RESOURCE REVIEW

Variation of United States environmental regulations on pesticide soil standard values

To specify the maximum allowable pesticide concentration in soil, pesticide residential soil regulatory guidance values (RGVs) have been promulgated by U.S. state regulatory jurisdictions to protect human health. A total of 12,451 RGVs for 456 identified pesticides adopted by 46 states were analyzed to evaluate whether there is the agreement among pesticide standard values regulated by the U.S.-related jurisdictions. Among them 62 pesticides with at least 50 RGVs were defined as the commonly regulated pesticides, and seven pesticides with at least 100 RGVs were defined as the most commonly regulated pesticides. A total of 12 states have provided over 500 pesticide soil RGVs and Texas alone has provided at least 1140 RGVs. Results indicate that these pesticide soil RGVs promulgated by the U.S. state jurisdictions for an individual pesticide could vary in a wide range of over six (DDT), seven (alpha-HCH), or even nine (Dieldrin) orders of magnitude. On the other hand, all of the seven most commonly regulated pesticides have a large RGV data cluster in which the state jurisdiction RGVs shared the U.S. Environmental Protection Agency (U.S. EPA) standards. To examine whether those pesticide soil RGVs could protect human health, cancer and non-cancer risk uncertainty bounds were calculated for the seven most commonly regulated pesticides. Results show that for the most commonly regulated pesticides, a total of 265 (41.8% of the total) soil RGVs exceeded the cancer risk uncertainty upper bounds and 30 (4.5% of the total) soil RGVs are above the non-cancer risk uncertainty bounds, which indicates that those RGVs cannot protect human health when exposing to the pesticides from soil.

By Zijian Li

INTRODUCTION

Pesticides have been widely used around the world to control pests in agriculture, home and garden, commercial, and industrial settings. The application of pesticides has great benefits to agriculture, forestry, and many other fields.[1] However, the pesticide residues retained in the environment can pose serious health risks to human beings. Pimentel and Levitan found that most pesticides applied in U.S. entered into the environment with little amount of pesticides remaining on crops.[2] Pesticides can enter the human body through different pathways, such as ingestion of contaminated food, water, and soil dust, inhalation of contaminated air, and dermal contact with contaminated objectives by pesticides.[3] Every year there is about one million chronic diseases and deaths caused by pesticides worldwide.[4]

Standard values of pesticides were promulgated by regulatory jurisdictions to control human health risk caused by pesticides, including pesticide drinking water maximum concentration levels, pesticide food maximum residue limits, and pesticide soil RGVs. Pesticide soil RGVs are usually derived to try to specify the maximum amount of a pesticide that may be present in soil without prompting the regulatory response (i.e. adverse health effect). Development of these standards, especially for pesticide soil RGVs, should consider all possible human exposure pathways to pesticides and human health risk calculation. The human exposure to the pesticide remained in soil includes inhalation of soil dust, ingestion of soil particle, and dermal contact. Many regulatory jurisdictions have provided pesticide soil RGVs around the world. Previous efforts have been made on the analysis of soil contamination standards in Europe, U. S., and Brazil.[5,6] The RGVs of original 2001 Stockholm Convention Persistent Organic Pollutants (POPs) pesticides vary by more than six orders of magnitude among international jurisdictions.[7] At least 14,862 pesticide soil RGVs, about 65% of the total RGVs worldwide, have been promulgated by U.S. jurisdictions, including national jurisdictions (880 RGVs), state regulations (12,451 RGVs), regional standards (252 RGVs), U.S. territory jurisdictions (256 RGVs), and autonomous Native American jurisdictions (1,163 RGVs).[8] Some of these worldwide RGVs might be too high to protect human health, and some of them are too low to achieve the remediation goal.[9,10] Many pesticide standard values from these states regulatory

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jurisdictions lack agreement. Since each state in U.S. has the authorization to develop the environmental regulatory standards and no study has investigated the variation and distribution of pesticide soil standards from U.S. state jurisdictions and compared soil RGVs among the state jurisdictions yet. The research presented here aims to analyze and compare the pesticide soil RGVs for states jurisdictions, and hopefully, the results will help regulators to optimize and formulate the uniform soil RGV throughout the U.S.

MATERIALS AND METHODS

Residential Soil RGVs from State Agencies

The materials used in this study are 12,451 soil RGVs for 456 identified pesticides regulated by state jurisdictions. States soil pesticide jurisdictions, RGVs numbers, and their sources are summarized in Appendix I. The pesticide soil RGV data analyzed in this study were provided in Appendix II. There are 46 states that have promulgated pesticide soil RGVs. North Dakota, South Dakota, South Carolina, and Utah do not have any pesticide soil RGVs. Some states such as Montana directly applied the U.S. Environmental Protection Agency (U.S. EPA) standards. Some states such as Arkansas developed its RGVs and applied the U.S. EPA standards as well. The RGVs were obtained by internet web search, and when internet addresses and online documents become unavailable and out of date, keywords from the jurisdictions titles would be used to address the new web location.

