

000302

COMISION NACIONAL DEL MEDIO AMBIENTE
 OFICINA DE PARTES Y ARCHIVO
 FAX:
 Nº INGRESO: 1185
 FECHA: 11 MAY 1999
 DESPACHADO:
 OBS.:

REPUBLICA DE CHILE
 MINISTERIO DE SALUD
 DIVISION DE SALUD AMBIENTAL

A WJTOZ

CUBIERTA DE FAX / COVER PAGE

FECHA / DATE	11 de Mayo 1999
DE / FROM	Dra. Silvia Figueroa
FONO / PHONE	6641119
FAX / FAX	6644288
A / TO	Sra. Andrea Contreras
INSTITUCION / INSTITUTION	COMUNA - Depto de Planes y Obras
FONO / PHONE	
FAX / FAX	2441262
Nº PAG / Nº PAGES	
MENSAJE / MESSAGE	Doc. Exposición Ocupacional según el proceso industrial.

EXPOSICION OCUPACIONAL

Según los procesos industriales:

- Extracción, Fundición, Refinación, Elaboración de artículos que lo contienen.

Según la actividad:

- Minería y fundición
- Industria: materia prima y subproductos. Alfarrería(vidriado), Baterías, elementos de protección contra radiaciones, tuberías de plomo, imprentas, califont, municiones, cañerías.
- Mayor riesgo con PLOMO a altas temperaturas, humos y vapores

EXPOSICION GENERAL

Fundamentalmente de origen antropogénico.

- Actividades industriales, mineras y combustión de motores de gasolina que contienen aditivos de plomo.
- A través de todos los componentes ambientales: aire, agua, suelo y de diversas fuentes.

Formas de exposición:

a) Por vecindad a fuentes

- Areas vecinas a las fuentes mineras o industriales debido a sus emisiones.
- El radio de riesgo depende de factores climáticos que puedan influir en la dispersión.

b) Por contacto con trabajadores expuestos

Transporte en la ropa de trabajo, viviendas vecinas al sitio de trabajo, alfareros.

c) Por inhalación de aire contaminado
En poblaciones urbanas: aditivo de plomo en la gasolina.
Vías congestionadas, intersecciones viales.

000304

d) Por ingestión de alimentos contaminados
El contenido de plomo depende de: tipo de alimento, tecnología de enlatado,
tipo de recipiente usado y la contaminación ambiental.

e) Por ingestión de agua potable contaminada
Dependiendo de la contaminación ambiental, instalaciones de distribución y
cañerías plomadas (agua blanda y ácida).

f) Ingestión de polvo o restos de pintura a base de plomo.

g) Por ambiente de carácter ocupacional familiar
Talleres de recuperación y reciclaje de Plomo.

