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ABSTRACT: Surface soil regulatory guidance values (RGVs) are available worldwide for nearly 800 pesticides. Part I of this study examined values applied to commonly used carcinogenic pesticides. Part II examines RGVs applied to 12 commonly used noncarcinogenic pesticides: 2,4-D, carbaryl, carbofuran, chlorpyrifos, diazinon, dicamba, diuron, glyphosate, malathion, MCPA, metolachlor, and picloram. The RGVs applied by 38 nations vary by as much as 9.3 orders of magnitude, but the RGV distributions do not fit the lognormal random variable model as well as those reported for other contaminants, and there are value clusters in each distribution. The largest clusters contain values similar to current or previous US Environmental Protection Agency, Australian national, and former USSR values. Because these pesticides are used worldwide, it is important that their RGVs protect human health. Analysis indicates that this goal has not yet been achieved for chlorpyrifos and MCPA.

KEYWORDS: Soil contamination, pesticides, regulatory guidance values, 2,4-D, carbaryl, carbofuran, chlorpyrifos, diazinon, dicamba, diuron, glyphosate, malathion, MCPA, metolachlor, picloram

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Introduction

This work examines the regulatory guidance values (RGVs) applied worldwide to manage human health risks of surface soil contaminated by commonly used noncarcinogenic pesticides. Regulatory guidance values specify the maximum amount of a contaminant that may be present without prompting regulatory action. National, regional, provincial, tribal, state, county, and city regulatory jurisdictions in at least 78 United Nations (UN) member states and at least 4 multinational organizations have promulgated soil RGVs. Most provide values based on the human health risks of direct contact with residential surface soil, and usually, these are based on health risks to children.

Previous studies have examined RGVs applied to several classes of soil contamination. This literature is discussed in the Part I manuscript. Most studies have found that RGVs vary widely, but none have examined the scope of jurisdictions or set of pesticides considered here.

In all, 15 commonly used pesticides were identified based on worldwide manufacturing, import/export, and application data and on the promulgation of RGVs. Part I of this study examined RGVs applied to 3 of these considered to be carcinogenic (atrazine, simazine, and trifluralin). Part II examines the RGVs applied to 12 usually considered to be noncarcinogenic (2,4-D, carbaryl, carbofuran, chlorpyrifos, diazinon, dicamba, diuron, glyphosate, malathion, MCPA, metolachlor, and picloram). The noncarcinogenic determination is debatable. The distinction used here is based on the determination made by the US Environmental Protection Agency (USEPA) in calculating its RGVs that the pesticide is noncarcinogenic, that its carcinogenic risk cannot be quantified with currently available information, or that its noncarcinogenic health risk exceeds its cancer risk. Here, these 12 pesticides are identified by their National Institute of Standards and Technology (NIST)[1] registry name. Additional information on other common names, type, International Union of Pure and Applied Chemistry (IUPAC)[2] nomenclature, and Chemical Abstract Service registry numbers (CAS No.)[3] is provided in Table 1.

Materials

The materials of this work are the 12 pesticides considered. The following sections discuss the origin and typical uses of each. Detailed information on their toxicology may be found in the National Library of Medicine Hazardous Substances Data Bank,[4] in the US Environmental Protection Agency Integrated Risk Information System (USEPA/IRIS),[5] and in Agency for Toxic Substances and Disease Registry (ATSDR)[6] publications and will not be discussed here. Rather, information is provided on how these toxicology data have been interpreted by organizations such as the American Conference of Government Industrial Hygienists (ACGIH),[7] the International Labour Organization (ILO),[8] The German Research Foundation (Deutshce Forschungsgemeinschaft [DFG]),[9] Safe Work Australia (SWA),[10] and USEPA. These are the determinations that have the greatest impact on RGV development.

Regulatory agencies worldwide have identified many of these pesticides as priority pollutants. Malathion appears on the UK "red list" of most dangerous substances.[11] Chlorpyrifos

Table 1. The most common current use pesticides generally considered to be noncarcinogenic.

COMMON USE PESTICIDE	TYPE	INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY (IUPAC) NAME	ELEMENTAL COMPOSITION	CAS NO.	NO. OF NIST, OTHER NAMES
2,4-D (Weed-B-Gon, Aqua-Kleen, Weedmaster)	Herbicide	2,4-dichlorophenoxyacetic acid	$C_8H_6Cl_2O_3$	94-75-7	121
Carbaryl (Sevin)[a]	Insecticide	1-naphthyl methylcarbamate	$C_{12}H_{11}NO_2$	63-25-2	88
Carbofuran (Furadan)	Insecticide	2,2-dimethyl-2,3-dihydro-1-benzofuran-7-yl methylcarbamate	$C_{12}H_{15}NO_3$	1563-66-2	41
Chlorpyrifos (Chlorpyriphos, Dursban)	Insecticide	*o,o*-diethyl *o*-3,5,6-trichloropyridin-2-yl phosphorothioate	$C_9H_{11}Cl_3NO_3PS$	2921-88-2	56
Diazinon (Diazinone, Basudin, Dazzel)	Insecticide	*o,o*-diethyl *o*-[4-methyl-6-(propan-2-yl) pyrimidin-2-yl] phosphorothioate	$C_{12}H_{21}N_2O_3PS$	333-41-5	84
Dicamba (Banvel, Diablo)	Herbicide	3,6-dichloro-2-methoxybenzoic acid	$C_8H_6Cl_2O_3$	1918-00-9	28
Diuron (DCMU, Karmex)	Herbicide	3-(3,4-dichlorophenyl)-1,1-dimethylurea	$C_9H_{10}Cl_2N_2O$	330-54-1	46
Glyphosate (Roundup)	Herbicide	*N*-(phosphonomethyl) glycine	$C_3H_8NO_5P$	1071-83-6	77[b]
Malathion (Celthion)	Insecticide	Diethyl 2-[(dimethoxyphosphorothioyl) sulfanyl]butanedioate	$C_{10}H_{19}O_6PS_2$	121-75-5	132
MCPA (Weed-B-Gone)	Herbicide	(4-chloro-2-methylphenoxy) acetic acid	$C_9H_9ClO_3$	94-74-6	90
Metolachlor (Dual)	Herbicide	(*RS*)-2-chloro-*N*-(2-ethyl-6-methyl-phenyl) -*N*-(1-methoxypropan-2-yl) acetamide	$C_{15}H_{22}ClNO_2$	51218-45-2	17
Picloram (Grazon, Tordon)	Herbicide	4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid	$C_6H_3Cl_3N_2O_2$	1918-02-1	22

Abbreviations: CAS No., Chemical Abstract Service Number; NIST: National Institute of Standards and Technology.

[a] (-----) indicates other common names for the indicated pesticide.

