Research article

Environmental Effects from Contamination of Agricultural Soils via Spraying and Dust Application to Crops and Animals

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Abstract Salinity from spraying may be important with crop cultivation and pasture for grazing. Soil guidelines can indicate salinity build up in soil. Effects on cultivated crops and soil cumulative contaminant loading limit trigger values are generally available for salinity, heavy metals and pesticides (kg/ha) for long-term application of irrigation water to soil. In addition, metal levels in meat from livestock and fowl species can be compared against food standard guidelines. The air quality guidelines of the World Health Organization (WHO), European Commission (EC) and United States Environmental Protection Agency (USEPA) are based on studies of health effects undertaken globally. However, little detail exists on effects of air particulates on terrestrial animals. Animals breathe air and may ingest deposited particles on soil surface or via ingestion of grass or other plants. Soil contamination guidelines are well developed for the ecological health case but may require extensive assessment for soil and the native/wild species that are not characterized. The German metal deposition guidelines (TA Luft) are useful in this case. In contrast to native/wild species, domestic animal effects from soil contamination and particularly pasture grazing by cattle, sheep, pigs and fowl are well understood. Such guidelines provide a basis for developing site specific criteria for spray deposition to farm land. Particle dispersion and deposition for prediction of environmental effects from spraying using risk assessment can be developed. Guidelines for air particulates and fall out may be relevant to assess if spraying is significant to humans or animals but limitations of guidelines for contaminants can occur. Risk-based assessment for environmental management of spray dispersion and deposition of agricultural wastewater can be undertaken as such contaminants may be significant if they are dispersed at sufficiently high concentrations.

Keywords crops, animals, spraying, contaminants, risks, management

INTRODUCTION

Particulate matter (PM) is defined by diameter (µm) or size based on its physical property (NEPC, 2016). PM_{10} (diameter 10 µm) and $PM_{2.5}$ (diameter 2.5 µm) can be mixtures of solid particles and liquid droplets in air (NEPC, 2016). Particle sizes <10 µm and 2.5 µm can penetrate deep into the human lung and transfer to the bloodstream. $PM_{2.5}$ approximate the fine mode particles giving alveolar deposition, while PM_{10} is the thoracic aerosol component (Raunemaa, 2002). Particles from mechanical means have larger-sized particles (> $PM_{2.5}$) compared with particulate matter generated during combustion (high temperature) processes having a higher percentage of fine particles < $PM_{2.5}$ to ultrafine particles. Particles generated from spraying activities can also be fine to ultrafine. Particles that fall out of suspension under gravity are collected using a dust deposition gauge and described as 'deposited matter'. People exposed to particulate contaminants in food, air and water receive background exposure primarily from food and water. The potential pathways for exposure of humans to contaminants are dermal, inhalation and ingestion (eNHealth, 2012). Only <PM_{250} (diameter 250 µm) fall out material can be ingested by humans or animals (Ng et al., 2015) as deposited larger particles on ground do not readily adhere to hands. Particle size dependence and oral exposure have specific associations (eNHealth, 2012).

Fall out guidelines in Australian are limited to nuisance soiling of property (Noller, 2018). The German air pollution control regulation and guidelines (TA LUFT, 1990 and Annex 2, 1999) provide metal and arsenic deposition guidelines for assessing deposition or spraying (Table 1). Higher deposition rates require additional evaluation using Annex 2 (TA LUFT 1999).

Table 1 Arsenic and metal deposition guidelines for fall out

Arsenic or metal	Standard ($\mu g/m^2$.day)	Averaging period
Arsenic	4	1-year
Cadmium	2	1-year
Lead		1-year
Protection of human health	100 (1990)	
Protection of crop land integrity	185 (1999)	
Protection of grassland integrity	1900 (1999)	
Nickel	15	1-year

Source: TA LUFT (1990, Annex 2 1999).

The Australian National Environmental Protection Measure (NEPM) soil contamination guidelines are well-developed, risk-based Health and Ecological criteria for respective receptors, and an alternative to fall out monitoring (Tables 2 and 3). Deposition to soil is assessed by measuring specified constituents in soil to a surface depth (e.g. 1 cm) per unit area and comparing concentrations against the NEPM soil contamination guidelines (NEPC, 2013). Soil cumulative contaminant loading limit (CCL) trigger values for metals and arsenic (kg/ha) (NWQMS, 2000) are applicable for long-term application of irrigation water to soil (Table 4). Excessive salinity from spraying or dust deposition may affect crop cultivation and pasture for grazing (Table 5). Comparison with soil guidelines can indicate salinity build up in soil and if soil cumulative contaminant loading limit trigger values for salinity and heavy metals (kg/ha) are occurring for long-term application of irrigation water to soil.