Vías de exposición más importante

- Ocupacional : Inhalatoria
- General : Digestiva

POBLACIONES DE ALTO RIESGO

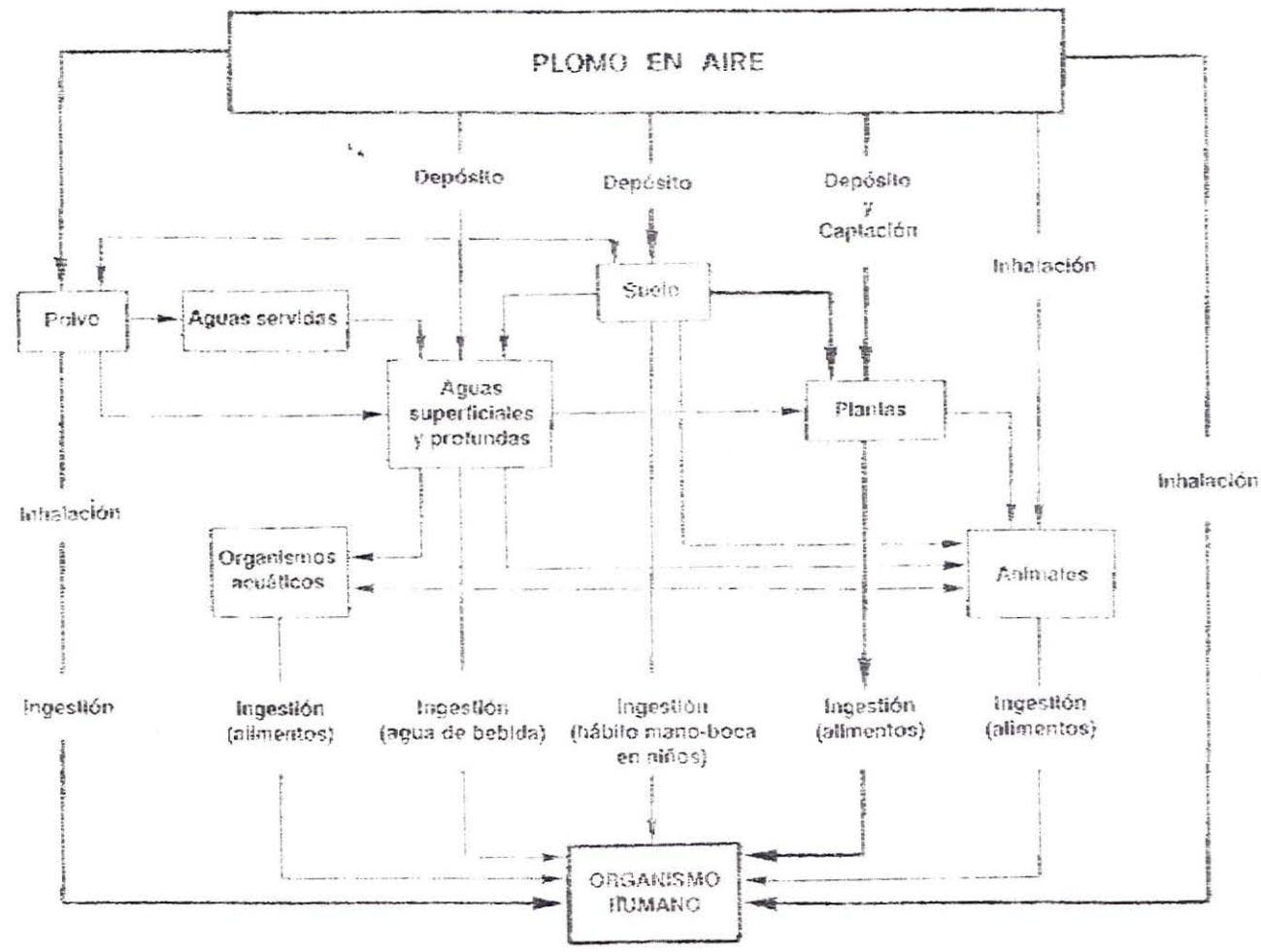
Grupo que por sus características tiene una mayor probabilidad de desarrollar una enfermedad o alguna condición anormal.

a) Mayor exposición: ocupacional (familia de los trabajadores); cercanía a fuentes mineras, industriales, parque vehicular.

b) Mayor vulnerabilidad: Hábitos, f. constitucionales, enfermedades subyacentes.

- Embarazadas, niños.
- Enfermedades a la sangre (anemia), neurológicas, deficiencias nutricionales.
- Alcohólicos, fumadores.

