Susan M. Leaman,[1] Jennifer C. McEntire,[2] Melanie Abley,[3] Conrad Choiniere,[4] Audrey Draper,[5] Natalie Krout-Greenberg,[6] Teressa Lopez,[7] and De Ann Davis[8]*

[1]iDecisionSciences, LLC, Scottsdale, AZ 85266, USA
[2]Food Safety Strategy, LLC, Frederick, MD 21704, USA
[3]U.S. Dept. of Agriculture, Food Safety and Inspection Service, Washington, D.C. 20250-3700, USA
[4]U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition, College Park, MD 20740, USA
[5]U.S. Dept. of Agriculture, Agricultural Marketing Service, Washington, D.C. 20250-3700, USA
[6]California Dept. of Food and Agriculture, Sacramento, CA 95814, USA
[7]Arizona Dept. of Agriculture, Phoenix, AZ 85007, USA
[8]Western Growers, Irvine, CA 92618, USA

PEER-REVIEWED ARTICLE

Food Protection Trends, Vol 45, No. 1, p. 19–26
https://doi.org/10.4315/FPT-24-026

Collaborating to Address Heavy Metals in Fresh Produce Supply—A Case Study of Cadmium in Spinach and Carrots Grown in Arizona and California

ABSTRACT

Providing consumers with safe, nutritious food is a common goal shared by the produce industry, the public health community, government agencies, and academia. To this end, these stakeholders have adopted a collaborative approach to address the challenge of improving the safety of food commonly eaten by infants and children. On 24 to 26 October 2023, Western Growers, in collaboration with federal and state government agencies, organized a pilot workshop in Salinas, CA, focused on cadmium in carrots and spinach grown in Arizona and California. Following a day of touring carrot and leafy green fields, workshop attendees participated in 2 days of panel discussions and presentations on cadmium toxicology and health effects, the nutritional benefits of carrots and spinach, Arizona's and California's carrot and spinach production practices, current research on plant uptake of cadmium, and mitigation methods and strategies. Panel discussions focused on obstacles that hinder adoption of methods to reduce cadmium, industry-regulator trust and communication, confidential data sharing, and industry-academia collaborative research. This article is a summary of workshop proceedings highlighting the stakeholders' expectations and roles as perceived by the attendees and essential support needed for continuous improvement going forward.

INTRODUCTION

Although the United States produces one of the safest food supplies in the world, the past 5 years have been replete with efforts to better understand and improve the safety of food commonly eaten by infants and children, especially in relation to heavy metal exposure. Driving these efforts are new findings from food surveys and studies of potential adverse health effects that have enhanced concern for the risk to infant and children's health from consuming food with elevated heavy metal levels. On the basis of a PubMed search, publications addressing heavy metal contaminants in the U.S. baby food supply more than doubled in the past decade (2013 to 2023) in comparison to the previous decade (2002 to 2012) *(Fig. 1)*. In 2019, the U.S. Food and Drug Administration (FDA) tested 384 baby food samples and

*Author for correspondence: Phone: +1 949.591.7171; Email: ddavis@wga.com

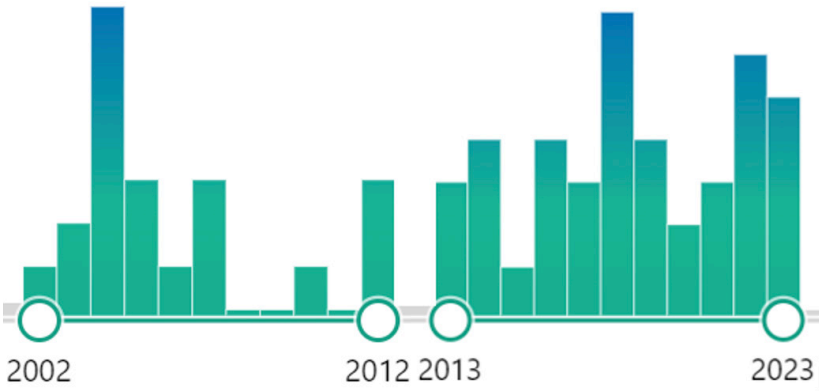

FIGURE 1. Published studies, per PubMed, addressing heavy metal contaminants in baby food in the United States.

reported 65, 51, 21, and 3% contained detectable levels of cadmium, arsenic, lead, and mercury, respectively *(49)*. In 2021, the FDA again conducted a survey of ready-to-eat baby foods sold in the United States and reported median cadmium, arsenic, lead, and mercury concentrations of 1.81, 2.60, 1.38, and 0.09 ppb, respectively *(20)*. In 2021, the U.S. House of Representatives' Committee on Oversight and Reform's Subcommittee on Economic and Consumer Policy issued two reports on heavy metal contaminants in baby foods, giving warnings of dangerous levels *(40, 41)*. In April 2021, the FDA, along with federal and state government partners, launched "Closer to Zero" (C2Z) for the purpose of reducing exposure to cadmium, lead, arsenic, and mercury found in foods that babies and young children typically eat *(14, 44, 47)*.