[b] NIST entry is incomplete. "Other names" were compiled from other sources.

and diuron appear on the European Commission's and Turkey's list of priority substances.[12,13] All but glyphosate and picloram appear on the ATSDR substance priority list,[14] and all have been found at multiple US National Priority List Superfund sites.[15]

2,4-D

2,4-D is a chlorophenoxy herbicide that was codiscovered in the United States and United Kingdom during World War II chemical warfare research. It was commercialized in 1946 and has become one of the most common broadleaf herbicides used on pastures, rangelands, residential lawns, roadways, and cropland.[16] 2,4-D was one of the 2 major components of Agent Orange used by the British during the 1950's Malayan Emergency and by the United States in Vietnam. By the end of 1971, 12% of the land area and 20% of the forests of South Vietnam had been sprayed.[17]

2,4-D is the most commonly used US home and garden pesticide and the seventh most commonly used US agricultural pesticides.[18] It is also among the top 10 pesticides applied in the United Kingdom,[19] the top 10 pesticide ingredients sold in Canada[20] and commercialized in Brazil,[21] and is China's sixth most exported herbicide.[22] 2,4-D is also among the most used pesticides in New Zealand,[23] South Africa,[24] Panama,[25] and Tanzania.[26]

The ACGIH indicates 2,4-D is A4—"not classifiable as a human carcinogen."[4] The SWA assigns it risk phrases 22, 37-41, 43, and 52-53, indicating ingestion, inhalation, and dermal contact toxicity and that it is harmful to aquatic organisms.[10] The ILO assigns it risk phrases 22 and 36/37/38, indicating that it is harmful by ingestion and inhalation.[8] The DFG indicates that it is toxic by dermal adsorption.[9] In 1997, the USEPA Office of Pesticide Programs (USEPA/OPP) concluded that 2,4-D "was not classifiable as to human carcinogenicity."[27] The USEPA/IRIS indicates that it "has not undergone a complete evaluation . . . for evidence of human carcinogenic potential."[5] The USEPA 2,4-D RGV is based on noncancer ingestion and dermal contact risks.[28]

Carbaryl

Carbaryl is a carbonate insecticide introduced by the Union Carbide Corporation in 1958 and registered in the United States in 1959. It is used in agricultural, forestry, rangeland, home, and garden applications to control moths, beetles, cockroaches, ants, ticks, slugs, snails, and mosquitoes. It is used on corn, soybean, cotton, fruit, nut, and vegetable crops, as well as on lawns, shade trees, and ornamental shrubs. It is also used on livestock, poultry, pets, and sometimes on humans to treat head lice.[29,30]

Carbaryl is the third most used US home and garden pesticide.[30] It is also a high percentage use pesticide in New Zealand[23] and is commonly used on Mexican chili pepper and tomato crops.[31]

Carbaryl was added to the California Environmental Protection Agency list of chemicals known to cause cancer or reproductive toxicity in 2010.[32] The International Agency for Research on Cancer (IARC) indicates that it is "not classifiable as to its carcinogenicity to humans."[33] The ACGIH indicates that it is "not classifiable as a human carcinogen."[4] The SWA assigns carbaryl risk phrases 40, 20/22, and 50, indicating ingestion and inhalation toxicity and that it is very toxic to aquatic organisms but that there is "limited evidence of a carcinogenic effect."[10] The ILO assigns it risk phrase 22, indicating harm by ingestion.[8] The DFG indicates a dermal adsorption risk.[9] In 2001, USEPA/OPP concluded that "it was likely to be carcinogenic to humans."[27] The USEPA/IRIS indicates that it "has not undergone a complete evaluation . . . for evidence of human carcinogenic potential."[5] The USEPA carbaryl RGV is based on noncancer ingestion and dermal contact risks.[18]

Carbofuran

Carbofuran is a carbamate insecticide first registered in the United States in 1969. It is used on field, fruit, vegetable, and forest crops. It has been used extensively on potatoes, corn, rice, soybeans, strawberries, alfalfa, grapes, and wheat.[34] Carbofuran is available in liquid and granular form, but the United States has banned the granular form except for limited use on spinach grown for seed, pine seedlings, bananas (in Hawaii only), and cucurbits. The USEPA has determined that all uses of carbofuran are ineligible for reregistration, so its US use is being phased out.[35]

Carbofuran is commonly used on Mexican chili peppers and tomatos.[31] It is also commonly used in Panama[25] and Tanzania.[26] The FMC Corporation markets carbofuran under the name Furadan and claims that it is used in more than 80 nations.[36]

The ACGHI assigns carbofuran a rating of A4—"not classifiable as a human carcinogen."[4] The SWA assigns it risk phrases 26/28 and 52-53, indicating that it is very toxic by ingestion and inhalation and that it is harmful to aquatic organisms.[10] The ILO assigns carbofuran risk phrase 26/28, indicating that it is very toxic by ingestion and inhalation.[8] In 1997, the USEPA/OPP concluded that "it was not likely to be carcinogenic to humans."[27] The USEPA/IRIS indicates that it "has not undergone a complete evaluation . . . for evidence of human carcinogenic potential."[5] The USEPA carbofuran RGV is based on noncancer ingestion and dermal contact risks.[28]

Chlorpyrifos

Chlorpyrifos is a broad-spectrum organophosphate insecticide introduced in 1965 by the Dow Chemical Company.[37] Residential uses include control of cockroaches, fleas, and termites. It was also used in some pet flea and tick collars,[38] but after several legal issues including a $732 000 fine for failing to report poisoning incidents, Dow withdraw its registration for all residential uses except child-proof insect baits.[39] It is still registered for nonresidential uses on fruits, grains, cotton, vegetables, and livestock and to control cutworms, rootworms, cockroaches, grubs, flea beetles, flies, termites, lice, and fire ants.[40]

Chlorpyrifos is the 14th most commonly used agricultural pesticides in the United States.[18] It is one of the top 10 pesticides used in the United Kingdom,[19] one of China's top 10 pesticide exports,[22] and one of Australia's 2 most commonly used insecticides.[41] Chlorpyrifos is also the 9th most used pesticide in India[42] and 22nd most used agricultural pesticide in South Africa.[24] It is a high percentage use pesticide in New Zealand,[23] Panama,[25] and Tanzania[26] and is commonly used on Mexican chili pepper and tomato crops.[31]

The ACGHI indicates that chlorpyrifos is "not classifiable as a human carcinogen."[4] The SWA assigns it risk phrases 25 and 50-53, indicating that it is toxic by ingestion and very toxic to aquatic organisms.[10] The ILO assigns chlorpyrifos risk phrases 24/25 and 50/53, indicating that it is toxic by ingestion or dermal contact and very toxic to aquatic organisms.[8] In 1993, the USEPA/OPP concluded that there was "evidence of noncarcinogenicity for humans."[27] USEPA/IRIS indicates that Chlorpyrifos has "not undergone a complete evaluation and determination . . . for evidence of human carcinogenic potential."[5] The USEPA chlorpyrifos RGV is based on noncancer ingestion and dermal contact risks.[28]

Diazinon

Diazinon is an organophosphorus pesticide developed in Switzerland in 1952 and used in the United States since 1956[43] to control insects on fruits, vegetables, nuts, field crops, golf courses, and cattle. It has also been used in residential applications to control cockroaches, silverfish, aphids, mites, ants, fleas, ticks, and yellow jackets and in pet flea collars.[44] At the height of its US popularity, 75 million household applications were made annually,[43] but all US residential uses ended in 2004.[45]

Diazinon is one of Australia's 2 most commonly used insecticides[41] and is a high percentage use pesticide in New Zealand.[23] It is commonly used on vegetables in Tanzania[26] and on Mexican chili pepper and tomato crops.[31]

The ACGHI assigns diazinon a rating of A4—"not classifiable as a human carcinogen."[4] The SWA assigns it risk phrases 22, 48/25, and 52-53, indicating that it is toxic by ingestion and is harmful to aquatic organisms.[10] The ILO assigns it risk phrases 22 and 50/53, indicating that it is harmful by ingestion and very toxic to aquatic organisms.[8] The DFG indicates that it is toxic by dermal adsorption.[9] In 1997, the USEPA/OPP concluded that it was "not likely to be carcinogenic to humans."[27] The USEPA/IRIS apparently does not include a diazinon entry. The USEPA diazinon RGV is based on noncancer ingestion and dermal contact risks.[28]

Dicamba

Dicamba is an organophenoxy herbicide first registered in the United States in 1967. It is used for postemergent plant control, often in combination with other pesticides such as 2,4-D. Dicamba is used for broad lead control on grain crops (its largest US use is on corn), cotton, soybeans, and rangeland. It is also used on residential lawns and public lands.[46] The demand for dicamba has recently grown because it can be mixed with glyphosate to help control weeds that are becoming glyphosate resistant.[47]

