Reflecting the above limitations, many countries only use AF methods to derive SQGs and/or WQGs when SSD methods cannot be used. For example, the Australian and New Zealand (ANZECC & ARMCANZ 2000), OECD (1995), the Netherlands (Crommentuijn 2000), Canadian (CCME 2006), Danish (Bro-Rasmussen et al. 1994) and South African (Roux et al. 1996) guidelines all now use a statistical extrapolation method in preference to an AF method, which is only used when there is insufficient data.

3.2.4 Geometric mean methodology of the US EPA

The US EPA has developed ecological soil screening levels (Eco-SSLs) for sites where terrestrial organisms may be exposed directly or indirectly to contaminated soil, using the geometric mean method. The geometric mean[7] method uses all the toxicity values at the highest relative bioavailability score for which sufficient data existed (that is, ≥3 data points). Thus, the Eco-SSL is really the geometric mean of the sensitivities of all organisms for which there is toxicity data in the most bioavailable situation. By using the geometric mean approach, there is no consistent level of protection being provided (that is, different percentages of species will be protected). This is not a particularly conservative approach for the soil ecosystems where the contaminant is most bioavailable. However, the percentage of species that could experience toxic effects will be less and the degree of conservatism greater in the soils where the contaminant is less bioavailable.

Geometric means are also used in the manipulation of toxicity data prior to use within SSD methods. However, the manner in which the geometric means are implemented is quite different to that of the US EPA Eco-SSLs. The geometric mean approach is a combination of the worst-case scenario and risk-based approaches. It is a worst-case scenario as it derives Eco-SSLs for the soil in which the contaminant is most bioavailable. It is consistent with risk-based approaches as it does not attempt to protect all species.

3.2.4.1 Strengths and limitations

The strengths of the geometric mean method are that:

- it is simple to use
- it is easily understood
- limit values can be derived with as little as three toxicity values
- it is at least partially consistent with risk-based concepts.

The limitations of the method are that:

- the resulting limit does not reflect the uncertainty in the toxicity data used in deriving the limit, e.g. a limit based on three acute laboratory-based toxicity data is treated the same as 25 field-based chronic toxicity data—whereas the latter data set is considerably more environmentally relevant than the former

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[7] The geometric mean is analogous to the normal arithmetic mean except that the values are logged before summing and being divided by the number of data points. The value is then anti-logged to provide the geometric mean. The formula for this is

Geometric mean = anti-log [(logA + log B +…..logN)/n] *(equation 13)*

In determining the geometric mean the data can be logged to any base (e.g. $\log_{10}$, $\log_2$ or the natural log) as long as the same base is used throughout equation 13.

The reason for using the geometric mean rather than the arithmetic mean is that the geometric mean is not affected as much by extremely low or high values. For example, the geometric and arithmetic means of a data set consisting of 10, 25, 40 are 21.5 and 25 respectively. If a value of 400 was added to the same data set then the geometric and arithmetic means would be 45 and 119 respectively.

accumulate in organisms and to biomagnify. These are often expressed in the logarithmic form (that is, log K_{ow}). Chemicals with a log K_{ow} value ≥4 are considered in this guideline to have the potential to biomagnify. There is a linear relationship between log K_{ow} and log K_{oc} values. Thus, K_{ow} can also be used to indicate the ability of chemical to leach to groundwater. A log K_{ow} value <2 indicates a chemical has the potential to leach to groundwater.

Organic carbon–water partition coefficient (K_{oc}) means the ratio of a chemical's solubility in organic carbon and water at equilibrium. This is widely used as a surrogate for the ability of a contaminant to accumulate in soils and conversely to leach to groundwater or to be removed by surface run-off. These are often expressed in the logarithmic form (that is, log K_{oc}). Chemicals with a log K_{oc} <2.4 were considered, in this guideline, to be mobile and therefore have the ability in some soils to leach to groundwater.

Precautionary principle is the general principle by which all that can reasonably be expected is done to prevent unnecessary risks.

