APPENDIX III

CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF CADMIUM CONTAMINATION IN COCOA BEANS
(For adoption at Step 5)

1. INTRODUCTION

1. The objective of this proposed draft Code of Practice (COP) is to provide guidance to member states and the cocoa production industry on the prevention and reduction of cadmium (Cd) contamination in cocoa beans during production and postharvest processing: fermentation, drying and storage; including during any transportation that might be involved.

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

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 prevent Cd presence in the soil and reduce Cd absorption.

4. Cd is not found in nature in its pure state. Its most common oxidation state is +2 and it is usually found associated with iron (Fe), zinc (Zn), lead (Pb), phosphorus (P), magnesium (Mg), calcium (Ca), or copper (Cu) through its "cation exchange capacity". The concentrations of Cd in soil solution 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 the availability for plants.

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

6. 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 or alleviate cadmium contamination in cocoa beans could be used to develop integrated systems for the management of cadmium levels in cocoa beans.

8. The grafting tool as a genetic strategy with low cadmium accumulation varieties is a viable option in various soil types and different Cd levels, but has only been tried experimentally for reducing Cd in cacao tress. Personal information obtained in field production areas of Peru showed that cocoa beans exported to Europe are crossed varieties with "Chuncho" Cacao". Leyva, C. 2019.

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

2. SCOPE

10. The scope of this Code of Practice is to provide guidance on recommended practices to prevent and reduce Cd contamination in cocoa beans before planting or for new plantations and during the production stage through the harvest and post-harvest phase including during any transportation phase that might be involved or existing plantations of cocoa trees that can produce beans for up to 25 years.

3. DEFINITIONS

Biochar – biocarbon is a byproduct of the pyrolysis of residual biomass.

Cocoa bean: The seed of the cocoa fruit composed of episperm (integument), embryo and cotyledon.

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

Harvesting and opening the fruits: Fruits are manually harvested and opened using a sickle, machete or wooden baton.

Bioremediation: The use of living organisms, primarily microorganisms, to degrade environmental contaminants into less toxic forms.

Phytoremediation: A type of bioremediation process that uses plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater.

Air emissions: They are defined as unwanted gaseous or particulate materials (Cadmium) released to the atmosphere as a direct result of production, accumulation or consumption activities in the economy.

Bioavailability: Bioavailability of a mineral in nutrition to plants and soils can be defined as its 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.

Adsorption, Absorption and Desorption: Physical, chemical or exchange adsorption of cadmium to soil particles is a concept that refers to the attraction and retention that a body makes on its surface of ions, atoms or molecules that belong to a different body. Absorption is a term that refers to the damping exerted by a body before a radiation that passes through it; to the 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. Desorption is the process of removing an absorbed or adsorbed substance.

Cachaza: by-product of sugar cane.

Cation Exchange Capacity (CEC): A measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants. 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 Mg, K and Ca cations by electrostatic force.

Electrical conductivity: Electrical conductivity in metals is a result of the movement of electrically charged particles. The atoms of metal elements are characterized by the presence of valence electrons, which are electrons in the outer shell of an atom that are free to move about. In addition, it is denoted by the symbol σ and has SI units of siemens per meter (S/m). Electrical conductivity of water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is; the purer the water, the lower the conductivity (the higher the resistivity). Conductivity measurements in water are often reported as specific conductance, relative to the conductivity of pure water at 25 °C.

Drying process: Drying of cocoa beans either under sunlight or in mechanical/solar dryers (or a combination of both) in order to reduce the moisture content (less than 8 %) to make them stable for storage.

Fermentation: process designed to degrade the pulp or mucilage and initiate biochemical changes in the cotyledon by enzymes and microorganisms inherent in the environment of the farm.

Humus: refers to compost that is obtained of artificial manner when organic waste is decomposed by organisms and beneficial microorganisms

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, magnesium carbonate, vinasse, zeolite (minerals that hydrate and dehydrate reversibly, adsorbents); 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.