Dicamba is the eighth most used US home and garden pesticide[18] It is also one of the top 10 pesticides applied in the United Kingdom[19] and is China's fifth largest herbicide export.[22]

The IARC indicates that dicamba is "not classifiable as a human carcinogen."[33] The SWA assigns it risk phrases 22, 41, and 52-53, indicating that it is toxic by ingestion, is an eye irritant, and is harmful to aquatic organisms.[10] In 1996, the USEPA/OPP concluded that "it was not classifiable as to human carcinogenicity."[27] The USEPA/IRIS indicates that its cancer risk evaluation "is not available at this time."[5] The USEPA dicamba RGV is based on noncancer ingestion and dermal contact risks.[28]

Diuron

Diuron is a photosynthesis inhibitor herbicide introduced by Bayer Corporation in 1954 and registered for US use in 1966. It is used for pre- and postemergent vegetation control, as a preservative in paints and stains, and as an algaecide in commercial fish production, residential ponds, and aquariums. It is used on citrus, alfalfa, artichoke, asparagus, bananas, barley, Bermuda grass, blueberries, cranberries, corn, pineapple, sugarcane, and fruit and nut trees. Rights-of-way applications account for its greatest nonagricultural use.[48]

Diuron is the 22th most commonly used US agricultural pesticide.[18]

Diuron was added to the California list of substances known to cause cancer or reproductive toxicity in 2002.[32] The SWA identifies it as a category 3 carcinogen and assigns it risk phrases 22, 48/22 and 50-53, indicating that it is "suspected of having carcinogenic potential," is toxic if ingested, and is harmful to aquatic organisms.[10] The ACGHI assigns it a rating of A4—"not classifiable as a human carcinogen."[4] The ILO assigns it risk phrase 48/22, indicating that it is toxic if ingested.[8] In 1997, the USEPA/OPP concluded that it was "known/likely" to be carcinogenic.[27] The USEPA/IRIS indicates that it "has not undergone a complete evaluation . . . for evidence of human carcinogenic potential."[5] The USEPA diuron RGV is based on noncancer ingestion and dermal contact risks.[28]

Glyphosate

Glyphosate is a broad-spectrum organophosphorus herbicide used to control broad-leaved weeds and grasses. Its herbicidal properties were discovered by the Monsanto Company in 1970. It was first registered in the United States in 1974 and marketed as Roundup.[49] Development of glyphosate-resistant "Roundup ready" crops has increased its use worldwide. Glyphosate has applications in agriculture, forestry, industrial weed control, lawn, garden, and aquatic environments. It is used on corn, wheat, sorghum, citrus, stone fruits, potatoes, onions, asparagus, coffee, peanuts, and pineapple. Nonagricultural uses include ornamental plants, turf, forests, rights-of-way, and weed control in ponds, reservoirs, waterfowl sanctuaries, and waterways.[50]

Glyphosate is the most used agricultural and the second most used home and garden herbicide in the United States.[18] It is one of the top 10 pesticides used in the United Kingdom[19] and sold in Canada.[20] It is the most commonly used agricultural herbicide in South Africa[24] and among the 3 most commonly used in Australia.[41] Glyphosate is also the second most common pesticide ingredient commercialized in France[51] and the first in Brazil,[21] is a high percentage use herbicide in New Zealand,[23] and is China's largest pesticide export.[22] It is also one of the most commonly used agricultural chemical in Panama[25] and Tanzania.[26]

The SWA assigns glyphosate risk phrases 41 and 51-53, indicating that exposure risks eye damage and is harmful to aquatic organisms.[10] It apparently has not been evaluated by the IARC, ACGHI, ILO, or DGF.[4,8,9,33] In 1991, the USEPA/OPP concluded that there was "evidence of carcinogenicity for humans."[27] The USEPA/IRIS indicates that it is "not classifiable as to human carcinogenicity."[5] The USEPA glyphosate RGV is based on noncancer ingestion and dermal contact risks.[28]

Malathion

Malathion is a broad-spectrum organophosphate insecticide first registered in the United States in 1956.[52] It is used on agricultural crops, stored products, golf courses, homes, gardens, and public parks. It is most commonly used on cotton, alfalfa, cherries, strawberries, lettuce, citrus, blueberries, wheat, and walnuts.[53] It has been used in US, Canadian, and Australian programs to control the Mediterranean fruit fly and West Nile virus.[54] Malathion is also used in pet flea and tick protection products and in shampoos for treating human head lice.[52]

Malathion is the seventh most commonly used US home and garden pesticides.[18] It is also the 10th most used pesticide in India[42] and is commonly used on Mexican vegetable crops.[31]

The IARC indicates that Malathion is "not classifiable as to its carcinogenicity to humans."[33] The ACGHI assigns it a rating of A4—"not classifiable as a human carcinogen."[4] The SWA assigns it risk phrases 22, 41, and 52-53, indicating that it is toxic by ingestion, is an eye irritant, and is harmful to aquatic organisms.[10] The ILO assigns it risk phrase 22, indicating that it is harmful by ingestion.[8] In 2000, the USEPA/OPP concluded that there was "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential."[27] The USEPA/IRIS indicates that its assessment is "not available at this time."[5] The USEPA malathion RGV is based on noncancer ingestion and dermal contact risks.[28]

Metolachlor

Metolachlor is a broad-spectrum preemergence chloroacetanilide herbicide. Its biological activity was identified by Swiss pharmaceutical company in 1970. It was registered in the United States in 1976. It is used to control broadleaf and grass-like weeds in corn, soybeans, peanuts, sorghum, potatoes, pod crops, cotton, safflower, stone fruits, nut trees, cabbage, pepper, radish, legume vegetable, peas, soybeans, and alfalfa. It is also used on nonfood crops, rights-of-way, golf courses, parks, ornamental plants, shade trees, flowers, lawns, and forests.[55]

Metolachlor is the fourth most used agricultural pesticide in the United States,[18] but scant information is available on how commonly it is used elsewhere.

Apparently, metolachlor has not been evaluated by IARC, ACGHI, SWA, ILO, or DGF.[4,8–10,33] In 1994, the USEPA/OPP identified it as a "Group C—possible human carcinogen."[27] The USEPA/IRIS also identifies metolachlor as a "C—possible human carcinogen,"[5] but the USEPA metolachlor RGV is based on noncancer ingestion and dermal contact risks.[27]

MCPA

MCPA is a postemergence phenoxy herbicide developed in 1945 that has been in commercial production since the 1950s.[56] It is similar to 2,4-D and was among the first hormone-based herbicides. It was registered for US use in 1973. MCPA is used for weed control in alfalfa, barley, clover, flax, oats, pasture and rangeland grass, peas, rice, rye, sorghum, and wheat. It is also used on turf, vines, rights-of-way, and forests and in residential applications, often in combination with other herbicides.[57]

MCPA is the 23rd most used agricultural pesticide in the United States[18] and the 17th most common pesticide commercialized in France.[51] It is also one of the top 10 pesticides applied in the United Kingdom[19] and sold in Canada,[20] is the 12th most used pesticide in South Africa,[24] and is a high percentage use pesticide in New Zealand.[23]

The SWA assigns MCPA risk phrases R22, R38-41 and R50-53, indicating that it is toxic by ingestion and very toxic to aquatic organisms but that there is limited evidence of a carcinogenic effect.[10] The ILO assigns it risk phrases 22, 38, 41, and 20/21/22, indicating that it is toxic by ingestion, dermal contact, or inhalation.[8] In 2003, the USEPA/OPP concluded that it was "not likely to be carcinogenic to humans."[27] The USEPA/IRIS indicates that MCPA "has not undergone a complete evaluation . . . for evidence of human carcinogenic potential."[5] The USEPA MCPA RGV is based on noncancer ingestion and dermal contact risk.[28]