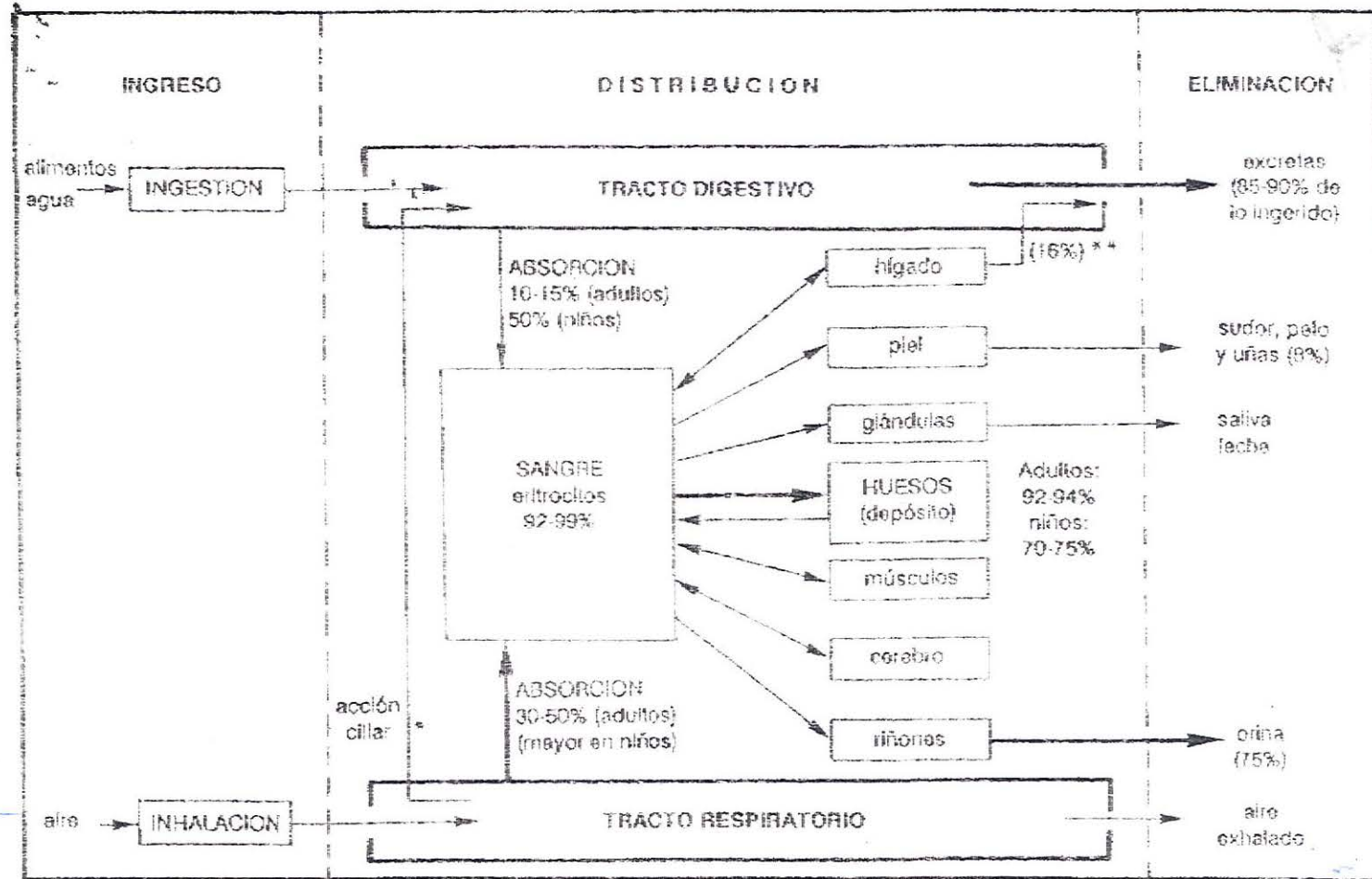
IMPORTANCIA DEL PLOMO ATMOSFERICO EN LA CONTAMINACION GLOBAL DEL AMBIENTE Y EN EL APORTE DE PLOMO AL ORGANISMO HUMANO.



FUENTE : Adaptado de Publicación Científica No. 366 de OPS, Criterios de Salud Ambiental 3, Plomo, 1979.

000305

VÍAS DE ABSORCIÓN, DISTRIBUCIÓN Y ELIMINACIÓN DEL PLOMO EN EL ORGANISMO HUMANO



* Puede deglutirse hasta un 40% del plomo inhalado como partículas de diámetro mayor.
 ** Implica secreciones gastrointestinales, que incluyen la bilis.

000306

EFFECTOS DEL PLOMO SOBRE LA SALUD

- ▶ El **PLOMO** es inhibidor de numerosas enzimas: efecto Sistémico.
- ▶ Cuadro clínico de difícil diagnóstico: síntomas y signos inespecíficos y manifestaciones de instalación lenta; asociado al antecedente de exposición.
- ▶ Población ocupacional: intoxicación aguda y crónica.
- ▶ Población general: más frecuente intoxicación crónica.
- ▶ Efecto depende: Vía de ingreso, dosis absorbida, susceptibilidad individual, tipo de exposición.

INTOXICACION CRONICA: "SATURNISMO"

Es la manifestación más frecuente y de mayor impacto Epidemiológico.

I. EFECTOS GENERALES

Decaimiento, fatiga, dolores articulares, tos, impotencia sexual, palidez y temblor.