Validation: Obtaining evidence that a control measure or combination of control measures, if properly implemented, is capable of controlling the hazard to a specified outcome.

Sampling: Procedure used to draw or constitute a sample. Empirical or punctual sampling procedures are not statistically-based procedures that are used to make a decision on the inspected lot.

Pruning: annually removal from shade trees and cocoa plants of branches that are dry, diseased or un-balanced.

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

Vinasse: A byproduct of the production of alcohol from sugarcane.

4. RECOMMENDED PRACTICES TO PREVENT AND REDUCE Cd CONTAMINATION IN COCOA BEANS

4.1 Contamination before sowing – new plantations

11. The prevention and reduction of Cd in cocoa should begin with the physical-chemical analysis of the soil and be an integral part of the practices before sowing or establishment of a new plantation. Physical analysis parameters are: Sand %, clay %, silt %, textural class. Chemical analysis should consider: pH, organic matter %, Total N %; Available ppm of P, K, Pb, Fe oxides and hydroxides, Mn carbonates, Cd and Zn; Changeable (cmol (+) /kg) of Ca, Mg, K, Na, Al and, H; CEC, Bas. Camb %, Ac. Camb. %, and Sat. Al. suitable for farmers, and it should be kept in mind as a control measure CXC 49-2001: Code of practice concerning source directed measures to reduce contamination of foods with chemicals.

12. No specific recommendation on Cd levels in cocoa growing areas has been identified, but 1.4 mg/kg[1] has been identified as an upper level for Cd in soil for growth of other crops, and could be applied for new cocoa plantations. Water levels can be monitored to determine if they are a potential source of Cd, e.g. higher than background levels due to point source contamination; as an upper limit for Cd in water could be 0,005 mg/lt. Nonetheless, a largest nationwide published survey in Ecuador of Cd in cacao in terms of number of trees collected (n=560) allows to estimate soil Cd concentrations, which correspond to specific concentrations in cocoa beans. The data show, that for example, for ensuring that the mean Cd concentration in cocoa beans do not significantly exceed 1 mg Cd/kg, the soil Cd should not exceed 0.4 mg Cd/kg if the soil pH=5.0. If the soil pH = 7, the Cd concentration in the soil should not exceed 1.0 mg Cd/kg.

13. Although there are known benefits to agroforestry, data on the impact of agroforestry vs. monoculture on Cd levels, they are preliminary. Studies that have systematically or statistically compared agroforestry with monoculture found no statistically significant difference in Cd uptake in cacao beans.

14. The most commonly used species are musaceae (bananas, moles and cambures) for temporary shadows and legumes such as the pore or bucare (Erythrina sp.) and guabas (Ingas) for permanent shades. Other shading species are being used that provide greater economic benefits such as timber species (laurel, cedar, Colombian mahogany (*Cariniana pyriformis*), cenizaro or rain tree and terminalia) and / or fruit trees (citrus, avocado, sapote, breadfruit, date palm etc.). It is advisable to sow short trees and use citrus or fruit trees for the borders of cocoa plantations.

15. Install plantations in areas far from roads or take measures to reduce the exposure of the cacao plantations to gases emitted by the combustion of 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 water because these could be a source of Cd.

16. Avoid flooded soils if the water sources are an increased source of Cd.

17. 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.

4.2 From production to the harvesting phase

18. 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 Cd analyzed, because depending on its source may contain levels of Cd and become a source to for the entry into the crop. Sewage sludges, fly ashes have high concentrations of Cd. The fertilizers applied should meet the specified criteria in relation to Cd levels.

19. 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. Furthermore, multivariate regression analysis showed that bean Cd concentrations increased with increasing total soil Cd.