Picloram

Picloram is a pyridine herbicide. US production was begun by the Dow Chemical Company in 1963, and it was registered for US use in 1964.[58] It is marketed by Dow AgroSciences as Tordon and Grazon[59] and is often combined with other herbicides such as diuron, 2,4-D, MCPA, and atrazine. Agent White (a 4:1 mixture of 2,4-D and picloram) was used as a defoliant in Vietnam. Most broad-leaved plants are susceptible to Picloram, whereas most grasses are not. It is most often used for brush control on rights-of-way, pastures, rangeland, and grain corps.[58]

Although the use of picloram is relatively common in the United States, little information is available on its use in other nations. It is a high percentage use pesticide in New Zealand[23] and is among China's top 10 herbicide exports.[22]

The IARC concluded that picloram was "not classifiable as to its carcinogenicity to humans."[33] The ACGHI classifies it as A4—"not classifiable as a human carcinogen."[4] It has apparently not been evaluated by SWA, ILO, or DGF.[8–10] In 1994, the USEPA/OPP concluded that there was "evidence of non-carcinogenicity for humans."[27] The USEPA/IRIS indicates that the picloram evaluation "is not available at this time."[5] The USEPA picloram RGV is based on noncancer ingestion and dermal contact risks.[28]

Methods

Pesticide RGV sources

Pesticide RGVs were taken from regulatory guidance documents identified by Internet searches. The methods used are documented in Jennings and Li[60] and in the Part I manuscript "Worldwide regulatory guidance values applied to direct contact surface soil pesticide contamination: Part I—Carcinogenic pesticides." All the RGVs used in this analysis are also documented in manuscript Part I, Supplemental Tables S1 and S2.

Analysis of RGVs

The RGV data sets are characterized by the total (N), US-related (N_{US}) and non–US-related (N_W) set sizes, extreme values, arithmetic mean, geometric mean, median, $\log_{10}$ mean (μ_L), and $\log_{10}$ standard deviation (σ_L). All values were given equal weight. Log-transformed value statistics are included because previous studies have indicated that RGV variability often resembles that of a lognormal random variable.

The empirical cumulative distributions illustrated here were constructed from RGV data sets as follows,

$$P(\mathrm{RGV}_r \le \mathrm{RGV}_i) \approx \frac{R_i}{N}; \quad \forall i = 1, N, \tag{1}$$

where RGV_r is a known value, RGV_i is a random RGV realization for this same pesticide, and R_i is the integer rank of RGV_r in the RGV set. Pearson (r) correlation analysis was used to quantify how well empirical distributions correlated with lognormal distributions calibrated with identical statistics. Value clusters were also identified and discussed. Apparently nonrandom clusters were identified as groups of values for which the binomial probability mass function indicated a random occurrence probability of less than .001.[64,65]

USEPA RGV Model Calculations

The USEPA pesticide RGVs are calculated from models that quantify their noncancer ingestion and dermal exposure risks. The USEPA does not consider inhalation risk for these pesticides. The models used are documented in USEPA[61] and in Equations (5) to (7) of the Part I manuscript. All of the chemical-independent exposure scenario coefficients, their USEPA values, and the range of values used by other jurisdictions are documented in the Part I manuscript. Chemical-specific coefficients for the pesticides considered here are as follows:

Gastrointestinal adsorption fraction (GIABS)—1.0 for all;

Dermal adsorption fraction ($\mathrm{ABS_d}$)—0.05 for 2,4-D, 0.10 for all others;

Chronic oral reference dose ($\mathrm{RfD_o}$)—0.01 for 2,4-D, 0.10 for carbaryl, 0.005 for carbofuran, 0.001 for chlorpyrifos, 0.0007 for diazinon, 0.03 for dicamba, 0.002 for diuron, 0.10 for glyphosate, 0.0005 for malathion, 0.02 for MCPA, 0.15 for metolachlor, and 0.07 for picloram

The USEPA noncancer risk models are only used to illustrate the impact of coefficient variations on RGV calculations. Their use should not be taken to imply that the USEPA analysis is correct. It remains the responsibility of individual jurisdictions to determine the most appropriate values.

Results

A total of 939 US-related valued were identified for the 12 pesticides considered. These came from 5 national organizations (USEPA, US Army, National Oceanic and Atmospheric Administration, ATSDR, and the Department of Energy [DOE]), 42 US states, 2 US territories (*Commonwealth of the Northern Mariana Islands* and Guam), Florida's Miami-Dade County, New York City, and 6 Native American Tribes (Nez Perce Tribe, Hoopa Valley Tribe, Confederated Tribes of the Colville Reservation, Jamestown S'Klallam Tribe, Spokane Tribe, and the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians). State values were not found for Louisiana, Missouri, New Jersey, North Dakota, Rhode Island, South Carolina, South Dakota, or Utah.

A total of 317 RGVs were identified from regulatory jurisdictions in other nations. These include values from 2 multinational organizations (East Africa Community and the World Health Organization) and national, regional, provincial, territorial, or city jurisdictions in 27 UN member states (Andorra, Armenia, Australia, the Bahamas, Belarus, Canada, Czech Republic, Ecuador, Estonia, Georgia, Italy, Latvia, Lithuania, Malaysia, Moldova, the Netherlands, New Zealand, Poland, Thailand, Russia, Serbia, Singapore, Spain, Tanzania, Uzbekistan, Ukraine, and Vietnam). USSR values were included because these are still in use in some areas.

Figures 1 to 6 illustrate empirical cumulative RGV distributions compared with cumulative distributions of lognormal random variables with identical μ_L and σ_L statistics. Uncertainty bounds computed from the noncancer risk models for each pesticide are indicated by shaded areas. Tables 2 and 3 summarize additional RGV statistics. Results for each pesticide are discussed in the following sections, but there are distribution features that are common to all.

There are RGV clusters in all the distributions. The largest is made up of values equal to the USEPA RGV health risk model based on a total hazard quotient (THQ) of 1.0 or 0.1. A THQ value of 1.0 yields the maximum allowable dose. Some jurisdictions use a THQ value of 0.1 to allow for similar health effects from other pollutants. Clusters of values essentially identical to the outcome of USEPA risk models have been identified as "USEPA THQ = 1.0 Cluster" or "USEPA THQ = 0.1 Cluster" on Figures 1 to 6. These clusters usually contain values from USEPA, Alabama, Arizona, Arkansas, Colorado, Delaware, Iowa, Kentucky, Montana, Nevada, New Mexico, Ohio, Oklahoma, Oregon, Tennessee, Vermont, Wyoming, the Hoopa Valley Tribe, and the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians.

There are also value clusters resulting from Australian national and provincial standards for residential sites with garden and/or accessible soil and residential sites with minimal soil access. These contain values from Australia, Australia Capital Territory, Queensland, Tasmania, New South Wales, Victoria, South Australia, Western Australia, and Northern Australia.