II. SISTEMA HEMATOPOYETICO

1. Altera la síntesis del grupo HEMO, precursor de la hemoglobina e inhibe la síntesis de globina.
2. Alteración morfológica de los precursores y de la membrana de los hematíes.

Clínica: Anemia hipocroma, normocítica o microcítica. Mayor susceptibilidad en los niños.

III. SISTEMA NERVIOSO

a) Sistema Nervioso Central

Encefalopatía Saturnina: los síntomas y signos van desde cambios psicológicos-conductuales hasta alteraciones neurológicas graves. Los niños tienen la mayor susceptibilidad y frecuentemente quedan con secuelas de diversa magnitud.

Clínica: irritabilidad, vértigo, cefaleas, visión nublada, temblor, alucinaciones, pérdida de memoria y de capacidad de concentración. Delirios, manías, convulsiones, parálisis, coma. Deterioro en el desarrollo psicomotor, retroceso en el control de esfínter y coordinación psicomotriz.

b) Sistema Nervioso Periférico

Parálisis Saturnina: debilidad de los músculos extensores por daño en los nervios motores.

Clínica: Falta de fuerza en las manos, hiperestesia analgesia, dolores musculares, calambres.

IV. SISTEMA URINARIO

Nefropatía Saturnina: fibrosis intersticial, atrofia glomerular, lesión tubular, degeneración hialina y ateroscleróticas de los vasos, aumenta la actividad de la Renina plasmática.

Clínica: La manifestación es bastante tardía y cursa con Insuficiencia Renal de Grado variable.

DIVISION DE SALUD

000309

Departamento de Desarrollo y Vigilancia Epidemiológica

III. SISTEMA CARDIOVASCULAR

Hipertensión Arterial: por acción directa sobre los vasos y/o sobre los riñones.

IV. SISTEMA REPRODUCTOR

Mujer: abortos, mortinatos, parto prematuro

Hombre: Astenoespermia, hipoespermia.

V. OTROS EFECTOS

1. Artralgias
2. Retardo en el crecimiento y menor estatura
3. Posibles efectos teratogénicos.
4. Deterioro de la función de la glándula Tiroidea: disminuye la captación de Yodo.
5. Alteración de la función de las Suprarrenales.
6. Alteración del metabolismo de la Vitamina D.
7. Gastrointestinales: Cólico saturnino, precedido de estreñimiento. Dolor intenso abdominal, vómitos.

DRA. SRQ

000310

PRINCIPALES EFECTOS ADVERSOS EN NIÑOS EN CONDICIONES DE EXPOSICIÓN ESTABLE A LARGO PLAZO AL PLOMO, SEGUN LAS CONCENTRACIONES SANGUINEAS ALCANZADAS POR EL METAL

µg Pb/100 ml de sangre	Efecto adverso que puede aparecer a la concentración de plomo señalada
10	<ul style="list-style-type: none"> - inhibición de la actividad de la enzima AAL-D - edad gestacional reducida (exposición prenatal) - bajo peso al nacer (exposición prenatal) - retraso en crecimiento
12	<ul style="list-style-type: none"> - interferencia en el metabolismo de la vitamina D
15 - 20	<ul style="list-style-type: none"> - elevación de protoporfirinas eritrocitarias - alteraciones electrofisiológicas en el SNC
20	<ul style="list-style-type: none"> - alteraciones conductuales, déficit en la atención
30	<ul style="list-style-type: none"> - disminución en la conducción nerviosa periférica
40	<ul style="list-style-type: none"> - aumento del AAL en suero y del AAL-U - aumento de las CP-U - reducción en la producción de hemoglobina - velocidad de conducción nerviosa periférica reducida - alteraciones en el aprendizaje - nefropatía (aminoaciduria) - síntomas gastrointestinales
50	<ul style="list-style-type: none"> - disminución marcada del cociente de inteligencia
70	<ul style="list-style-type: none"> - anemia franca - nefropatía grave
80	<ul style="list-style-type: none"> - encefalopatía - daño cerebral grave - retardo mental grave

000311

PRINCIPALES EFECTOS ADVERSOS EN ADULTOS EN CONTACIONES DE EXPOSICION ESTABLE A LARGO PLAZO AL PLOMO, SEGUN LAS CONCENTRACIONES SANGUINEAS ALCANZADAS POR EL METAL