Table 2 Soil Health Investigation Levels for various land use

Arsenic or metal	Health Investigation Levels (HIL) for soil (mg/kg)			
	HIL Level A Urban residential with garden	HIL Level B Urban residential without garden	HIL Level C Public open space	HIL Level D Commercial and industrial
Arsenic	100	500	300	3,000-
Cadmium	20	150	90	900
Copper	6,000	30,000	17,000	240,000
Lead	300	1,200	600	1,500
Nickel	400	1,200	1,200	6,000
Zinc	7,400	60,000	30,000	400,000

Source: NEPC (2013) Australian soil contamination guidelines for health risk assessments.

Table 3 Soil Ecological Investigation Levels in soil for various land uses

Arsenic or metal and age of contamination (fresh/aged)	Ecological Investigation Levels (EIL) for soil (mg/kg) and various land uses		
	Area of ecological significance	Urban residential/ public open space	Commercial and industrial
Arsenic	20/40	50-100	80/160
Copper	15-60/20-80	30-120/60-230	45-200/85-340
Lead	110/470	270/1100	440/1800
Nickel	1-25/5-95	10-170/30-560	20-350/55-800
Zinc	7-130/15-280	25-500/70-1300	15.64

Source: NEPC (2013) Australian soil contamination guidelines for ecological risk assessments.

Table 4 Soil cumulative contaminant loading limits (CCL) and preferred level in soil

Element	Soil cumulative contaminant loading limit (CCL) (kg/ha) (NWQMS, 2000)	Preferred level in soil (mg/kg) (NSW Soil, 2011)
Arsenic	20	<20
Cadmium	2	<1
Copper	140	2-50
Lead	260	<35
Nickel	85	1-20
Zinc	300	1-200

Source: Soil cumulative contaminant loading limit (CCL) (NWQMS, 2000) and preferred level in soil (NSW Soil, 2011)

Table 5 Soil guidelines associated with salinity

Test	Agriculture Victoria (2017)	Rural Solutions SA (2016)	NSW Soil (2011)
Available sulfur (KCl 40 test)	>8 mg/kg	>10 mg/kg	
Total sulfur			10-20 mg/kg
Exchangeable Calcium	>5 meq/100g		>5 meq/100g
	65-80% Total Cation	65-75% Total Cation	
Exchangeable Magnesium	>1.6 meq/100g		>1.6 meq/100g
	10-20% Total Cation	10-15% Total Cation	
Exchangeable Potassium	>0.5 meq/100g		>0.5 meq/100g
	<1% Total Cation	3-8% Total Cation	>0.5% Total Cation
Exchangeable Sodium	<0.1 meq/100g		>1.0 meq/100g
	<1% Total Cation	<6% Total Cation	<0-1% Total Cation
Soil salinity (dS/m)	<0.2% dS/m	Many plants affected 4-8 dS/m	Plants tolerant <8.6 dS/m
		Tolerant plants affected 8-16 dS/m	Tolerant plants affected 8-16 dS/m

Source: Agriculture Victoria (2017), Rural Solutions SA (2016) and NSW Soil (2011) Soil guidelines for sulfur, calcium, magnesium, potassium, sodium and salinity

Contributions to human diet are assessed by comparing contaminant levels with food guidelines (FSANZ, 2009). Metal and arsenic levels in meat from livestock and fowl species can be compared against food standard guidelines. Wild (game) animals for consumption as food can also be compared similarly. However, wild species that are part of the ecosystem generally have no guidelines for estimating exposure to specific contaminants. Although particulate matter effect is not normally assessed for domesticated terrestrial animals, wild animals also breathe air and may ingest deposited particles on soil surface or via grazing of grass or other plants (Arslan and Aybek, 2012; Serita, 1999). Wild animals may also be exposed when air particulates drift over natural open land or forest (Isaksson, 2010). In contrast, domestic animal effects from soil contamination and particularly pasture grazing by cattle, sheep, pigs and fowl are well understood.

OBJECTIVE

The Objective is to use a risk-based approach to examine contamination of agricultural activities in selected studies from air particulates and fall out produced from spray-base activities with irrigation waters or other dust-generating agricultural activities, to provide a means to assess the significance of effects to humans via uptake in crops, domesticated animals, and potentially for wild animals.

METHODOLOGY

Details from published papers, reports and other sources were summarized. Selected data for salinity, arsenic and heavy metals was used as case studies from Australian locations. Monitoring data for air particulates and fall out for ambient air quality in Australia (NEPC 2016) is described (Noller, 2018). Deposition of metals and arsenic to soil is assessed by collecting fall out and by measuring specified constituents in soil for comparison against guidelines (Table 1). Soil requires sufficient characterization of the site (Standards Australia, 2005); selection of appropriate guidelines ensures that meaningful and appropriate comparison is made (Tables 1-4). Salinity from spraying may also be important with crop cultivation and well as pasture (Table 5) and give rise to a buildup in soil affecting cultivated crops. The tolerances of pasture and other plant species to various forms of salinity can be low but salinity build-up is likely when existing soil levels are high (Table 5). Data for various livestock body weight, peak water intake and peak food intake is summarised (ANZECC/ARMCANZ, 2000 p 9.3-16). Peak food intake assumes importance with cattle and sheep from grazing and involuntary ingestion because (Thornton and Abrahams, 1983): (i) cattle ingest up to 20% as soil (2 kg); and (ii) sheep ingest up to 30% as soil (0.7 kg). Spraying deposition over open farmlands used for grazing may be significant if contamination occurs.