There are other clusters that are more dispersed but distinct enough to warrant identification. One appears to be related to previous USEPA RGVs. Prior to 2008, there were different RGV sets for USEPA Regions III, VI, and IX and the Superfund program. These were harmonized in 2008, but pre-2008 Region III values appear to be the source of 2,4-D, metolachlor, carbaryl, chlorpyrifos, glyphosate, dicamba, diuron, MCPA, and malathion RGV clusters. These are identified as "USEPA III Cluster" and are usually made up of values from

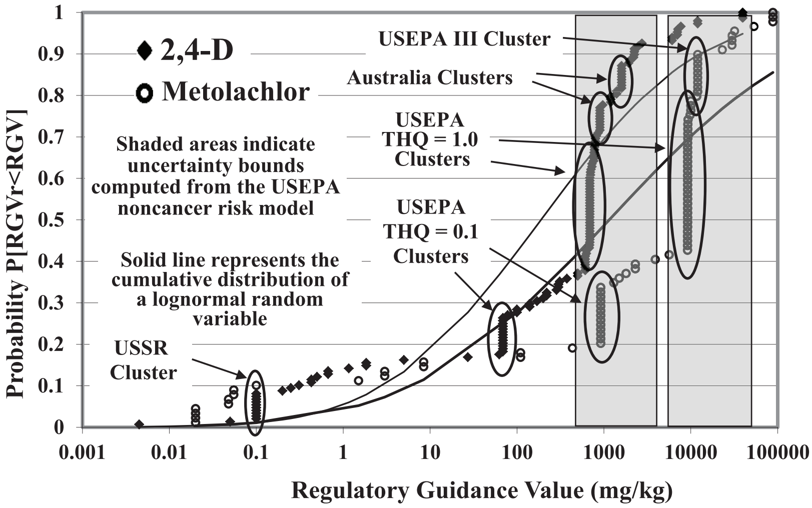

Figure 1. Cumulative distributions of 2,4-D and metolachlor regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

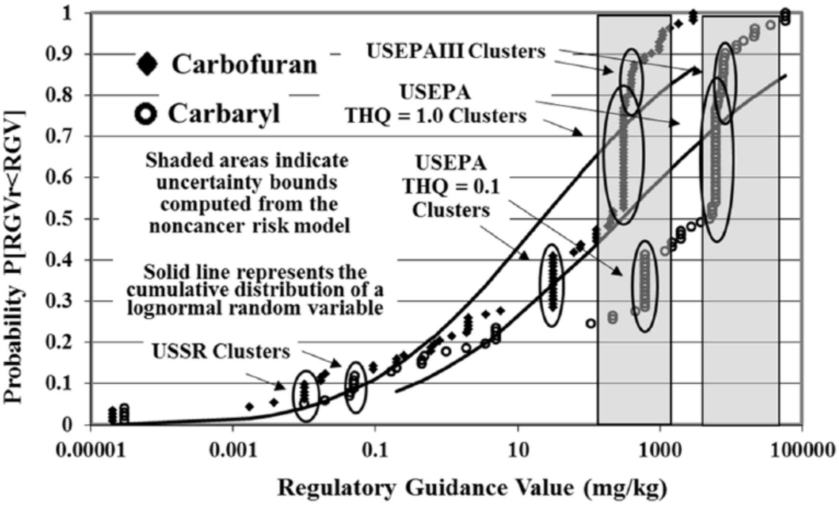

Figure 2. Cumulative distributions of carbofuran and carbaryl regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

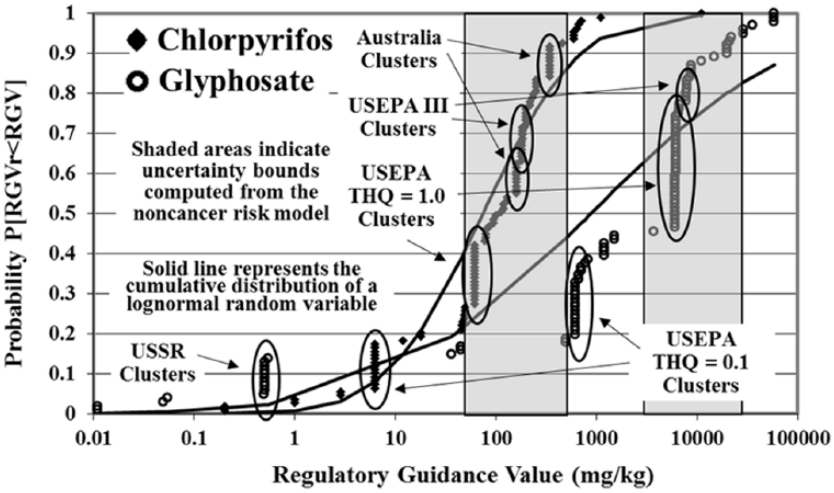

Figure 3. Cumulative distributions of chlorpyrifos and glyphosate regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

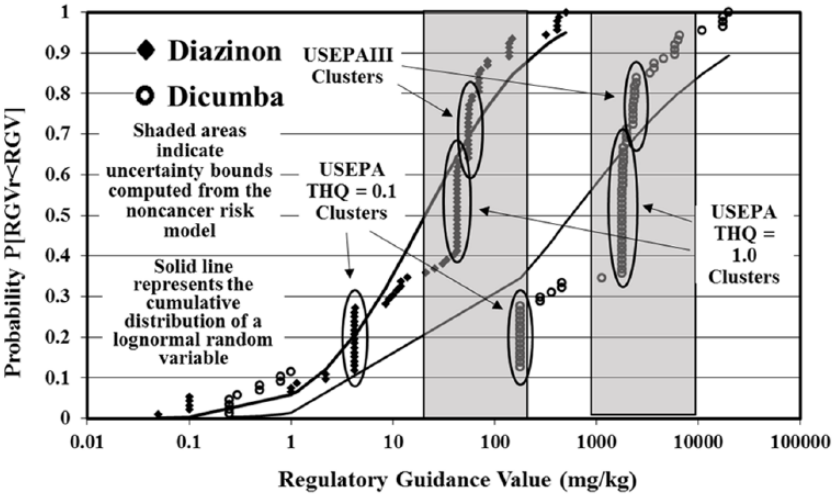

Figure 4. Cumulative distributions of diazinon and dicamba regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

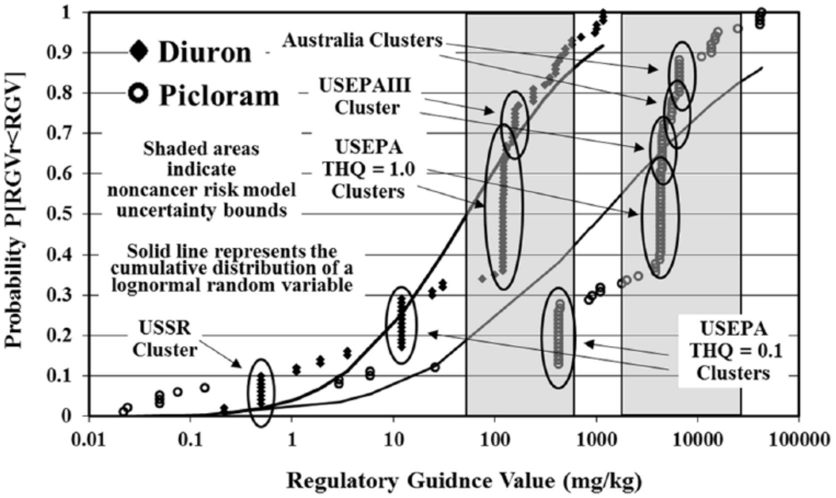

Figure 5. Cumulative distributions of diuron and picloram regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

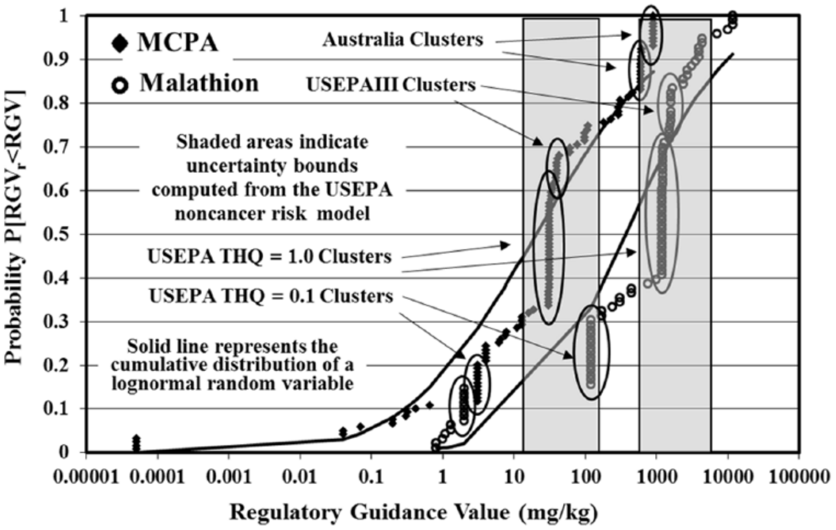

Figure 6. Cumulative distributions of MCPA and malathion regulatory guidance values compared with the cumulative distributions of lognormal random variables. RGV indicates regulatory guidance value; THQ, total hazard quotient; USEPA, US Environmental Protection Agency.

