CHARACTERIZING RISKS TO LIVESTOCK FROM PETROLEUM HYDROCARBON EXPOSURES

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Abstract

Livestock may be exposed to accidental releases of petroleum hydrocarbons at or near exploration and production sites. In these cases, there may be a need to estimate potential risks to these receptors. A framework was developed to: 1) determine when livestock should be included in a risk evaluation; and 2) estimate risks of petroleum hydrocarbon exposure to livestock. A conceptual site model (CSM) was developed to assess whether complete and significant exposure pathways exist at a site. To estimate potential risks, toxicity reference values (TRVs) and drinking water and soil risk-based screening levels (RBSLs) for petroleum hydrocarbons (including: crude oil; benzene, toluene, ethylbenzene, and xylene [BTEX]; and polycyclic aromatic hydrocarbons [PAHs]) were developed for a variety of livestock receptors. The TRVs and RBSLs developed for this framework were comparable to human health RBSLs and other published livestock guidelines.

Introduction

Consumption of petroleum hydrocarbons by livestock has been found to potentially lead to a range of health problems, including: neurotoxicity (5); fetal toxicity (5); and damage to the gastrointestinal tract (5); respiratory system, kidney, and liver (5, 6). Petroleum ingestion has also been linked to anorexia (8), lethargy (7, 18), and fatal poisoning in cattle (18).

The purpose of this study was to:

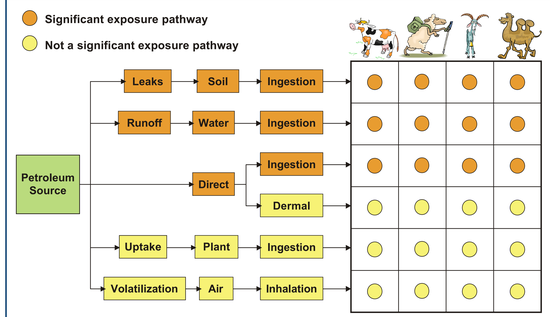
- Determine when livestock should be included in a risk evaluation; and
- Estimate risks of petroleum hydrocarbon exposures to livestock.

The approach used to characterize risks to livestock from petroleum hydrocarbon exposures was divided into two steps:

Step 1: Develop a CSM.

Step 2: Develop TRVs and RBSLs for the protection of livestock.

Conceptual Site Model (CSM)



Exposure: Receptor and Pathway Evaluation

Table 1. Exposure Assumptions for Livestock

Parameter	Dairy Cattle	Beef Cattle	Calves	Sheep	Goats	Camels
Body Weight (kg)	540(20)	454(15)	50(19)	56.7(15)	29.5(15)	600(11)
Soil in diet (%)	17.9(24)	18.8(14)	18.8(14)	30(24)	30[a]	30[a]
Forage in diet (%)	82.1[b]	81.2[b]	81.2[b]	70[b]	70[b]	70[b]
Food IR dw (kg/day)	13.5(15)	11.4(15)	1.25(15)	1.98(15)	1.18(15)	6.07(11)
Soil IR dw (kg/day)	2.42[c]	2.13[c]	0.235[c]	0.595[c]	0.354[c]	1.82[c]
Water IR (L/day)	95(1)	86(1)	36(1)	14(1)	10(13)	16.5(11)

(xx) References cited in parentheses
a = based on similar feeding habits as sheep.
b = calculated; assuming main food in diet.
c = calculated based on Food IR and % soil in diet.

Exposures are generally measured by estimating the intake rates in kilograms per day (kg/day) or liters per day (L/day) that livestock might ingest and converting this to a dose expressed in milligrams per kilogram body weight per day (mg/kg bw/day):

Equation 1 **Dose = {[(IRsoil* Csoil) + (IRwater*Cwater)]*SUF} ÷ BW**

Toxicity Values and Risk-Based Screening Levels

TRVs were developed for livestock based on the NOAEL endpoints in the toxicity studies (Table 2) for crude oil, BTEX, and PAHs. A scaling factor (SF) was used to allometrically adjust for differences in body weights between test species and livestock receptor (21). Drinking water and soil RBSLs were developed for the protection of livestock based on the TRVs and associated with a target hazard quotient of 1 (and assuming Site Use Factor =1):

Equation 2 **RBSL = (1* BW*TRV) ÷ IR**

Table 2. Toxicity Studies Used in the Development of TRVs and RBSLs for Livestock