As an interagency initiative, C2Z is a four-stage approach designed as a framework for achieving "continual improvement over time" *(14, 47)*. The framework uses a cyclical process of evaluating the scientific basis for action levels, establishing action levels, monitoring levels over time, and determining whether adjustments to action levels are necessary. In the process of evaluating the scientific basis for action levels, the FDA, the USDA, and their partners are developing new and improved methods for testing for heavy metals, assessing toxicological end points and reference values, conducting surveys of the food supply to better understand variation in heavy metal concentrations, exploring strategies to reduce heavy metal levels in food, evaluating consumption patterns to assess dietary exposure and identify levels of concern, and assessing other dietary nutrients to gain a better understanding of how they affect health concerns *(47)*. On the basis of these efforts, action levels and best practices could be established to decrease levels of heavy metals in food products. The FDA will track industry progress by testing food within specified time frames. Throughout the cyclical process, the FDA will continue to monitor select food items, while conducting and funding research and enforcing any established limits. The agency prioritized setting action levels for lead and arsenic, followed by cadmium and mercury. To date, the FDA has set an action level for inorganic arsenic in apple juice (June 2023) *(51)* and draft action levels for lead in juice (April 2022) *(48)* and in food intended for babies and young children (January 2023) *(50)*.

Many public health agencies and organizations worldwide have set action levels and thresholds or are in the process of determining thresholds for heavy metals in food *(8, 37)*. In the United States, both the FDA and the U.S. Environmental Protection Agency (U.S. EPA) set a maximum contaminant level of 5 µg/liter for cadmium in bottled and drinking water, respectively *(46)*. In 2023, the FDA developed and published an oral toxicological reference value (0.21 to 0.36 µg/kg body weight per day) for characterizing potential health concerns from exposure to cadmium in food *(38)*. The U.S. EPA has recommended a reference dose (an estimate of a daily exposure that is likely to not cause deleterious effects during a lifetime) for cadmium in food as 0.001 mg/kg body weight per day *(45)*. The California Department of Public Health (CDPH) requires baby food manufacturers to test baby food sold or distributed in the state for cadmium at least once a month *(6)*. In support of the ongoing efforts to establish standards for cadmium levels in food, the body of research findings has been rapidly expanding as toxicologists, epidemiologists, and other scientists analyze levels in food, soil, and humans (blood and urine), while studying the potential health risks to infants and children related to measured levels *(16, 17, 19, 25, 32, 37)*.

As the FDA initiated its C2Z plan and began considering action levels for heavy metals in fruits and vegetables commonly eaten by infants and children, the agency, its government partners, and industry stakeholders recognized the importance of a collaborative approach as opposed to individual efforts for successful goal achievement. In keeping with a collaborative approach, Western Growers, with the Arizona and California departments of agriculture, the

Arizona and California leafy greens marketing agreements, the FDA, and the USDA, organized a pilot workshop held in Salinas, CA, on 24 to 26 October 2023. The workshop was attended by the FDA's Deputy Commissioner for Human Food and the USDA's Office of the Chief Scientist in addition to other federal employees and approximately 40 members of the produce industry, Arizona and California government agencies, academia, and representatives from the medical field, consumer groups, and seed companies. The 3-day workshop focused on a continuous improvement process to address cadmium levels in carrots and spinach grown in Arizona and California but also included general information about cadmium levels in soil, water, and agronomical inputs and human exposure and health risks related to cadmium in food. The event began with a day of touring the growing and processing operations for leafy greens and carrots in the Salinas area. For 2 days following the field and facility tours, the workshop attendees listened to scientific presentations and panel discussions and discussed industry practices and mitigation strategies. The workshop focused on spinach and carrots because studies show that cadmium tends to accumulate in these produce products *(2, 18, 24, 33)*. These study findings are corroborated by the FDA's Total Diet Study, a survey of foods commonly consumed in the United States that includes measurements of heavy metals and other contaminants in the food sampled. For example, from the baby foods sampled during 2018 to 2020, baby food (n = 384) containing spinach and carrots had the highest and second highest levels of cadmium, respectively *(49)*.

WORKSHOP SESSIONS OVERVIEW

How much cadmium is in the food supply, especially food commonly eaten by infants and children, and the resulting public health consequences have been discussed for some time *(20, 34)*. On the first day of the workshop's in-class sessions, the FDA gave an overview of the toxicology of cadmium, the potential risks to human health from cadmium exposure, and the role of nutrition and a produce-rich diet in protecting infant and children from other diet-related adverse health effects. Cadmium, when chronically ingested, primarily targets the kidneys and bones but has also been associated with other negative effects, such as cardiovascular, neurological, and reproductive outcomes *(8, 35–37)*. For infants and children, research supporting exposure to cadmium leading to acute or developmental health effects is limited.