RESULTS AND DISCUSSION

Data from case studies is examined to demonstrate how deposition to soil by fall out or via irrigation can be assessed using guidelines given in Tables 1-5. Background concentrations of metals and arsenic in the soil from natural mineralisation of the Line of Load at Broken Hill, NSW, Australia (AARC, 2011) are given together with fall out data for the deposition of lead in Broken Hill city, nearby the Rasp Mine (Rasp Mine, 2010). Comparison of soil concentrations in Table 6 with the Soil Health Investigation Levels (Table 2) shows that HIL Level A (urban residential) is exceeded for arsenic, cadmium, lead and zinc, and HIL Level C (public open space) is exceeded for lead and zinc. Comparison with the Soil Ecological Investigation Levels for various land uses (Table 3) shows that all categories of land use are exceeded for arsenic and all metals. Comparison of lead in fall out at Broken Hill for both high and low deposition exceed the guideline for protection of crop land but not grassland (Table 1). Thus the extent of contamination is indicated.

Table 6 Background concentrations of metals and arsenic in the soil with natural mineralisation of the Line of Load at Broken Hill, NSW, Australia and deposition of lead

Element	Concentration (mg/kg) Mean ± sd (n) (AARC, 2011)	Fall out ($\mu g/m^2$.day) (Rasp Mine, 2010)
Arsenic	290±51 (9)	
Cadmium	89±45 (6)	
Copper	585±254 (6)	
Lead	8317±10161 (65)	High deposition 822 Low deposition 274
Zinc	45,510±76943 (20)	

Source: AARC (2011) background concentrations of metals and arsenic in Line of Lode at Broken Hill and data for fall out in Broken Hill (Rasp Mine, 2010)

Potential build-up of salinity from a mining operation within a cattle station in Northern Australia is given in Tables 7 - 8 (Noller, 2017). Total and water soluble sulfate, salinity based on EC are all very low (Table 7). Similarly water soluble calcium, magnesium, potassium and sodium are also very low (Table 8). The location is in the wet-dry tropics receiving high rainfall during the annual monsoonal wet season in excess of 1500 mm. Comparison with guidelines (Table 5) shows the soil is highly leached by rainfall and shows no buildup of salinity. In fact the soil is deficient in sulfur for pasture growth for cattle feed and requires addition of supplement.

Table 7 Total and water soluble sulfate and electrical conductivity (EC) of water extract of soil from cattle station

Test	Total Sulfur (mg/kg)	Soluble Sulfur (mg/kg)	Electrical conductivity (1:5) (dS/m)
Within Mine Lease 1			
Surface (0-10 cm)	<100	<10	0.025
Depth (100 cm)	<100	<10	0.0085
Within Mine Lease 2			
Surface (0-10 cm)	130	<10	0.0164
Depth (100 cm)	<100	10	0.0089
Property Lot 1			
Surface (0-10 cm)	300	<10	0.0353
Depth (100 cm)	<100	<10	0.007
Property Lot 2			
Surface (0-10 cm)	100	<10	0.0324
Depth (100 cm)	<100	<10	0.0573

Source: ANZECC/ARMCANZ, 2000 (p 9.3-16 and explanation) Electrical conductivity measured in a 1:5 water extract

Table 8 Water soluble calcium, magnesium, potassium and sodium in soil from cattle station

Test	Calcium (meq/100g)	Magnesium (meq/100g)	Potassium (meq/100g)	Sodium (meq/100g)
Within Mine Lease 1				
Surface (0-10 cm)	<0.05	<0.082	0.033	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Within Mine Lease 2				
Surface (0-10 cm)	<0.05	<0.082	<0.026	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Property Lot 1				
Surface (0-10 cm)	0.10	<0.082	0.052	<0.043
Depth (100 cm)	<0.05	<0.082	<0.026	<0.043
Property Lot 2				
Surface (0-10 cm)	0.0850	<0.082	<0.026	<0.043
Depth (100 cm)	0.15	<0.082	<0.026	<0.043

Source: ANZECC/ARMCANZ, 2000 (p 9.3-16 and explanation) meq/100g = milli-equivalents per 100 grams soil. Electrical conductivity measured in a 1:5 water extract.

CONCLUSION

The use a risk-based approach to examine contamination of agricultural activities from air particulates and fall out in two dust-generating studies is able to provide a means to assess the significance of effects to humans via uptake in crops and domesticated animals. For terrestrial species, NEPM soil contamination guidelines for ecological effects are able to provide a comprehensive assessment procedure to follow. In contrast to native/wild species, domestic animal effects from soil contamination and particularly pasture grazing by cattle and sheep are well understood. Thus application of such guidelines provides a basis for developing site specific criteria for fall out from dust and spray deposition to farm land.

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