Table 2. Summary of pesticide RGV statistics (2,4-D through dicamba).

STATISTIC	CURRENT USE PESTICIDES					
	2,4-D	CARBARYL	CARBOFURAN	CHLORPYRIFOS	DIAZINON	DICAMBA
N	148	102	112	109	92	87
N_{us} (% total)	101 (68.2)	73 (71.6)	80 (71.4)	76 (69.7)	75 (81.5)	73 (83.9)
N_w (% total)	47 (31.8)	29 (28.4)	32 (28.6)	33 (30.3)	17 (18.5)	14 (16.1)
Minimum, mg/kg	0.0045	0.00003	0.00002	0.2	0.05	0.25
Maximum, mg/kg	39 500	58 700	2930	11 000	500	20 000
Log orders of variation	6.9	9.3	8.2	4.7	4.0	4.9
Mean, mg/kg	1834	6065	318	260	63.2	2531
Standard deviation, mg/kg	5750	10 763	538	1054	99.8	3910
Log mean	2.275	2.458	1.347	1.869	1.318	2.754
Log standard deviation	1.422	2.252	1.921	0.761	0.839	1.246
Geometric mean, mg/kg	189	287	22.2	74.0	20.8	567
Median, mg/kg	690	5540	220	113	43	1800
N_{us} (% US RGV) > median	51 (45.1)	46 (63.0)	50 (62.5)	30 (39.5)	39 (52.0)	42 (57.5)
N_w (% worldwide RGV) > median	22 (62.9)	4 (13.8)	5 (15.6)	24 (72.7)	5 (29.4)	1 (7.1)
Correlation with lognormal random variable model	0.905	0.891	0.918	0.962	0.949	0.895

Abbreviation: RGV, regulatory guidance value.

Arizona, the Bahamas, the Confederated Tribes of the Colville Reservation, Florida, Illinois, Indiana, the Jamestown S'Klallam Tribe, Florida's Miami-Dade County, Mississippi, Texas, Washington, and West Virginia. There are also small value clusters at the low end of some distributions. Membership is variable but is dominated by values from former USSR republics that still use the USSR 1983 value. This has been identified at the "USSR Cluster" and is usually made up of values from Armenia, Belarus, Georgia, Lithuania, Moldova, Ukraine, and Russia.

2,4-D

The 148 2,4-D RGVs are illustrated in Figure 1. The values are dispersed over nearly 7 orders of magnitude from a minimum of 0.0045 mg/kg from Virginia to a maximum of 39 500 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics is $r = 0.905$.

There are 5 RGV clusters in the distribution. The Australia clusters yield 9 values (6.1% of N) at 1600 and 900 mg/kg. The USEPA THQ = 1.0 cluster contains 24 values (16.2 % of N) at 689 to 690 mg/kg. The USEPA THQ = 0.1 cluster contains 13 values (8.8% of N) at 69 mg/kg. The USSR cluster contains 10 values (6.7% of N) at 0.1 mg/kg. The noncancer risk model THQ = 1.0 uncertainty bounds of 430 to 3690 mg/kg contains 84 (56.8%) of the RGVs.

Carbaryl

The 102 carbaryl RGVs are illustrated in Figure 2. The values are dispersed over 9.3 orders of magnitude from a minimum of 0.00003 mg/kg from Latvia, the Netherlands, Russia Tatarstan, and Singapore to a maximum of 58 700 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics ($r = 0.891$) is the lowest for the pesticides considered here.

There are 4 RGV clusters in the distribution. The USEPA THQ = 1.0 cluster contains 24 values (23.5% of N) at 6100 to 6200 mg/kg. The USEPA THQ = 0.1 cluster contains 14 values at 620 mg/kg (13.7% of N). The USEPA III cluster contains 10 values (9.8% of N) at 7700 to 8,500 mg/kg from Indiana, Texas, Washington, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Mississippi, West Virginia, Florida, Miami-Dade County, and the Bahamas. The USSR cluster contains 6 values (5.9% of N) in the neighborhood of 0.05 mg/kg. The carbaryl noncancer risk model THQ = 1.0 uncertainty bounds of 3000 to 32 100 mg/kg contains 49 (48.0 % of N) of the RGVs.

Table 3. Summary of pesticide RGV statistics (diuron through picloram).

STATISTIC	CURRENT USE PESTICIDES					
	DIURON	GLYPHOSATE	MALATHION	MPCA	METOLACHLOR	PICLORAM
N	100	101	96	119	89	101
N_{us} (% total)	82 (82.0)	81 (80.2)	76 (79.2)	77 (64.7)	74 (83.1)	71 (70.2)
N_w (% total)	18 (18.0)	20 (19.8)	20 (20.8)	42 (35.3)	15 (16.8)	30 (29.7)
Minimum, mg/kg	0.216	0.011	0.82	0.00005	0.02	0.022
Maximum, mg/kg	1170	58 700	11 700	900	88 000	43 000
Log orders of variation	3.7	6.7	4.2	7.2	6.6	6.3
Mean, mg/kg	193.1	6978	1569	171.1	10 320	5650
Standard deviation, mg/kg	268.9	11 310	2373	278.9	16 890	8404
Log mean	1.724	2.944	2.566	1.310	3.061	3.065
Log standard deviation	0.066	1.603	1.113	1.441	1.776	1.431
Geometric mean, mg/kg	53.1	878	368	20.4	1152	1162
Median, mg/kg	120	6100	1200	31	9200	4300
N_{us} (% US RGV) > median	46 (56.1)	48 (59.3)	45 (59.2)	38 (49.4)	43 (58.1)	32 (45.0)
N_w (% worldwide RGV) > median	3 (16.7)	1 (10.0)	2 (10)	21 (50)	1 (6.7)	18 (60.0)
Correlation with lognormal random variable model	0.938	0.902	0.921	0.962	0.873	0.875

Abbreviation: RGV, regulatory guidance value.

Carbofuran

The 112 carbofuran RGVs are also illustrated in Figure 2. The values are dispersed over 8.2 orders of magnitude from a minimum of 0.00002 mg/kg from Latvia, the Netherlands, Russia Tatarstan, and Singapore to a maximum of 2930 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.918.

There are 4 RGV clusters. The USEPA THQ = 1.0 cluster contains 19 values (17.0% of N) at 310 mg/kg. The USEPA THQ = 0.1 cluster contains 15 values at 31 mg/kg (13.4% of N). The USEPA III cluster contains 12 values (10.7 % of N) at 330 to 435 mg/kg from the Netherlands, Indiana, Texas, Washington, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Mississippi, Illinois, West Virginia, Arizona, and Texas. The USSR cluster contains 8 values at 0.01 to 0.02 mg/kg (7.1% of N). The carbofuran noncancer risk model THQ = 1.0 uncertainty bounds of 150 to 1610 mg/kg contains 55 (49.1%) of the RGVs.