After the C2Z initiative launch, the FDA conducted a systemic review of the scientific literature and identified the need for more research on associations between cadmium exposure in humans less than 19 years of age and adverse renal and nervous system effects *(19)*. The FDA reported that how long it remains in the body is an important factor in cadmium's adverse effect on health. Cadmium's half-life in humans is an estimated average of 14 years; however, study results range from approximately 10 to 33 years, depending on numerous factors such as its chemical state, the amount present in the body (body burden), and a person's smoking status *(8, 35–37)*. In addition to cadmium's direct negative effect on health, concern extends to effects on overall health if nutritionally beneficial foods with reportedly high cadmium levels are avoided. With all the known benefits of eating fruits and vegetables, reduced consumption because of contaminants such as cadmium may result in infants and children missing the essential and beneficial nutrients that these foods provide *(7)*. There was recognition that the risk of cadmium in produce must be weighed against the risk of a diet lacking adequate fruit and vegetable consumption.

In the presentation, the USDA addressed the challenge of balancing infants' and children's needs for essential and beneficial nutrients in vegetables with the potential exposure to cadmium from consuming vegetables. According to the USDA's (2020) dietary guidelines for Americans report *(43)*, children between 12 and 23 months are eating less vegetables on average than the recommended daily intake. Public health agencies are concerned that further reductions in consumption because of consumer concerns or regulations establishing threshold standards could be detrimental to infants' and children's development and overall health.

Because the workshop was specifically focused on carrots and spinach grown in Arizona and California, the Arizona Department of Agriculture and the California Department of Food and Agriculture (CDFA) presented overviews of production areas and volumes produced in the respective states. During the 2022 to 2023 growing season, Arizona produced 90,938 tons of spinach on approximately 12,200 acres. Carrots, a very minor vegetable crop in the state, are grown on 3,151 acres. California, however, is first in U.S. carrot and spinach production. The state produced 1.3 million tons of carrots harvested in 2021 from 61,400 acres, which is 93% of U.S. carrot receipts *(4)*. That same year, California produced 258,700 tons of spinach harvested from 39,800 acres. More than half (53%) of the state-grown spinach came from one county alone, Monterey County *(4)*.

Scientists from the CDFA, the CDPH, and the University of Arizona summarized what is known about cadmium background levels and sources in the growing regions of the respective states and how spinach and carrots take up cadmium from soil, water, and the atmosphere. Background levels are important because cadmium occurs naturally in our environment (e.g., soil, water, atmosphere) and soil levels vary across U.S. produce-growing regions *(Fig. 2)*. Cadmium originates primarily from rocks, and as rocks erode, cadmium is distributed to soil, water, and atmospheric particulates *(26)*. Natural events such as forest or brush fires, commonplace in California and parts of the southwest, and volcanic eruptions also release cadmium into the environment *(26)*. Cadmium may be present in the soil in which food grows, in the agricultural water applied to crops, or in the agronomical products (e.g., fertilizer) that are mined

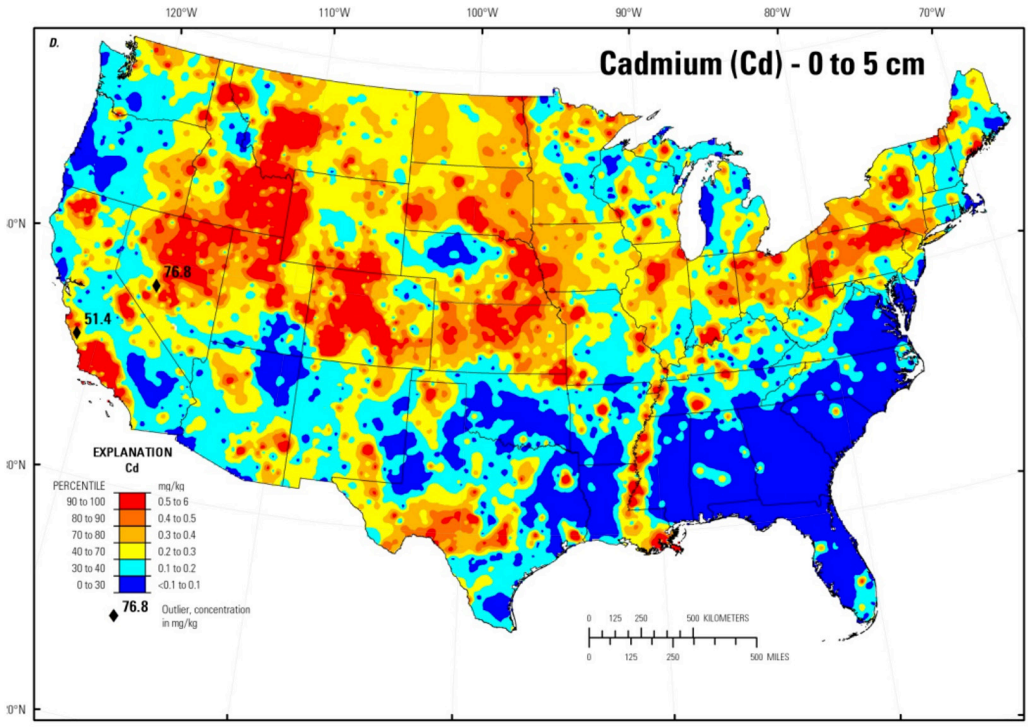

FIGURE 2. Cadmium parts per million in U.S. soil.[a]