$\mu\text{g Pb}/100 \text{ ml}$ de sangre	Efecto adverso que puede aparecer a la concentración de plomo señalada
10	<ul style="list-style-type: none"> - inhibición de la actividad de la enzima ALAD
15 - 20	<ul style="list-style-type: none"> - elevación de protoporfirinas eritrocitarias en mujeres
20 - 30	<ul style="list-style-type: none"> - elevación de protoporfirinas eritrocitarias en hombres
30	<ul style="list-style-type: none"> - disminución en la conducción de nervios periféricos - respuestas fisiológicas alteradas en el sistema nervioso central - elevación de la presión arterial en hombres mayores de 40 años - alteraciones cromosómicas?
40	<ul style="list-style-type: none"> - aumento del ALAD en suero y del ALAD-U - aumento de las CP-U - marcado aumento de las protoporfirinas eritrocitarias - disfunción nerviosa periférica - alteración de función visual: nictalopia (oscurecimiento nocturno) - alteraciones psicosensores (sueño, estado de ánimo, memoria, atención) - nefropatía - síntomas gastrointestinales - alteraciones espermáticas
50	<ul style="list-style-type: none"> - disminución en la producción de hemoglobina - alteraciones morfológicas de los eritrocitos - parestesias en miembros superiores - debilidad en miembros inferiores - fatiga, ovide, distracción - subencefalopatía - alteración de la función testicular
60	<ul style="list-style-type: none"> - acortamiento en la vida de nematocitos - aumento exponencial de protoporfirinas eritrocitarias - efectos reproductivos en la mujer - alteraciones patológicas del electrocardiograma
80	<ul style="list-style-type: none"> - anemia franca
100	<ul style="list-style-type: none"> - encefalopatía grave - nefropatía crónica

ACTA DE REUNION DE COMITÉ OPERATIVO Y COMITÉ AMPLIADO

FECHA REUNION : 10 de Mayo de 1999

LUGAR : CONAMA -Santiago

HORARIO : 9:30 – 17:00 hrs.

ASISTENCIA :

Silvia Riquelme	Ministerio de Salud
Andrei N. Tchernitchin	Colegio Médico de Chile
Catterina Ferreccio	Consultora GREDIS
Eduardo Giesen	ENAMI
Bartolomé Alfaro	CODELCO
Manuel Cortés	S. Salud Antofagasta
Carlos Salvo	SONAMI
Andrea Varas	CNE
Jamal Soto	CNE
M. de la Luz Vásquez	Min. Minería
Jaime Retamal	MTT (Subsec. Transporte)
M. Angélica Ruiz-Tagle	CONAMA Antofagasta
Andrea Muñoz	CONAMA
Rodrigo Lucero	CONAMA
Maritza Jadrijevic	CONAMA
Andrea Urrutia	Memorista Universidad de Chile

Tabla :

1. Exposición “ Plomo y Salud”, Dra. Silvia Riquelme, Ministerio de Salud.
2. Presentación de cronograma de actividades de los grupos de trabajo del Comité Operativo y Ampliado, Andrea Muñoz, Depto. Descontaminación, Planes y Normas.
3. Presentación del 2º informe de avance del estudio “ Preparación de Antecedentes Técnico-para la Elaboración de la Norma de Calidad Primaria de Plomo en el Aire”, Consultora GREDIS.

Preguntas y discusión .

1.- Durante la presentación de la Dra. Silvia Riquelme se efectuaron las siguientes preguntas y observaciones:

- ¿Cuál es el tiempo necesario de exposición del plomo en el aire para que este se detecte en la sangre?. Se indica que la exposición depende de una serie de factores como cercanía a las calles altura respecto al suelo, etc. En general es necesario 1 mes de exposición para que se detecte el plomo en la sangre

- ¿Qué niveles de plomo en sangre hay en Santiago?. La Dra. Riquelme indica que no han detectado valores muy altos.

El Dr. Tchernitchin hace referencia a un estudio que compara los niveles de sangre en niños de Santiago y Los Andes. También menciona que la U. de Chile elaboró un programa computacional para determinar efectos de Pb en la sangre de niños, para lo cual se estudiaron reflejos y su retardo.