Chlorpyrifos

The 109 chlorpyrifos RGVs are illustrated in Figure 3. The values are dispersed over 4.7 orders of magnitude from a minimum of 0.2 mg/kg specified by Belarus and Ukraine to a maximum of 11 000 mg/kg specified by Michigan. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.962.

There are 5 value clusters. The Australia clusters contain 9 values (8.2% of N) at 340 and 160 mg/kg. The USEPA THQ = 1.0 cluster contains 17 values at 61 to 62 mg/kg. The USEPA THQ = 0.1 cluster contains 13 (11.9% of N) values at 6.2 mg/kg. The USEPA III cluster contains 9 values (8.3% of N) at 200 to 250 mg/kg from Florida, Texas, Miami-Dade County, the Bahamas, Mississippi, West Virginia, Canada (Alberta and Nova Scotia), and Arizona. The chlorpyrifos noncancer risk model THQ = 1.0 uncertainty bounds of 30 to 321 mg/kg contains 69 (63.3%) of the RGVs.

Diazinon

The 92 diazinon RGVs are illustrated in Figure 4. The values are dispersed over 4.0 orders of magnitude (lowest for any of the pesticides considered here) from a minimum of 0.05 mg/kg specified by Vietnam to a maximum of 500 mg/kg specified by ATSDR. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.949

There are 3 value clusters. The USEPA THQ = 1.0 cluster contains 17 values (18.5% of N) at 43 to 43.1 mg/kg. The USEPA THQ = 0.1 cluster contains 15 values (16.3% of N) at 4.2 mg/kg and includes values from Canadian Alberta and Manitoba. The USEPA III cluster contains 15 values (14.1% of N) at 55 to 56 mg/kg from Indiana, Arizona, Washington, the Confederates Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Illinois, Missouri, Nevada, the Hoopa Valley Tribe, British Columbia, and Malaysia. The diazinon noncancer risk model THQ = 1.0 uncertainty bounds of 21 to 220 mg/kg contains 54 (58.7%) of the RGVs.

Dicamba

The 87 dicamba RGVs are also illustrated in Figure 4. This is the fewest RGVs identified for any of the pesticides considered here. The values are dispersed over 4.9 orders of magnitude from a minimum of 0.25 mg/kg specified by Armenia, Belarus, Georgia, and Ukraine to a maximum of 20 000 mg/kg specified by ATSDR. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.895.

There are 3 value clusters. The USEPA THQ = 1.0 cluster contains 28 values (32.2% of N) at 1800 to 1850 mg/kg. The USEPA THQ = 0.1 cluster contains 15 (17.2% of N) values at 180 mg/kg. The USEPA III cluster containing 11 values (12.6% of N) at 2300 to 2400 mg/kg are specified by Indiana, Texas, Washington, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Mississippi, Florida, Illinois, West Virginia, Miami-Dade County, and the Bahamas. The dicamba noncancer risk model THQ = 1.0 uncertainty bounds of 910 to 9600 mg/kg contains 53 (60.9%) of the RGVs.

Diuron

The 100 diuron RGVs are also illustrated in Figure 5. The values are dispersed over 3.7 orders of magnitude (the smallest value span for the pesticides considered here) from a minimum of 0.216 mg/kg specified by Idaho and the Nez Perce Tribe to a maximum of 1170 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.938.

There are 4 clusters of values. The USEPA THQ = 1.0 cluster contains 28 values (28.0% of N) at 120 to 123 mg/kg. The USEPA THQ = 0.1 cluster contains 13 (13.0% of N) values at 12.0 mg/kg. The USEPA III cluster contains 14 values (14 % of N) at 130 to 170 mg/kg from Indiana, Texas, Washington, West Virginia, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Mississippi, Florida, Miami-Dade County, the Bahamas, Arizona, Iowa, and Texas. The USSR cluster contains 8 values at 0.5 mg/kg. The diuron noncancer risk model THQ = 1.0 uncertainty bounds of 60 to 640 mg/kg contains 60 (60.0%) of the RGVs.

Glyphosate

The 101 glyphosate RGVs are also illustrated in Figure 3. They are dispersed over 6.7 orders of magnitude from a minimum of 0.011mg/kg specified by the Commonwealth of the Northern Mariana Islands and Guam to a maximum of 58 700 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.902.

There are 4 RGV clusters. The USEPA THQ = 1.0 cluster contains 29 values (28.7% of N) at 6060 to 6200 mg/kg. The USEPS THQ = 0.1 cluster contains 14 values (13.9% of N) values at 610 to 620 mg/kg. The USEPA III cluster contains 9 values (8.9 % of N) at 7800 to 8800 mg/kg from Florida, Miami-Dade County, the Bahamas, Indiana, Washington, the Jamestown S'Klallam Tribe, the Confederated Tribes of the Colville Reservation, Mississippi, Illinois, and West Virginia. The USSR cluster contains 8 values (7.9% of N) at 0.5 mg/kg. The glyphosate noncancer risk model THQ = 1.0 uncertainty bounds of 3000 to 32 000 mg/kg contains 52 (51.5%) of the RGVs.

Malathion

The 96 Malathion RGVs are illustrated in Figure 6. These are dispersed over 4.2 orders of magnitude from a minimum of 0.82 mg/kg specified by Canadian Alberta and Manitoba to a maximum of 11 700 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal distribution with identical statistics is 0.921

There are 4 RGV clusters. The USEPA THQ = 1.0 cluster contains 29 values (30.2% of N) at 1200 to 1230 mg/kg. The USEPA THQ = 0.1 cluster contains 15 (15.6% of N) values at 4.2 mg/kg. The USEPA III cluster contains 11 values at 1500 to 1600 mg/kg from Illinois, Texas, Washington, West Virginia, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Spain's Junta of Andalusia, Mississippi, Florida, Miami-Dade County, and the Bahamas. The USSR cluster contains 8 values (8.3% of N) at 2.0 mg/kg. The Malathion noncancer risk model THQ = 1.0 uncertainty bounds of 600 to 6400 mg/kg contains 55 (57.3%) of the RGVs.

MCPA

The 119 MCPA RGVs are also illustrated in Figure 6, 42 (35.3%) of which come from non-US jurisdictions. This is the most of any of the pesticides considered here. The values are dispersed over 7.2 orders of magnitude from a minimum of 0.00005 mg/kg specified by Latvia, the Netherlands, Serbia, and Singapore to a maximum of 900 mg/kg specified by Australian jurisdictions. The correlation between the empirical distribution and a lognormal random variable with identical statistics is 0.962. This is the highest of the pesticides considered.

There are 5 RGV clusters. The Australia clusters contain 9 values (each 7.6% of N) at 900 and 600 mg/kg. The USEPA THQ = 1.0 cluster contains 29 values (24.4% of N) at 30 to 31 mg/kg. The USEPA THQ = 0.1 cluster contains 11 (9.2 % of N) values at 3.1 mg/kg. The USEPA III cluster contains 10 values (8.4% of N) at 35 to 43 mg/kg from Indiana, Texas, Washington, the Confederated Tribes of the Colville

Reservation, the Jamestown S'Klallam Tribe, Mississippi, Illinois, West Virginia, Florida, and the Bahamas. The MCPA noncancer risk model THQ = 1.0 uncertainty bounds of 15 to 160 mg/kg contains 52 (43.7%) of the RGVs.

Metolachlor

The 89 metolachlor RGVs are also illustrated in Figure 1. The values are dispersed over 6.6 orders of magnitude from a minimum of 0.02 mg/kg specified by Armenia, Belarus, Georgia, and Ukraine to a maximum of 88 000 mg/kg specified by the DOE, Delaware, and Maine. The correlation between the empirical distribution and a lognormal random variable with identical statistics is 0.873.