[a]Source: https://pubs.usgs.gov/sir/2017/5118/elements/Cadmium/OFR-2014-1082-Cd.pdf.

from the earth and added to soil as nutrients essential for plant growth *(42)*. In addition to agronomic inputs, other anthropogenic sources of cadmium are batteries, solar cells, pigments, metal and plastic products, fossil fuel combustion, and industrial activities such as mining and smelting that release cadmium into the environment *(42, 50)*. With natural occurrence in the soil, water, and atmosphere and contamination from anthropogenic activities, it is not surprising that cadmium is present in varying amounts throughout our food supply *(15, 20, 23, 33)*.

The Arizona Department of Agriculture, CDFA, and CDPH reported that in Arizona and California most spinach and carrots are produced on land that has been used for crops for decades, and inorganic fertilizers were thought to be the primary source of added cadmium in these soils. A 2001 study of California cropland soil showed that soil cadmium content had increased in five of seven vegetable-growing regions between 1967 and 2001. However, in only two of those regions, the increases in soil cadmium content was proportional to levels of phosphorus fertilization, indicating that the increase was likely due to inorganic phosphorus fertilizer applications, whereas in the other three vegetable-growing regions, where soil cadmium content had increased, the increase was attributed to diffuse sources, such as irrigation, natural weathering of rocks, and atmospheric deposition *(11–13)*. In 2002, the CDFA set limits for cadmium in fertilizer: 4 ppm for each percent of inorganic phosphate in a fertilizer and 12 ppm for each percent of manganese, zinc, and iron content *(5)*. To date, Arizona does not have limiting standards for cadmium in fertilizer products. The source of cadmium affects the efficacy of some mitigation measures, as was discussed later in the workshop.

Scientists from the University of California's Division of Agriculture and Natural Resources and the University of Arizona presented study findings showing that plant uptake varies on the basis of produce crops, plant variety and cultivar, soil type and properties, and available nutrients in the soil *(11, 12, 18, 21, 22, 30, 34)*. Cadmium can be actively or passively taken up by plant roots from the soil and absorbed from airborne particulates containing cadmium that settle on plant surfaces *(26)*. In both cases for leafy greens, cadmium disperses throughout the plant with high mobility but tends to concentrate in older leaves more than in the stem, roots, or younger leaves *(2, 27, 28)*. Organic matter content and soil pH are the soil properties that most influence cadmium uptake by leafy green plants *(30)*. For root vegetables, soil pH and zinc content have been shown to have the most influence on cadmium uptake *(30)*. Because plants do not distinguish well between cadmium and zinc, the relative amount of each that is taken up by plants is governed by the zinc and cadmium concentrations in the soil. Normal soils have a zinc:cadmium ratio of approximately

200:1, but some California soils have ratios as low as 10:1 *(10, 31)*. Leafy vegetables tend to have higher cadmium concentrations than stalk, solanaceous, or root vegetables *(2, 18, 30)*. Because of the multitude of factors that affect cadmium levels in food crops, the approaches to mitigation, too, will vary.

On the final day of the workshop, the group focused on new science and current research projects that can help the grower community make informed decisions related to remediating land with high cadmium levels and mitigating plant uptake of cadmium. Several research projects exploring mitigation strategies for elevated cadmium in soil were presented by scientists from the USDA, the University of Delaware, and the University of California, Davis. Those mitigation strategies include the following: amending soil with zinc; adding lime to the soil to reduce cadmium solubility and thus plant uptake; use of vegetable varieties that take up less cadmium; use of irrigation water with low levels of chloride; and use of biological products to reduce plant uptake of cadmium *(1, 10, 18, 29, 31)*. The effectiveness of different mitigations seems dependent on multiple factors, including whether the cadmium resides only on the surface of soil (e.g., as the result of deposition) or is present due to the geology of the area. Seemingly conflicting results related to some mitigations (e.g., soil acidity) also revealed a complex set of interactions that limits a one-size-fits-all approach to mitigating cadmium in spinach and carrots in these regions *(9)*.

New and ongoing projects are investigating ways to reduce cadmium in carrots and leafy greens, including breeding carrot cultivars and baby spinach varieties that take up less cadmium from the soil and using soil chemistry to reduce cadmium uptake. Researchers from the University of California, Davis, presented results of an ongoing project *(3)*, funded by the California Leafy Greens Research Board, showing progress in breeding spinach varieties that accumulate less cadmium when grown in cadmium-contaminated soil. According to USDA research, genetics plays a major role in carrots' cadmium uptake, making carrots a good candidate for breeding varieties with low cadmium uptake (unpublished data). Zinc fertilization has been useful for reducing cadmium uptake from soils with cadmium present. Researchers recommend using zinc fertilizers when cadmium soil levels are above 1.0 ppm and not planting spinach or carrots in soils with cadmium levels above 2.0 ppm *(39)*.

