfruit, date palm). It is advisable to plant short shade trees and use citrus or fruit trees for the borders of cocoa plantations.
8. Install plantations in areas separate from roads or take measures to reduce the exposure of the cocoa plantations to emissions from the combustion engines (e.g. in vehicles) because they may contain Cd. Likewise, they should be located in areas separated from dumps in cities, mining areas, smelting areas, industrial wastes, sewage and household waste, and water because these could be sources of Cd.
9. Avoid flooded soils if the water sources are an increased source of Cd.
10. When planting new plantations, it should be recommended to plant varieties of cocoa trees, which are less prone to cadmium uptake.

### 4.2 From production to harvesting

1. Knowledge of the sources and the distribution of Cd in the soil is important. In general, it should be noted that any organic or inorganic amendment applied to the crop should be previously analyzed for Cd, because depending on its source, it may contain Cd and become a Cd source for crops. Sewage sludges, fly ashes, and phosphate fertilizers can have high concentrations of Cd. The phosphate fertilizers applied should contain low Cd levels, and the Cd levels should be evaluated with respect to the phosphorus concentrations. To decrease Cd uptake, phosphate fertilizers for cocoa farms should meet national criteria with respect to the ratio of Cd to phosphorus (Cd: P or Cd: $P_2O$).
2. Data suggest that there is a positive correlation between higher levels of Cd in soil (as measured by soil tests) and elevated levels of Cd in plant tissues and cocoa beans.
3. Soil characterization analysis for cocoa plantations should be conducted by accredited laboratories; using validated methods which include the use of certified reference materials, standards and associated uncertainties. In addition, it is very important to carry out soil analyses with internationally recognized methods (e.g. endorsed by Codex). These methods should include appropriate ones for use by local farmers trying to export cocoa. These soil characterization analyses should not only include Cd but other nutrients too.
4. The soil sampling protocol should consider obtaining samples representative of each farm because Cd content could be variable in the same production area of cocoa. The protocol should take into account international standards for taking samples in soils specifically contaminated with metals. The depth of soil sampling in surveys and field evaluation is 0-15 cm. Because litterfall of cocoa leaves and branches contains higher Cd than the soil they are grown in, allowing litterfall to be metabolized on the soil adds Cd

to the top 0 -5 cm of soil. Taking 0-15 cm soil samples provides a more representative measure of soil Cd.

5. In areas where cocoa beans have relatively higher levels of Cd it is important to determine soil and irrigation water salinity (chloride salts) since the absorption of Cd by plants increases with increased chloride concentrations. However, this effect is most pronounced in alkaline soils (pH>7.0). Therefore, when Cd levels in cocoa beans are of concern and soil is alkaline, it is important to determine the electrical conductivity of soil and water which should be less than 2mS/cm.

### 4.3 Strategies to immobilize cadmium in the soil

1. When there is a deficiency of Zn in the soil, soil Zn levels should be increased. Cd competes with Zn for uptake by plants, and Cd is more likely to enter plants and accumulate in cocoa beans when Zn soil concentration is low. Moreover, it is recommended to specify critical levels of Zn for cocoa growing soils.
2. The application of zinc sulfate is carried out with fertilization that is conducted annually at the cocoa plantation, according to the requirements of the crop and the Zn content of the soil. However, if zinc sulfate is added at high rates to inhibit Cd uptake from higher Cd soils (e.g., 25 kg Zn/ha), soil acidification could occur, requiring addition of limestone to counteract the effects of the acidification.
3. The most effective method developed to date to decrease Cd bioavailability is through liming the soil when soil pH is below 6. Liming is an agronomic management practice that reduces Cd uptake by cocoa trees cultivated on highly acidic soils, and its addition also might improve nutrition and production of cocoa trees. However, it is important to verify that the lime does not introduce Cd, as lime Cd contains variable levels of Cd. Soil pH should be managed with a goal of pH>6, and if Cd levels are a problem for the soil, a higher pH may be needed to reduce Cd accumulation by cocoa trees.
4. Apply lime in low doses (3 t/ha/year), preferably as dolomite $CaMg(CO_3)_2$, to gradually increase the pH and incorporate Ca and Mg, which are essential for the growth of cocoa trees. This can help precipitate Cd and decrease its bioavailability. Over liming should be avoided as this can reduce micronutrient bioavailability.
5. A greater amount of soil organic matter may increase soil Cd absorption and thus may help to decrease Cd in cocoa beans, based on field studies. The use of organic fertilizers such as treated manure from stabled livestock, or compost, increases the organic matter content of the soil and improves its microbiological activity.
6. Phosphate fertilizers and sedimentary phosphoric rock contain Cd as an impurity. Nonetheless, for successful cocoa production it is vital to add phosphate fertilizers because tropical soils have very limited native phosphorus content. However, producers should control the amount of Cd in phosphate fertilizers they use or comply with any national limits established or given by governments for phosphate fertilizers. In addition, by using organic fertilizers the phosphorus content of the soil can be improved, as these fertilizers show a high phosphorus bioavailability.
7. In general, the formula for the ratio of nitrogen, phosphorus and potassium in NPK fertilizers to be applied to cocoa crops will vary according to the age of the plant and the characteristics of the soil. The heavy metal content of fertilizers needs to be verified through analysis prior to application to soil to ensure that Cd content is low.
8. The application of soil amendments (magnesium, sulfate, dolomitic limestone, vinasse, zeolite, humus, charcoal, calcium sulfate ($CaSO_4$), cachaza and zinc sulfate ($ZnSO_4$)), which vary depending on the characteristics of the soils, can help decrease Cd concentrations in cocoa beans.
9. Vinasse is a source of K that promotes the installation of fungi that form mycorrhizas in the roots of the cocoa tree, thereby increasing the efficiency of P nutrition and immobilizing Cd.
10. Lime and sugarcane cake can reduce the bioavailability of Cd in the soil profile. Zeolite is another option in soils with high sand content and in clay-textured soils. Apatite (or rock phosphate) which can contain Cd, should be avoided where possible. Also, apatite is expensive and may not be cost effective for farmers who grow cocoa.
11. Biochar has been shown to reduce the bioavailability of Cd in cocoa beans. The reduction rates are comparable to liming and have an additive influence on liming. However, biochar is an expensive soil amendment and may not be cost effective for farmers who grow cacao.
12. Biochar and compost have significant effects on soil physicochemical features, metal bioavailability