Test Species	Chemical	Final Dose (mg/kg bw/day)	Exposure Duration	Effect	Endpoint	Study
Cow	Whole fresh crude oil	211	127 days	Liver, GI, hematological, and neurological effects	NOAEL	(23)
Rat	Benzene	357	84 weeks	Hematological effects and decreased body weight	LOAEL	Maltoni et al., 1983[a]
Rat	Benzene	35.7	NA	NA	NOAEL	[b]
Rat	Toluene	223	13 weeks	Hepatic/renal effects	NOAEL	NTP, 1989[a]
Rat	Ethylbenzene	291	182 days	Hepatic/renal effects	LOAEL	Wolf et al., 1956[a]
Rat	Ethylbenzene	29.1	NA	NA	NOAEL	[b]
Rat	Xylene	179	103 weeks	Growth and development effects	NOAEL	NTP, 1986[a]
Rat	Naphthalene	50	Days 6-15 of gestation	Maternal lethargy and slow breathing	LOAEL	(21)
Rat	Naphthalene	5	NA	NA	NOAEL	[b]
Mouse	Benzo(a)pyrene	10	Days 7-16 of gestation	Decreased pregnancy rates and reduced viable liter	LOAEL	(16)
Mouse	Benzo(a)pyrene	1	NA	NA	NOAEL	[b]

a = as cited in EPA/IRIS (10).
b = extrapolated from LOAEL using UF of 10 (9).

Table 3. Crude Oil TRVs and RBSLs for Livestock

Livestock	TRV (mg/kg bw/day)	Drinking Water RBSL (mg/L)	Soil RBSL (mg/kg)
Dairy Cattle	211	1,199	47,151
Beef Cattle	211	1,114	44,894
Calves	211	293	44,894
Sheep	211	855	20,095
Goats	211	622	17,583
Camels	211	7,673	69,522

XX minimum value XX maximum value

Table 4. BTEX TRVs* for Livestock (mg/kg bw/day)

Livestock	Benzene	Toluene	Ethylbenzene	Xylene
Dairy Cattle	5.70	35.6	4.65	28.5
Beef Cattle	5.95	37.1	4.86	29.8
Calves	10.3	64.5	8.43	51.7
Sheep	10.0	62.5	8.17	50.1
Goats	11.8	73.6	9.62	58.9
Camels	5.55	34.6	4.53	27.8

*SF was used to adjust for difference in body weights.
XX minimum value XX maximum value

Table 5. BTEX Drinking Water RBSLs for Livestock (mg/L)

Livestock	Benzene	Toluene	Ethylbenzene	Xylene
Dairy Cattle	32.4	202	26.4	162
Beef Cattle	31.3	196	25.6	157
Calves	14.3	89.5	11.7	71.7
Sheep	40.5	253	33.1	203
Goats	34.8	217	28.4	174
Camels	202	1,259	165	1,009

XX minimum value XX maximum value

Table 6. BTEX Soil RBSLs for Livestock (mg/kg)

Livestock	Benzene	Toluene	Ethylbenzene	Xylene
Dairy Cattle	1,273	7,946	1,039	6,367
Beef Cattle	1,266	7,901	1,033	6,331
Calves	2,198	13,715	1,794	10,990
Sheep	953	5,949	778	4,767
Goats	982	6,129	802	4,911
Camels	1,829	11,412	1,492	9,144

XX minimum value XX maximum value

Table 7. PAH TRVs* and RBSLs for Livestock

Livestock	TRV (mg/kg bw/day)		Drinking Water RBSL (mg/L)		Soil RBSL (mg/kg)	
	LMW PAH	HMW PAH	LMW PAH	HMW PAH	LMW PAH	HMW PAH
Dairy Cattle	0.798	0.160	4.53	0.907	178	35.7
Beef Cattle	0.833	0.167	4.40	0.880	177	35.5
Calves	1.45	0.289	2.01	0.402	308	61.5
Sheep	1.40	0.280	5.68	1.14	133	26.7
Goats	1.65	0.330	4.87	0.974	138	27.5
Camels	0.777	0.155	28.3	5.65	106	51.2

*SF was used to adjust for difference in body weights. XX minimum value XX maximum value

Other Available Guidelines

The following two agencies have developed toxicity values and screening levels for wildlife for the protection of livestock exposed to petroleum compounds: Canada-Wide Standards (CWS; [4]) and Alberta Environment (2001; [2,3]). However, the approaches used by these agencies have their limitations. The approach presented herein addresses many of those limitations and presents a more consistent risk-based approach.

Conclusions

If no significant and complete exposure pathways exist for petroleum hydrocarbons, there is little to no likelihood of unacceptable risk to livestock from these compounds. The toxicity values and screening levels for crude oil developed in this paper for soil ingestion in livestock are comparable to the recommended human health RBSLs for sites impacted with crude oils. Suggested RBSLs for human residential and non-residential scenarios are the 95th percentile values (for all exposure pathways) of 2,800 mg/kg and 41,300 mg/kg, respectively (17). Similarly, a comparable total petroleum hydrocarbon (TPH) screening level of 10,000 parts per million (ppm) was previously recommended for groundwater and plants (12).

To characterize risks to livestock from petroleum hydrocarbon exposures at a site, drinking water and soil RBSLs developed in this study can be used as screening values for soil, surface water, and groundwater for the protection of livestock. If the effective size of the contamination is available, site-specific RBSLs can also be developed using SUFs in order to estimate potential risks to livestock from exposure to that particular site. If required, a quantitative risk evaluation could be conducted using the TRVs and exposure factors presented in this study.

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