There are 3 RGV clusters. The USEPA THQ = 1.0 cluster contains 24 values (27.0% of N) at 9200 to 9300 mg/kg. The USEPA THQ = 0.1 cluster contains 13 values (14.6% of N) at 920 mg/kg. The USEPA III cluster contains 10 values (11.2% of N) from Florida, Illinois, Texas, Washington, West Virginia, Miami-Dade County, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, the Bahamas, and Mississippi. The metolachlor noncancer risk model THQ = 1.0 uncertainty bounds of 4500 to 48 000 mg/kg contains 49 (55.1%) of the RGVs.

Picloram

The 101 picloram RGVs are also illustrated in Figure 5. The values are dispersed over 6.3 orders of magnitude from a minimum of 0.022 mg/kg specified by Canadian Manitoba to a maximum of 43 000 mg/kg specified by Nevada. The correlation between the empirical distribution and a lognormal random variable with identical statistics is 0.875.

There are 5 RGV clusters. The Australia clusters contain 9 values at 6600 and 4500 mg/kg (each 8.9% of N). The USEPA THQ = 1.0 cluster contains 23 values (22.8% of N) at 4280 to 4310 mg/kg. The USEPA THQ = 0.1 cluster contains 14 values (13.9% of N) at 430 mg/kg. The USEPA III cluster contains 9 values at 4600 to 5,700 mg/kg specified by Texas, Washington, the Confederated Tribes of the Colville Reservation, the Jamestown S'Klallam Tribe, Illinois, West Virginia, Texas, and Arizona. The picloram noncancer risk model THQ = 1.0 uncertainty bounds of 2100 to 22 000 mg/kg contains 62 (61.4% of N) of the RGVs.

Summary and Conclusions

Pesticides are used worldwide in agricultural and residential applications. They are used in large quantities and spread over large surface areas. Their benefits derive from their ability to interrupt biological systems and they are often lethal to their target organisms. Therein lies their potential danger. When pesticides reach unintended organisms, such as children playing on treated lawns, they can deliver unacceptable health risks. The guidance values discussed here are intended to control these risks.

Results are presented for 12 of the most frequently used noncarcinogenic pesticides. The ranges of RGVs applied to these vary from 3.7 orders of magnitude for diuron to 9.3 orders of magnitude for carbaryl and averages 6 orders of magnitude. The RGV distributions are distinct from those reported for many other soil pollutants. Although most other RGV distributions resemble the distributions of lognormal random variables, the distributions presented here do not. All are dominated by clusters of values, and the largest clusters tend to be near the high end of the distribution. A total of 940 of the 1256 values (74.8%) are from US-related jurisdictions. Of these, 469 (55.3%) fall within uncertainty bounds of noncancer risk model calculations.

Overall, a total of 686 of the 1256 values (54.6%) fall within uncertainty bounds of noncancer risk model calculations. However, an additional 460 values (36.6%) fall below the lower uncertainty bound of the noncancer risk model. Only 110 values (8.8%) exceed the upper uncertainty bound of the noncancer risk model. These 110 values are dominated by 18 values for chlorpyrifos and 38 values for MCPA. If one accepts that surface soil exposure to these pesticides should be based on their noncancer health risk potential, then with the possible exception of chlorpyrifos and MCPA RGVs, it might be concluded that the current state of the art is sufficiently protective of the human health. This is, however, a conclusion that could change if any of the pesticides are determined to be carcinogenic.

Figure 7 illustrates the percentage of RGVs that exceed the median value for the 12 noncarcinogenic pesticides considered here and the 3 carcinogenic pesticides analyzed in the Part I manuscript. Previous RGV studies have suggested that, on average, US-related regulatory jurisdictions promulgate more conservative (lower) RGVs than other nations when cancer risk is the limiting consideration.[66,67]

The reverse has been noted for noncarcinogenic pollutants.[67] This does not appear to be true for the 15 pesticides in Figure 7. The percentage of US-related RGVs is greater than 50% and greater than this same statistic for RGVs from all other nations for 11 of the pesticides. For 7 noncarcinogenic pesticides, the percentage is much greater than that of other nations, indicating that, on average, the RGVs from other nations are more conservative. There is also no evidence of the US-related values being more conservative than values from elsewhere for the carcinogenic pesticides. On average, the US values appear to be less conservative. This may be why the United States continues to use these pesticides although they have been banned in many other nations.

It should probably be reiterated that the determination of which of these 15 pesticides are carcinogenic is debatable. The determination used here is based on the results of USEPA risk model calculations. It is probably true that some of these pesticides pose some cancer risk as well as noncarcinogenic toxicity. The classification used here is based on which of these considerations yields the lower RGV.

The RGV distributions for the pesticides considered here and in the Part I manuscript are encouraging, but puzzling.

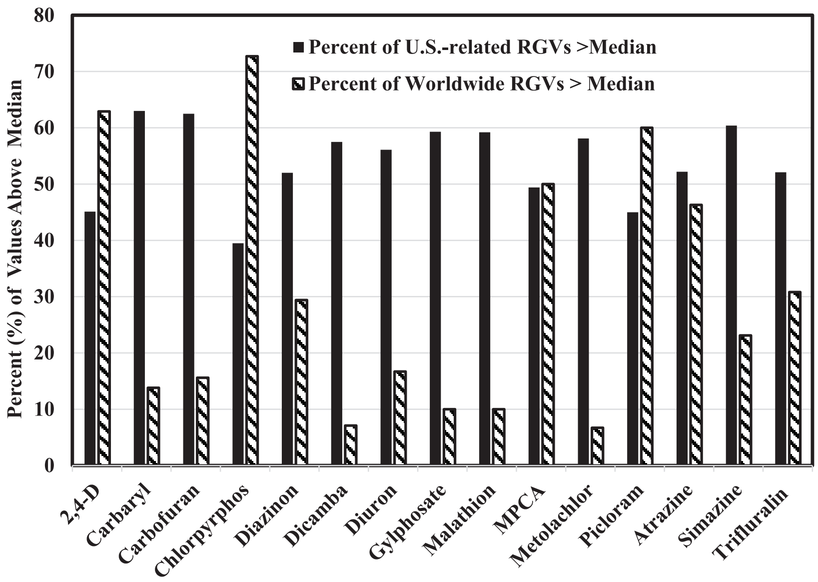

Figure 7. Percentage of regulatory guidance values above the median value for US jurisdictions and jurisdictions of all other nations for 12 noncarcinogenic and 3 carcinogenic current use pesticides. RGV indicates regulatory guidance value.

Jennings and Li[62,63] found 2915 RGVs for the 18 pesticides banned under the 2001 Stockholm convention (an average of 162 RGVs/Persistent Organic Pollutant). These were first-generation pesticides, such as DDT, commercialized shortly after World War II. Most were already banned in many nations by the time the Stockholm convention was adopted. In contrast, only 1691 RGVs were identified for the 15 currently used carcinogenic and noncarcinogenic pesticides considered here (113 RGVs/pesticide). There are more RGVs for pesticides no longer in use than there are for the pesticides most frequently used today. It is these currently used pesticides that are most likely to be responsible for future pesticide-related health impacts. Regulatory jurisdictions should be more aggressive about regulating them. The RGVs used must be reasonable (ie, not dispersed over several orders of magnitude), but without reasonable values, it is difficult to see how we are adequately protecting human health.

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Author Contributions

Conceived and designed the experiments: does not apply. Analysed the data: AAJ, ZL Wrote the first draft of the manuscript: AAJ. Contributed to the writing of the manuscript: ZL. Agree with manuscript results and conclusions: AAJ, ZL. Jointly developed the structure and arguments for the paper: AAJ, ZL. Made critical revisions and approved final version: AAJ. All authors reviewed and approved of the final manuscript.

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