The USDA's National Institute of Food and Agriculture (NIFA) presented a summary of the recommendations stemming from the April 2022 workshop, "Toxic Elements in Food: Identification of Critical Knowledge Gaps to Ensure a Safe Food Supply," to identify knowledge and data gaps in support of the C2Z initiative. Recommendations included the establishment of a centerlike funding mechanism, as needed, to address toxic metal exposure in food and to ensure that NIFA-funded research projects are cohesive and interdisciplinary and not conducted in isolation from one another. Going forward, the NIFA's C2Z core team will offer additional educational workshops on mitigating heavy metal contamination of food for industry, scientists, government regulators, and other stakeholders.

On both days of in-class sessions, the group discussed the obstacles and barriers hindering improvements and implementation of methods that would reduce cadmium levels in soil and agronomic inputs and mitigation of cadmium uptake by plants. Workshop participants identified the need for more data to better understand cadmium levels associated with these crops under current production practices and pragmatic, effective mitigation strategies as a major challenge to reducing levels in food. Specific areas in which more data and information are needed include cadmium levels in Arizona and California soils, where carrots and spinach are grown, the amount taken up by these crops, and the amount of cadmium that is bioavailable following ingestion. Another major challenge noted by the group at-large involved the need to strengthen the relationship between regulators and industry. All parties noted the availability of cost-effective, reliable mitigation practices as a challenge, and industry members were particularly concerned about the confidentiality surrounding sharing practices and data, as it may have long-term impacts on production economics.

STAKEHOLDER FEEDBACK

Throughout the 2-day in-class portion of the workshop, participants explored how they can contribute to and what they expect from efforts to reduce cadmium levels in spinach and carrots grown in Arizona and California by recording ideas on large sheets of paper hung around the meeting room. For participation in this exercise, all workshop attendees had the opportunity to identify the expectations of different stakeholder groups (e.g., state agricultural departments, researchers, produce companies, the FDA, the USDA, consumer groups). The expectations listed in the following do not suggest a commitment from industry, regulators, or researchers, and they are not necessarily an accurate reflection of the role of each group. However, understanding how the workshop participants viewed the roles of each stakeholder can aid to clarify roles and set reasonable expectations moving forward.

Expectations of industry

With the access to product and soil as producer, processor, and distributor of carrots and spinach, the industry was viewed by workshop participants as being in the best position to address soil and product sampling to better understand the scope of contamination. Industry members are central to the effort to reduce cadmium in these produce products, and without input and cooperation, success is unlikely. Industry participation and involvement in research and a willingness to share data were identified as being intricately tied to

achieving continuous improvement. Industry members were also viewed as having a role in educating other stakeholders on currently used mitigation practices and implementing any new or improved practices shown to be effective in reducing cadmium levels in soil and produce products.

Expectations of regulators

Workshop participants seek a collaborative approach with the FDA for achieving the common goals of managing cadmium levels in spinach and carrots and determining risk-based approaches that are protective of public health. Reducing uncertainty both for consumers and the produce industry was a prominent message. Stakeholders noted the importance of the FDA being transparent and providing accurate information to both industry and the public throughout the process of addressing heavy metals in the food supply and establishing the action levels for infant's and children's foods. Sentiments shared by several workshop participants included understanding the importance of timeliness but also continued dialogue and engagement with stakeholders, including nutrition experts, establishing regulatory management approaches for cadmium on the basis of sound science, understanding the impacts of regulations on industry, and remaining accessible to industry, not only as a regulator but as a resource and partner. State agricultural departments were expected by workshop participants to partner with federal agencies, be a liaison among various stakeholders, and help industry and government agencies better understand regional issues by making data and other resources usable and accessible. Regional expertise places them in the unique position to partner with growers in their states in developing best management practices to prevent and reduce cadmium contamination in spinach and carrots. They were also expected to play a role in identifying research needs and educating the grower community when best management practices are established.

Expectations of researchers

Researchers were identified as being able to help identify gaps in the available science and work with industry to design studies to cover the missing data and information. One area of research that participants saw as integral to reducing cadmium is breeding varieties and cultivars that take up less cadmium from the soil when it is present and identifying soil properties or additives that reduce cadmium uptake by plants. Establishing a research road map by effectively addressing the knowledge gaps, validating work that has been completed, publishing study findings, and supporting industry in applying the results and standardizing best practices in growing operations are contributions workshop participants felt researchers can make in the overall effort to reduce cadmium levels in spinach and carrots.