(including Cd), and enzyme activities in heavy metal-polluted soil. Therefore, they help to mitigate Cd concentrations in the cacao trees.

13. The cacao plant genotypes identified with low bioaccumulation of Cd have the potential to be used for Cd mitigation through grafting plants onto rootstocks with low cadmium uptake and obtaining new varieties that are not as prone to the absorption of Cd.
14. These Cd resistant Streptomyces sp. strain has been shown to reduce Cd uptake in cocoa plants on an experimental basis.

### 4.4 Avoiding further cadmium contamination of the soil

1. To reduce soil Cd contributions, remove pruned cocoa and shade tree limbs and leaves from the ground as they could contain Cd, which can be released into the top layers of the soil during decomposition. The practice should include removing pruned materials in orchards with high foliar Cd levels.
2. Avoid the application of sewage sludge
3. Avoid burial or incineration of household waste, as approximately 10% of garbage is made up of metals, including Cd. Their burial can contaminate the groundwater, while incine ration can cause contamination, release volatile metals into the atmosphere and consequently pollute soils
4. National or regional authorities should consider limiting main polluting industrial activities near cocoa plantations, such as non-ferrous mining and smelting, metal using industry, leather tanning, coal combustion and phosphate fertilizer manufacturing.

### 4.5 Post-harvest phase

1. The process of fermentation of cocoa beans should be an important practice that any producer and export organization should carry out to develop chocolate flavors.
2. Mucilage draining improves the sensorial quality of cocoa beans in the process of fermentation reducing its acidity. Studies have shown that mucilage draining times up to 12, 24 or 36 hours reduces the cadmium concentrations, without affecting the organoleptic quality of the cocoa.
3. Based on experimental studies, a longer draining time may lower Cd content in a few cocoa bean cultivars, but an optimal draining time is not known and this has only been studied in a few cultivars. A longer fermentation time than normal also may result in less Cd, based on research studies, but an optimal fermentation time for Cd is not known
4. It is a recommended practice to make sure that during the fermentation of cocoa beans they are not contaminated with smoke, or with gases coming from dryers or vehicles, or industrial discharges.
5. The strain of *Saccharomyces cerevisiae* is one of the strains that intervenes in cocoa fermentation, therefore by increasing its population in such process could improve the absorption of Cd and the safety of cocoa.
6. After fermentation, cocoa beans should be dried on clean solid surfaces to avoid contamination by soil.
7. During storage, contamination of cocoa beans due to spills of fuels, exhaust gases or fumes should be prevented.

### 4.6 Transport phase

It is recommended to carry out good practices for proper transportation:

1. Cover loading/unloading areas to protect from rain.
2. Ensure that vehicles are well maintained and thoroughly cleaned.
3. Ensure that tarpaulins/covers are clean and free from damage.
4. Ensure that containers have not been used for chemicals or noxious substances and that they are well- maintained and clean.

5. Ensure that the humidity levels are as low as possible by using ventilated containers if available and cardboard/kraft paper lining.
6. For bagged cocoa: load bags carefully and cover with materials to absorb condensation.
7. For cocoa in bulk: use a sealable plastic liner if possible and ensure that it is kept clear of the roof of the container.
8. Ensure that the ventilation holes in containers are free from clogging.
9. Try to ensure that the cocoa is not exposed to temperature fluctuations and that it is not stored near noxious materials.

## Bibliography

a. A survey in Ecuador of soil Cd concentrations corresponding to specific Cd concentrations in cocoa beans found that the soil Cd should not exceed 0.4 mg Cd/kg if the soil pH=5.0, in order for the mean Cd concentration in cocoa beans to not significantly exceed 1 mg Cd/Kg (See paragraph 14).

b. Vanderschueren R, Mesmaeker V De, Mounicou S, Marie-Pierre I, Doelsch E, et al., 2020. The impact of fermentation on the distribution of cadmium in cacao beans. Food Res Int 127:108743. doi: 10.1016/j.foodres.2019.108743 (see paragraph 46)