Reference site is a relatively uncontaminated site used for comparison with contaminated sites in environmental monitoring studies or used for the assessment of ambient background concentrations of contaminants.

Risk assessment is a process intended to calculate or estimate the risk to a given target organism, system or sub-population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characterisations of the agent of concern as well as the characterisation of the specific target.

Risk means the probability in a certain timeframe that an adverse outcome will occur in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a chemical substance; that is, it depends on both the level of toxicity of the chemical substance and the level of exposure to it.

Secondary poisoning is the product of biomagnification and toxicity.

Soil quality guideline (SQG) is a collective term used to describe any quantitative or qualitative limit that controls the concentration of contaminants in soils. Ecological investigation levels (EILs) are a type of SQG.

Soil-specific soil quality guidelines is a suite of concentration-based values, where each value applies to a soil with different physicochemical properties. These values take into account properties of soils that modify the bioavailability and toxicity of contaminants. These can only be derived if normalisation relationships are available. Compare these to generic SQGs.

Speciation is the exact chemical form of contaminant in which an element occurs in a sample.

Species sensitivity distribution (SSD) is a suite of methods that are the main method used to derive quality guidelines for contaminants in different compartments of the environment (for example, soil, water, sediment). Basically, these plot toxicity data (one value per species) as a cumulative frequency distribution against the concentration at which the toxic effect occurs. A statistical distribution is then fitted to the plot from which it can be estimated what concentration is required to protect any chosen percentage of species. In Australia, the SSD method used to derive guidelines uses the Burr type III family of distributions and is called the BurrliOZ method.

Statistically significant effects are effects (responses) in the exposed population which are different from those in the controls at a statistical probability level of p <0.05.

Steady state is the non-equilibrium state of a system in which matter flows in and out at equal rates so that all of the components remain at constant concentrations (dynamic equilibrium).

Water to soil partition coefficient (K_d) is the ratio of the concentration of a contaminant in soil pore water to that in the solid phase of soil at equilibrium. The units are L/kg. This contaminant property is affected by physicochemical properties of the contaminant and the soil. This property is usually expressed as a logarithm (that is, log K_d). In this guideline, chemicals with log K_d <3 are considered to have the potential to leach.

7 Shortened forms

ABC	ambient background concentration
ACL	added contaminant limit
ACR	acute-to-chronic ratio
AF	assessment factor
ALF	ageing/leaching factor
ANZECC	Australia and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BAF	bioaccumulation factor
BCF	bioconcentration factor
BMF	biomagnification factor
CCME	Canadian Council of Ministers of the Environment
CEC	cation exchange capacity
DAF	dilution and attenuation factor
DOC	dissolved organic carbon
DTA	direct toxicity assessment
Eco-SSL	ecological soil screening level
ECB	European Chemicals Bureau
EC_{30}	30% effect concentration
EGV	environmental guideline value
EIL	ecological investigation level
ERA	ecological risk assessment
EqP	equilibrium partitioning method
EQG	environmental quality guideline
EU	European Union
HC	hazardous concentration
HIL	health investigation level
LOEC	lowest observed effect concentration

MATC	maximum acceptable toxicant concentration
NBRP	National Biosolids Research Program
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOEC	no observed effect concentration
OECD	Organisation for Economic Cooperation and Development
OM	organic matter
PC	protective concentration
PLS	partial least squares
PNEC	predicted no-effect concentration
QAAR	quantitative activity–activity relationship
QSAR	quantitative structure–activity relationship
QSPR	quantitative structure–property relationship
SGV	soil guideline value
SIN	substrate-induced nitrification
SQG	soil quality guideline
SQV	soil quality value
SSD	species sensitivity distribution
US EPA	United States Environmental Protection Agency
TGD	technical guidance document
TRV	toxicity reference value
TV	trigger value
USA	United States of America
VROM	Ministry of Housing, Spatial Planning, and the Environment (Netherlands)
WHC	water holding capacity
WQG	water quality guideline