Supplementary Materials

Concentrations of HMs in agricultural soils vary between countries (Table S1). Representative surveys of soil show how frequently observed HM concentrations exceed allowable limits, and the wide range between average and maximum concentrations of many elements (Table S2). Many jurisdictions also regulate the concentrations of HMs that accumulate in edible portions of plants (Table S3) which are significantly higher than the maximum allowable limits recommended by Codex Alimentarius commission (Table S4).

**Table S1.** Maximum allowable concentrations of HM elements in agricultural soil in several countries.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **As** | **Cd** | **Cr** | **Cu** | **Hg** | **Ni** | **Pb** | **Zn** |
|  | mg kg-1 soil | | | | | | | |
| Australia | 20 | 3 | 50 | 100 | 1 | 60 | 300 | 200 |
| Canada | 20 | 3 | 250 | 150 | 0.8 | 100 | 200 | 500 |
| China | 20 – 40 | 0.3 - 0.6 | 150 – 300 | 50 – 200 | 0.3 - 1.0 | 40 – 60 | 80 | 200 – 300 |
| Germany | 50 | 5 | 500 | 200 | 5 | 200 | 1000 | 600 |
| Tanzania | 1 | 1 | 100 | 200 | 2 | 100 | 200 | 150 |
| Netherlands | 76 | 13 | 180 | 190 | 36 | 100 | 530 | 720 |
| New Zealand | 17 | 3 | 290 | >104 | 200 | N/A | 160 | N/A |
| United Kingdom | 43 | 1.8 | N/A | N/A | 26 | 230 | N/A | N/A |
| United States | 0.11 | 0.48 | 11 | 270 | 1 | 72 | 200 | 1100 |

Source: [244].

**Table S2.** HM contamination in the soil of arable lands through suspected agricultural practices.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HM**  **Elements** | **MAX level**  **mg kg-1 soil** | **Mean BKG level mg kg-1 soil** | **FD\*** | **Survey site** | **References** |
| As | 280 | 16.8 | 16.7 |  | Zarcinas et al., [50] |
| Cd | 2.02 | 0.12 | 16.8 | 241 farm soil samples from peninsular Malaysia |
| Co | 38.7 | 2.8 | 13.8 |
| Cr | 72.7 | 25.9 | 2.8 |
| Cu | 114 | 16.4 | 7.0 |
| Hg | 0.86 | 0.15 | 5.9 |
| Ni | 73.5 | 13.7 | 5.4 |
| Pb | 90.0 | 26.4 | 3.4 |
| Zn | 137 | 38.0 | 3.6 |
| Cu | 99.9 | 16.7 | 6.0 | Soil samples from Huizhou (Guangdong  Province),  China | Cai et al., [245] |
| Zn | 248 | 57.2 | 4.3 |
| Ni | 112 | 14.9 | 7.5 |
| Cr | 81 | 27.6 | 2.9 |
| Pb | 108 | 44.7 | 2.4 |
| Cd | 1.12 | 0.10 | 11.2 |
| As | 137 | 10.9 | 12.6 |
| Hg | 3.39 | 0.22 | 15.4 |

MAX = maximum values; BKG = Average background values; \*FD = Fold difference: MAX values/ BKG values.