CONCLUSIONS

The workshop concluded with a facilitated discussion on what is essential for supporting continual improvement going forward. All parties agreed that improved communication and transparency and a continuance and formalization of stakeholder collaborations were essential for making progress toward the C2Z initiative. Continuous improvement will be difficult, if not unattainable, if all parties act in isolation. Next steps include funding additional research to develop, refine, or implement effective mitigation techniques and strategies and to gain a better understanding of the relationship between cadmium exposures and adverse health effects. Permeating all the discussions and brainstorming was the issue of data, especially privately owned industry data, and the need for confidential data sharing among stakeholders potentially in the form of a data trust that would be responsible to collect, hold, and use the data in support of the data owners. The ideas, learning, and action items stemming from the workshop are fueling continuing efforts among industry, researchers, and government to improve the safety of the U.S. food supply specific to cadmium in foods intended for infants and children.

REFERENCES

1. Al Mamun, S., G. Chanson, Muliadi, E. Benyas, M. Aktar, N. Lehto, R. McDowell, J. Cavanagh, L. Kellermann, L. Clucas, and B. Robinson. 2016. Municipal composts reduce the transfer of Cd from soil to vegetables. *Environ. Pollut.* 213:8–15.
2. Baldantoni, D., L. Morra, M. Zaccardelli, and A. Alfani. 2016. Cadmium accumulation in leaves of leafy vegetables. *Ecotoxicol. Environ. Saf.* 123:89–94.
3. Brummer, E. C., A. Van Deynze, A. Krill-Brown, D. Pap, and S. Klosterman. 2023. Breeding baby leaf spinach for California growers. California Leafy Greens Research Board. Available at: https://calgreens.org/wp-content/uploads/2023/11/Brummer-Breeding-Baby-Leaf-Spinach-for-California-Growers.pdf. Accessed 14 May 2024.
4. California Department of Food and Agriculture. 2022. California agricultural statistics review, 2021–2022. Available at: https://www.cdfa.ca.gov/Statistics/PDFs/2021_Ag_Stats_Review.pdf. Accessed 19 February 2024.
5. California Department of Food and Agriculture. California Code of Regulations. 2013, California fertilizer laws and regulations. § 2302 Non-Nutritive Standards, Title 3. Available at: Fertilizer_Law_and_Regs.pdf (ca.gov). Accessed 12 February 2024.
6. California Department of Public Health. 2023. Baby food safety. Available at: https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/CLPPB/Pages/BabyFoodSafety.aspx. Accessed 11 February 2024.
7. Callen, C., J. Bhatia, L. Czerkies, W. J. Klish, and G. M. Gray. 2018. Challenges and considerations when balancing the risks of contaminants with the benefits of fruits and vegetables for infants and toddlers. *Nutrients* 10:1572.
8. Centers for Disease Control and Prevention. 2015. Toxicological profile for cadmium. Agency for Toxic Substances and Disease Registry. Available at: https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=48&tid=15. Accessed 13 May 2024.
9. Chaney, R. L. 2010. Cadmium and zinc, p. 409–439. *In* P. S. Hooda (ed.), Trace elements in soils. Blackwell Publishing, Oxford.

10. Chaney, R. L., C. E. Green, H. A. Ajwa, and R. F. Smith. 2009. Zinc fertilization plus liming to reduce cadmium uptake by romaine lettuce on Cd-mineralized Lockwood soil. Available at: Zinc Fertilization Plus Liming to Reduce Cadmium Uptake by Romaine Lettuce on Cd-Mineralized Lockwood Soil (escholarship.org). Accessed 11 February 2024.

11. Chang, A. C., A. L. Page, and N. J. Krage. 2004. Final report: role of fertilizer and micronutrient applications on arsenic, cadmium, and lead accumulation in California cropland soils. Available at: https://www.cdfa.ca.gov/is/docs/CDFAFinalReport.pdf. Accessed 13 May 2024.

12. Chang, A. C., M. Petreas, M. Khosravifard, A. Maan, S. Mauch, and J. Van Rein. 2004. Evaluation of heavy metals & dioxin in inorganic commercial fertilizers and California cropland soils. Available at: https://www.cdfa.ca.gov/is/docs/MetalsReport12-23-04.pdf. Accessed 11 February 2024.

13. Chen, W., N. Krage, L. Wu, G. Pan, M. Khosrivafard, and A. C. Chang. 2008. Arsenic, cadmium, and lead in California cropland soils: role of phosphate and micronutrient fertilizers. *J. Environ. Qual.* 37:689–695.

14. Choiniere, C., C. Callen, Y. Chen, D. A. Davis, T. Neltner, P. Starke-Reed, and S. Hermansky. 2024. A roundtable on moving Closer to Zero: challenges and opportunities for reducing children's exposures to toxic elements from foods. *Food Prot. Trends* 44:50–57.

15. Collado-López, S., L. Betanzos-Robledo, M. M. Téllez-Rojo, H. Lamadrid-Figueroa, M. Reyes, C. Ríos, and A. Cantoral. 2022. Heavy metals in unprocessed or minimally processed foods consumed by humans worldwide: a scoping review. *Int. J. Environ. Res. Public Health* 19:8651.