Cumulative Distribution Function (CDF) Analysis

The number of pesticide residential soil RGVs for the U.S. state jurisdictions is characterized by N. The statistical parameters including arithmetic mean (μ), median, geometric mean (μ_G), log10 mean (μ_L), and log10 standard deviation (σ_L) were applied to the RGVs for the most commonly regulated pesticides. The log-transformed analysis was conducted if the RGV data set presents a lognormal random variability. The empirical cumulative distribution applied in this research for the pesticide soil RGV data sets analysis is expressed as follows,

$$\text{Probability } P(RGVr \le RGVi) \approx \frac{Ni}{N}; \forall i = 1, N \quad (1)$$

Where RGV_i is the known value for a certain pesticide and RGV_r is a random variable for the same pesticide. N_i is the integer ordinal rank in the N known values ranked array of RGV_i.

Human Health Risk Models

Human health cancer and non-cancer risk models, used in previous studies,[9,10] were developed based on major human exposures to the toxic chemicals such as ingestion, dermal contact, and inhalation. Cancer and non-cancer risk uncertainty bounds were computed through Eqs. (3)–(10). Table 1 lists the parameters applied to pesticides in cancer and non-cancer risk models in this research. The current U.S. EPA values and the range of exposure coefficients in equations used by the U.S. states were defined in the following.[11,12]

The Reginal Screen Levels (RSLs) (mg/kg) derived by the cancer risk models of residential soil ingestion, dermal soil contact, and soil dust inhalation is calculated as follows.[12]

$$RSL_{cancer-ingestion} = \frac{TR \times AT \times LT}{CSF_0 \times IFS_{adj} \times EF_r \times 10^{-6} \times \frac{kg}{mg}} \quad (3)$$

TR – Target risk (1×10^{-6} unitless)
AT – Averaging time (365 days/year)
LT – Lifetime (70 yrs) [70,75]
CSF_o – Chronic oral slope factor (see Table 2) (kg-day/mg)
EF – Exposure frequency (350 days/year) [143,365]
IFS_{adj} – Resident soil ingestion rate (114 mg-year/kg-day) [87,127]

$$RSL_{cancer-dermal} = \frac{TR \times AT \times LT}{\left[\frac{CSF_0}{GIABS}\right] \times EF_r \times DFS_{adj} \times ABS_d \times 10^{-6} \times \frac{kg}{mg}} \quad (4)$$

GIABS – Fraction of contaminant absorbed in gastrointestinal tract (see Table 2) (unit less)
DFS_{adj} – Resident soil dermal contact factor (360.8 mg-year/kg-day), [253,1257]
ABS_d – Fraction of contaminant absorbed dermally from soil (see Table 1) (unit less)

$$RSL_{cancer-inhalation} = \frac{TR \times AT \times LT}{IUR \times EF_r \times ED \times ET \times \left[\frac{1}{VF_s} + \frac{1}{PEF_W}\right] \times \left(\frac{1000}{24}\right)} \quad (5)$$

IUR – Chronic inhalation unit risk (see Table 3) ($m^3/\mu g$)

Table 1. Risk-based Values for the Seven Most Commonly Regulated Pesticides in the U.S.[12]

Pesticide	ABSd	CSFo $(mg/kg\text{-}day)^{-1}$	GIABS	IUR $(ug/m^3)^{-1}$	RfDo (mg/kg-day)	RfC (mg/m^3)	VFs (m^3/kg)
DDD	1.00E-01	2.40E-01	1	6.90E-05	–[a]	–	–
DDT	3.00E-02	3.40E-01	1	9.70E-05	5.00E-04	–	–
Dieldrin	1.00E-01	1.60E+01	1	–	5.00E-05	–	–
Heptachlor	1.00E-01	4.50E+00	1	1.30E-03	5.00E-04	–	–
Heptachlor Epoxide	–	9.10E+00	1	2.60E-03	1.30E-05	–	8.40E-05
Lindane	4.00E-02	1.10E+00	1	3.10E-04	3.00E-04	–	–
Pentachlorophenol	1.00E+00	4.00E-01	1	5.10E-06	5.00E-03	–	–

ABS – absorption factor; CSF – cancer slope factor; GIABS – gastrointestinal absorption factor; IUR – inhalation unit risk; RfD – reference dose; RfC – reference concentration; VF – volatile factor.
[a] The notation – indicates that the U.S. EPA did not provide the toxicity information.

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