**Table S3.** A summary of concentration fold differences of several HM elements in the edible plant parts of a number crop and vegetable species reported in some studies.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | As | Cd | Cr | Cu | Hg | Ni | Pb | Zn | Ref. |
|  | Fold differences | | | | | | | |  |
| Rice | 2.0 | 3.6 | 7.3 | 1.6 | 2.1 | 3.2 | 2.9 | 6.3 | Zarcinas et al., [50] |
| Chili | 2.3 | 2.2 | 2.6 | 8.0 | 7.3 | 1.8 | 1.4 | 1.6 |
| Corn | 1.9 | 2.0 | 7.4 | 1.4 | 2.4 | 1.8 | 4.8 | 1.5 |
| Long bean | 1.9 | 2.5 | 1.9 | 1.8 | - | 2.1 | 4.2 | 1.4 |
| Mustard | 1.0 | 2.8 | 4.3 | 1.5 | 3.1 | 1.8 | 2.3 | 1.7 |
| Angled loofa | 1.8 | 2.8 | - | 1.6 | 1.4 | 2.1 | 2.0 | 1.4 |
| Brinjal | 1.9 | 1.9 | 1.2 | 1.8 | - | 1.5 | 2.7 | 1.2 |
| Cabbage | 2.2 | 3.5 | 3.8 | 5.6 | 3.8 | 2.2 | 3.1 | 2.0 |
| Cocoa | 2.2 | 2.5 | 2.9 | 1.9 | 2.6 | 2.0 | 4.1 | 1.5 |
| Cucumber | 2.0 | 2.0 | 1.2 | 1.1 | 1.1 | 1.3 | 1.4 | 1.3 |
| Groundnut | 1.0 | 1.6 | 1.8 | 1.2 | 3.0 | 2.5 | 2.9 | 1.1 |
| Lady’s finger | 1.9 | 2.5 | 3.8 | 1.7 | 2.8 | 1.4 | 4.9 | 1.5 |
| Spinach | 1.7 | 4.3 | 2.8 | 1.6 | 1.6 | 1.9 | 3.2 | 3.0 |
| Water convolvulus | 3.2 | 2.1 | 2.4 | 2.0 | 1.5 | 1.6 | 2.9 | 2.0 |
| Corn | - | 2.7 | - | 5.6 | - | - | 2.3 | 2.1 | Jung, [64] |
| Jujube | - | 1.1 | - | 1.1 | - | - | 1.9 | 1.3 |
| Perilla | - | 1.3 | - | 1.2 | - | - | 1.2 | 1.5 |
| Soybean | - | 4.2 | - | 1.8 | - | - | 1.6 | 3.0 |
| Pepper | - | 1.3 | - | 3.0 | - | - | 3.2 | 1.1 |
| Onion | - | 2.4 | - | 1.4 | - | - | 1.4 | 5.3 |
| Cabbage | - | 7.0 | 1.8 | 1.8 | - | 1.0 | 3.8 | 1.6 | Berihun et al., [58] |
| Swiss Chard | - | 6.0 | 2.0 | 1.2 | - | 7.0 | 9.5 | 2.5 |
| Kale | - | 27 | 2.3 | 1.5 | - | 1.5 | 7.1 | 4.6 |
| Tomato | - | 11 | 1.0 | 1.2 | - | 1.9 | 5.9 | 1.3 |
| Potato | - | 26 | 1.1 | 7.0 | - | 2.7 | 9.5 | 3.0 |
| Onion | - | 17 | 1.2 | 1.3 | - | 1.2 | - | 1.0 |
| Lettuce | - | 1.0 | 1.1 | 1.0 | - | 6.5 | 2.4 | 3.4 |
| Lettuce | - | - | - | - | 56.5 | - | - | - | Li et al., [246] |
| Amaranth | - | - | - | - | 71.5 | - | - | - |
| Spinach | - | - | - | - | 63.2 | - | - | - |
| Tomato | - | - | - | - | 62.5 | - | - | - |
| Egg plant | - | - | - | - | 54.7 | - | - | - |
| Pepper | - | - | - | - | 31.9 | - | - | - |
| Cucumber | - | - | - | - | 18.3 | - | - | - |
| Cowpea | - | - | - | - | 31.7 | - | - | - |
| Rice | - | - | - | - | 77.8 | - | - | - |
| Maize | - | - | - | - | 12.7 | - | - | - |
| Vegetables  Area A  Area B  Area C |  | | | | | | | | Ahmed et al., [16] |
| 14.3 | 1.7 | 22.6 | 0.5 | - | - | 22.1 | 3.1 |
| 13.3 | 1.5 | 14.7 | 0.4 | - | - | 18.3 | 3.0 |
| 11.0 | 2.0 | 20.7 | 0.5 | - | - | 22.2 | 3.4 |

Fold differences: maximum/background levels.

**Table S4.** Maximum allowable limits of certain HM elements in food plants and plant-derived food commodities recommended by Codex Alimentarius commission.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type of edible plant product | Maximum limit (mg Kg-1) | | | | |
| Cd | Pb | As | Cu | Fe |
| Brassica vegetables | 0.05 | 0.10 | - | - | - |
| Bulb vegetables | 0.05 | 0.10 | - | - | - |
| Fruiting vegetables | 0.05 | 0.05 | - | - | - |
| Leafy vegetables | 0.20 | 0.30 | - | - | - |
| Legume vegetables | 0.10 | 0.10 | - | - | - |
| Pulses | 0.10 | 0.10 | - | - | - |
| Root and tuber vegetables | 0.10 | 0.10 | - | - | - |
| Stalk and stem vegetables | 0.10 | - | - | - | - |
| Vegetable oils | - | - | - | 0.01R/0.40C | 1.5R |
| Cereal grains | 0.10 | 0.20 | - | - | - |
| Rice | 0.40P | Na | 0.20P/0.35H | - | - |
| Wheat | 0.20 | 0.20 | - | - | - |
| Cranberry | - | 0.20 | - | - | - |
| Currants | - | 0.20 | - | - | - |
| Elderberry | - | 0.20 | - | - | - |
| Fruits | - | 0.10 | - | - | - |
| Mushrooms | - | 0.30 | - | - | - |
| Canned fruits | - | 0.10 | - | - | - |
| Mango chutney | - | 0.40 | - | - | - |
| Canned vegetables | - | 0.10 | - | - | - |
| Preserved tomatoes | - | 0.05 | - | - | - |
| Olive oils | - | 0.40 | - | - | 3.0 |
| Palm oil | - | Na | - | - | 5.0 to 7.0C |
| Cucumber pickles | - | 0.10 | - | - | - |
| Canned chestnuts | - | 0.05 | - | - | - |
| Fruit juices | - | 0.03 to  0.05 | - | - | - |

P = polished, H = husked, C = crude, R = refined. Source: CF/14 INF/1 [247].