16. Dettwiler, M., A. C. Flynn, and J. Rigutto-Farebrother. 2023. Effects of non-essential "toxic" trace elements on pregnancy outcomes: a narrative overview of recent literature syntheses. *Int. J. Environ. Res. Public Health* 20:5536.

17. Dolan, L. C., B. M. Flannery, D. Hoffman-Pennesi, A. Gavelek, O. E. Jones, R. Kanwal, B. Wolpert, K. Gensheimer, S. Dennis, and S. Fitzpatrick. 2020. A review of the evidence to support interim reference level for dietary lead exposure in adults. *Regul. Toxicol. Pharmacol.* 111:104579.

18. Fang, H. W., W. S. Li, S. X. Tu, Y. Z. Ding, R. G. Wang, C. Rensing, Y. P. Li, and R. W. Feng. 2019. Differences in cadmium absorption by 71 leaf vegetable varieties from different families and genera and their health risk assessment. *Ecotoxicol. Environ. Saf.* 184:109593.

19. Flannery, B. M., H. R. Schaefer, and K. B. Middleton. 2022. A scoping review of infant and children health effects associated with cadmium exposure. *Regul. Toxicol. Pharmacol.* 131:105155.

20. Gray, P. J. 2023. A survey of toxic elements in ready to eat baby foods in the U.S. market 2021. *Food Addit. Contam. Part B Surveill.* 16:79–85.

21. Haider, F. U., C. Liqun, J. A. Coulter, S. A. Cheema, J. Wu, R. Zhang, M. Wenjun, and M. Farooq. 2021. Cadmium toxicity in plants: impacts and remediation strategies. *Ecotoxicol. Environ. Saf.* 211:111887.

22. Huang, L., Q. Wang, Q. Zhou, L. Ma, Y. Wu, Q. Liu, S. Wang, and Y. Feng. 2020. Cadmium uptake from soil and transport by leafy vegetables: a meta-analysis. *Environ. Pollut.* 264:114677.

23. Kim, K., M. M. Melough, T. M. Vance, H. Noh, S. I. Koo, and O. K. Chun. 2019. Dietary cadmium intake and sources in the U.S. *Nutrients* 11:2.

24. Knez, E., K. Kadac-Czapska, K. Dmochowska-Ślęzak, and M. Grembecka. 2022. Root vegetables—composition, health effects, and contaminants. *Int. J. Environ. Res. Public Health* 19:15531.

25. Kordas, K., A. Cantoral, G. Desai, O. Halabicky, A. J. Signes-Pastor, M. M. Tellez-Rojo, K. E. Peterson, and M. R. Karagas. 2022. Dietary exposure to toxic elements and the health of young children: methodological considerations and data needs. *J. Nutr.* 152:2572–2581.

26. Kubier, A., R. T. Wilkin, and T. Pichler. 2019. Cadmium in soils and groundwater: a review. *Appl. Geochem.* 108:104388.

27. McKenna, I. M., R. L. Chaney, and F. M. Williams. 1993. The effects of cadmium and zinc interactions on the accumulation and tissue distribution of zinc and cadmium in lettuce and spinach. *Environ. Pollut.* 79:113–120.

28. Mendoza-Cózatl, D. G., T. O. Jobe, F. Hauser, and J. I. Schroeder. 2011. Long-distance transport, vacuolar sequestration, tolerance, and transcriptional responses induced by cadmium and arsenic. *Curr. Opin. Plant Biol.* 14:554–562.

29. Ondrasek, G., D. Romic, and Z. Rengel. 2020. Interactions of humates and chlorides with cadmium drive soil cadmium chemistry and uptake by radish cultivars. *Sci. Total Environ.* 702:134887.

30. Pan, S. F., X. H. Ji, Y. H. Xie, S. H. Liu, F. X. Tian, and X. L. Liu. 2022. Influence of soil properties on cadmium accumulation in vegetables: thresholds, prediction and pathway models based on big data. *Environ. Pollut.* 304:119225.

31. Paul, A. L. D., and R. L. Chaney. 2017. Effect of soil amendments on Cd accumulation by spinach from a Cd-mineralized soil. *J. Environ. Qual.* 46:707–713.

32. Pokharel, A., and F. Wu. 2023. Dietary exposure to cadmium from six common foods in the United States. *Food Chem. Toxicol.* 178:113873.

33. Rusin, M., J. Domagalska, D. Rogala, M. Razzaghi, and I. Szymala. 2021. Concentration of cadmium and lead in vegetables and fruits. *Sci. Rep.* 11:11913.

34. Sanchez, C. A., and R. Krieger. 2006. Survey and exposure estimates of cadmium in desert lettuce. Available at: Survey and exposure estimates of cadmium in desert lettuce.pdf (az.gov). Accessed 14 February 2024.

35. Satarug, S. 2018. Dietary cadmium intake and its effects on kidneys. *Toxics* 6:15.

36. Satarug, S., D. A. Vesey, G. C. Gobe, and K. R. Phelps. 2023. Estimation of health risks associated with dietary cadmium exposure. *Arch. Toxicol.* 97:329–358.