20. Soil characterization analysis laboratories for cocoa plantations should be conducted by laboratories that are accredited with the worldwide recognized ISO/IEC 17025:2017 standard; 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 Alimentarius) such as Flame Atomic Absorption Spectrometry (F-AAS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Graphite Furnace with Atomic Absorption Spectrometry (GF-AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). These methods include appropriate ones for local farmers trying to export cocoa. These analyses not only include Cd but other nutrients too. It is important to clearly state here that soils well supplied with nutrients are less likely to bioaccumulate Cd.

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[1] Supreme Decree N° 011-2017-MINAM - Approval of Environmental Quality Standards (EQS) for Soil

21. 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.

22. In areas where cocoa beans have relatively higher levels of Cd it is important to determine soil and irrigation water salinity (Cd chloride salts) since the absorption of Cd by plants increases with chloride. Therefore, it is important to determine the electrical conductivity of soil and water which should be less than 2mS/cm. It seems that these measures would not be needed if there are no concerns regarding Cd levels in cocoa beans.

4.2.1 ***Strategies to immobilize cadmium in the soil***

23. When there is a deficiency of Zn in the soil, soil Zn levels should be increased. Cd competes with Zn, and Cd is more likely to enter the plant and accumulate in cocoa beans when Zn soil concentration is low. Moreover, it is recommended to specify critical levels of Zn for cocoa, taking as a reference various methods of sample analysis, for example: DTPA, Olsen modified; with the aim of making the strategy more applicable.

24. The application of zinc sulphate is carried out with the balanced fertilization that is conducted annually at the cocoa plantation, according to the requirements of the crop and the soil. However, with the addition of zinc sulfate, soil acidification occurs, requiring addition of limestone.

25. 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 know the content of Cd in these limes as they come from mines and are highly variable so everything depends on the origin of the raw materials used.

26. The most effective methods developed to date to decrease Cd bioavailability is through liming the soil when soil pH is below 5.5. When the pH is higher than 5.5 it should be known how to be managed.

27. Apply liming levels in low doses (3 t/ha/year) and preferably dolomite $CaMg(CO_3)_2$ to gradually increase the pH and incorporate Ca and Mg that are essential for the growth of cocoa and can precipitate Cd decreasing its bioavailability. Over liming should be avoided.

28. A greater amount of soil organic matter causes a lower absorption of Cd and may help decrease Cd in cocoa beans, based on experimental studies. The use of organic fertilizers such as treated manure from stabled livestock, compost, etc. increases the organic matter content of the soil and improves its microbiological activity. Levels of 3 to 4 % of organic matter in cocoa plantations decreases cadmium in cocoa beans.

29. Phosphate fertilizers and sedimentary phosphoric rock may 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 given by governments. In addition, by using organic fertilizers the phosphorus content of the soil can be improved, while these fertilizers show a high phosphorus bioavailability.

30. In general, the formula for the doses of nitrogen, phosphorus and potassium (NPK) in fertilizers to be applied to cocoa crop vary according to the age of the plant and the characteristics of the soil. Verify the heavy metal analysis prior of application to ensure that Cd content is low. Soils well supplied with nutrients are less likely to bioaccumulate Cd.

31. The application of soil amendments (**magnesium carbonate** ($MgCO_3$), 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.

32. Vinasse is a source of K that promotes the installation of fungi that form mycorrhizas in the roots of the cacao tree, increasing the efficiency of P nutrition and immobilizing Cd.

33. Lime and sugarcane cake can reduce the flow of Cd in the soil profile. Zeolite is another option in soils with high sand content in clay-textured soils. Also, Apatite (rock phosphate) would be very expensive compared to use of dolomitic limestone to raise pH and reduce soil Cd Phyto availability.

34. 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 cocoa.

35. Biochar, compost and their combinations have significant effects on soil physicochemical features, metals (Cd) availability and enzyme activities in heavy metal-polluted soil. Therefore, they mitigate Cd concentration in soil.