37. Schaefer, H. R., B. M. Flannery, L. Crosby, O. E. Jones-Dominic, C. Punzalan, and K. Middleton. 2022. A systematic review of adverse health effects associated with oral cadmium exposure. R*egul. Toxicol. Pharmacol.* 134:105243.

38. Schaefer, H. R., B. M. Flannery, L. M. Crosby, R. Pouillot, S. M. S. Farakos, J. M. Van Doren, S. Dennis, S. Fitzpatrick, and K. Middleton. 2023. Reassessment of the cadmium toxicological reference value for use in human health assessments of foods. *Regul. Toxicol. Pharmacol.* 144:105487.

39. Smith, R., and T. Hartz. 2017. Evaluation of practices to reduce cadmium uptake by leafy greens. Available at: https://calgreens.org/wp-content/uploads/2022/03/evaluation-of-practices-to-reduce-cadmium-uptake-by-leafy-greens_2017.pdf. Accessed 14 May 2024.

40. Subcommittee on Economic and Consumer Policy. 2021. Baby foods are tainted with dangerous levels of arsenic, lead, cadmium, and mercury. U.S. House of Representatives, Washington, D.C.

41. Subcommittee on Economic and Consumer Policy. 2021. New disclosures show dangerous levels of toxic heavy metals in even more baby foods. U.S. House of Representatives, Washington, D.C.

42. Thorton, I. 1992. Sources and pathways of cadmium in the environment. *IARC Sci. Publ.* 118:149–162.

43. U.S. Department of Agriculture. 2020. Make every bite count with dietary guidelines: Dietary guidelines for Americans, 2020–2025. Available at: https://www.dietaryguidelines.gov/sites/default/files/2021-03/Dietary_Guidelines_for_Americans-2020-2025.pdf. Accessed 31 January 2024.

44. U.S. Department of Agriculture. 2022. Closer to Zero: Partnership to protect our food. Available at: https://www.usda.gov/media/blog/2022/01/21/closer-zero-partnership-protect-our-food. Accessed 18 February 2024.

45. U.S. Environmental Protection Agency. 1987. Cadmium (CASRN 7440-43-9). Available at: https://iris.epa.gov/static/pdfs/0141_summary.pdf. Accessed 11 February 2024.

46. U.S. Environmental Protection Agency. 1991. Chemical contaminant rules. Available at: https://www.epa.gov/dwreginfo/chemical-contaminant-rules. Accessed 18 February 2024.

47. U.S. Food and Drug Administration. 2021. Closer to Zero: Reducing childhood exposure to contaminants from foods. Available at: https://www.fda.gov/food/environmental-contaminants-food/closer-zero-reducing-childhood-exposure-contaminants-foods. Accessed 25 January 2024.
48. U.S. Food and Drug Administration. 2022. Draft guidance for industry: Action levels for lead in juice. Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/draft-guidance-industry-action-levels-lead-juice. Accessed 28 January 2024.
49. U.S. Food and Drug Administration. 2022. Total Diet Study report: Fiscal years 2018–2020 elements data. Available at: download (fda.gov). Accessed 14 February 2024.
50. U.S. Food and Drug Administration. 2023. Action levels for lead in food intended for babies and young children: Draft guidance for industry. Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/draft-guidance-industry-action-levels-lead-food-intended-babies-and-young-children. Accessed 28 January 2024.
51. U.S. Food and Drug Administration. 2023. Guidance for industry: Action level for inorganic arsenic in apple juice. Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-action-level-inorganic-arsenic-apple-juice. Accessed 3 June 2024.

2025 Samuel J. Crumbine Consumer Protection Award for Excellence in Food Protection

Named for one of America's most renowned health officers and health educators, Samuel J. Crumbine, MD (1862–1954), the award encourages innovative programs and methods that reduce or eliminate the occurrence of foodborne illnesses, recognizes the importance of food protection at the local level, and stimulates public interest in foodservice sanitation.

All local environmental health jurisdictions in the U.S. and Canada are encouraged to apply, if they meet the following basic criteria:

- Sustained excellence over the preceding four to six years, as documented by specific outcomes and achievements, and evidenced by continual improvements in the basic components of a comprehensive program;
- Demonstrated improvements in planning, managing and evaluating a comprehensive program;
- Innovative and effective use of program methods and problem solving to identify and reduce risk factors that are known to cause foodborne illness; and
- Providing targeted outreach; forming partnerships; and participating in forums that foster communication and information exchange among the regulators, industry and consumer representatives.

To apply, visit www.crumbineaward.com.

Deadline for entries is March 15, 2025.

Award sponsored by the Conference for Food Protection, in cooperation with the American Academy of Sanitarians, American Public Health Association, Association of Food and Drug Officials, Food Marketing Institute, Foodservice Packaging Institute, International Association for Food Protection, National Association of County and City Health Officials, National Environmental Health Association and NSF International.