36. The genotypes identified with low bioaccumulation of Cd have the potential to be used as rootstocks in the production of propagation material to reduce the absorption of Cd from soil; Moreover, Cd mitigation could be done by grafting plants with rootstocks with low cadmium content and obtaining new varieties that are not as prone to the absorption of Cd and modify soils to reduce Cd absorption by plants. Eleven cultivars of the "Chuncho" Cacao variety from Cusco – Peru had a range concentration of Cd (mg/kg) from <0.05 to 0.11, so the "Chuncho" Cacao variety could be used for grafting. Furthermore, when planting new plantations, it should be recommended to plant varieties of cocoa trees, which are less prone to cadmium uptake.

37. The Streptomyces sp. strain has bioremediation activity as it reduces Cd uptake in cocoa plants. This has been demonstrated on an experimental basis.

38. The legumes coinoculated with plant growth promoting bacteria Cd resistant such Streptomyces of the family Streptomycetaceae could be useful in phytoremediation of Cd-contaminated soils and biofertilization.

4.2.2. ***Avoiding further cadmium contamination of the soil***

39. In areas where soil levels of Cd are high, remove pruned material from the ground as they could contain Cd, which will be released into the top layers of the soil after decay. The practice should be to remove pruned material from the crop field.

40. To avoid the application of sewage sludge

41. To 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 incineration can contaminate the atmosphere by releasing volatile metals and consequently polluting soils

42. To take action at the level of national or regional authorities to limit main polluting industrial activities near cocoa plantations, such as non-ferrous mining and smelting, metal using industry, coal combustion and phosphate fertilizer manufactures.

4.3 **Post-harvest phase**

43. Mucilage draining improves the sensorial quality of cocoa beans in the process of fermentation reducing its acidity. The time bean draining effect in a thesis of 0, 2, 4 and 6 hours of creole cocoa from Peru, concluded that the best one with fermentation above 80 % was 4 hours of drainage, while another thesis studying the effect of draining time in the clon CCN51 (cocoa beans which contain more water) including 0, 12, 24, 36 hours concluded that 36 hours was the best one with 86.00 ± 9.63 of fermentation and the draining of 12 hours had a fermentation percentage of 83.83 ± 1.48. An experimental study demonstrated that the draining of pulp or mucilage for 12 hours (longer time than normal) significantly reduced the content of Cd in cocoa beans in one variety without affecting the physical or organoleptic quality of the cocoa at the time of the evaluation. An experimental study demonstrated that the draining of the pulp or mucilage for 12 hours (longer time than normal) significantly reduced the content of Cd in cocoa beans of the clonal hybrid (cultivar) CCN-51 without affecting physical or organoleptic quality of the cocoa at the time of the evaluation.

44. After fermentation, cocoa beans should be dried on clean solid surfaces to avoid contamination by soil.

45. 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.

46. The process of fermentation of cocoa beans should be an important practice that any export organization should carry out to reduce the levels of Cd of their cocoa beans.

47. During storage, contamination of cocoa beans due to spills of fuels, exhaust gases or fumes should be prevented.

48. The longer the fermentation process (80 %), the less Cd in cocoa beans. This statement is confirmed by a reliable cited scientific publication which indicates that Cd concentrations decrease as the fermentation proceeds. Cd beans can be reduced if pH is sufficiently acidified during fermentation.

49. 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.

4.4 **Transport phase**

Protect cocoa from becoming wet and contaminated from other materials:

50. Cover loading/unloading areas to protect from rain.

51. Ensure vehicles are well maintained and thoroughly cleaned.

52. Ensure tarpaulins/covers are clean and free from damage.

53. Ensure containers have not been used for chemicals or noxious substances, are well-maintained and clean.

54. Ensure humidity levels are as low as possible by using ventilated containers if available and cardboard/kraft paper lining, with silica gel bags.

55. For bagged cocoa: load bags carefully and cover with materials to absorb condensation.

56. For cocoa in bulk: use a sealable plastic liner if possible and ensure it is kept clear of the roof of the container.

57. Ensure ventilation holes in containers are free from clogging.

58. Try to ensure cocoa is not exposed to temperature fluctuations or stored near noxious materials.