- CODELCO recalca la necesidad de correlacionar los niveles de plomo en el aire con las concentraciones en la sangre 000313

- ¿Cuál es la concentración natural de plomo en el aire?. El plomo en el aire es netamente antropogénico, y en el aire no contaminado el nivel de plomo debiera ser cero.

- ¿Se hace especiación de plomo? ¿hay especies mas tóxicas que otras?. El plomo orgánico es menos tóxico. En general se mide el plomo total sin distinción de especies.

- ¿Es la piel vía de exposición? La absorción es mínima y no se considera.

- ¿Que animales o vegetales concentran el plomo?. Los bivalvos lo concentran, las plantas no lo concentran si no que se contaminan con él. Se indica que en Europa hay una norma que prohíbe plantar vegetales a menos de 200 m de las autopistas o calles.

2.- Presentación de CONAMA. La Sra. Andrea Muñoz entrega la siguiente información:

- El proceso de la norma se prorrogó por 189 días.
- Se presentan los grupos de trabajo con sus objetivos generales y resultados esperados.
- Se presenta el cronograma de trabajo de cada grupo
- Se presenta el cronograma del proceso normativo.

- CODELCO indica que hay traslape entre el trabajo de algunos grupos y que en algunos casos el trabajo no debiera ser paralelo. Se responde que los grupos están abiertos y que algunos plazos pueden ajustarse.

- El MINMIN solicita participar en el grupo de metodología de medición.

- Se confirma que las reuniones de Comité Operativo serán los días Lunes.

3.- Presentación de GREDIS, Catterina Ferreccio

- Fuentes móviles de plomo.
- Fuentes fijas por región
- Plomo en Salud

Preguntas y observaciones:

- Se indica que los valores de Pb en gasolina fueron dados por el SEC y representan el peor caso
- Se sugiere a la consultora que solicite información al SERNAGEOMIN sobre el Pb en la minería.

- Respecto a los acopios de plomo en la I región, El Dr. Tchernitchin indica que los valores de concentraciones de plomo presentados son menores a los que ha medido el Colegio Medico.

- Se pregunta porqué se ha considerado solo la Minería del Plomo, ya que es posible que otro tipo de minería, como el cobre o el oro, también sean emisoras de plomo al aire.

La consultora responde que no tiene acceso a esa información. CODELCO pregunta por que no se les solicita la información ahora. Ventanas indica que a ellos no se les pidió claramente esa información y por eso no la entregaron. Los representantes de las empresas mineras afirman que entregarán la información de sus emisiones de plomo.

- CONAMA indica que si bien este estudio tiene sus limitaciones respecto a la información a la que puede tener acceso, debería al menos indicar cuales son las fuentes a las que hay que solicitar la información.

- Respecto al plomo en salud el Dr. Tchernitchin señala que actualmente se esta estudiando la norma en EEUU y que hay mucha discusión sobre el nivel mínimo en el cual el plomo no tendría efectos en la Salud.

- 000314
- Se consulta respecto de la importancia relativa del ingreso de plomo al organismo vía ingesta y vía inhalación, a lo cual se responde que esa información estará en el tercer informe.
 - Se solicita fotocopias de la presentación de la Dra. Ferreccio.



Andrea Muñoz
Depto. Descontaminación, Planes y Normas
CONAMA

20/11/98

RACION SOCIAL	DIRECCION	COMUNA	FUENTES FIJAS	EMISIO Kg/h.	HRS h/dia	DIAS dia/año
ALEE ITS CHILE LTDA. 7453287(88)	CAM. EL OTONO SITIO 4 PARQ. IND.	LAMPA	HORNO DE FUNDICION DE VOLTEO 500 KGS. (BRONCE)	0.070	8.0	260
BATERIAS COSMOS LTDA.	CAM. LAMPA LOTE 1 PARCELA 2	LAMPA	HORNO ROTATORIO DE FUNDICION	0.133	24.0	240
CIA. ELABORADORA DE METALES S.A.	SAN NICOLAS 860	S.MIGUEL	EQUIPO EMPLOMADO (POR INMERSION)	0.153	7.2	230
CIA. IND. DE TUBOS DE ACERO S.A. (CINTAC)	CAM. A MELIPILLA 8920	MAIPU	HORNO ZINC PETROLEO 5	0.140	24.0	365
<i>↳ Giro Industrial metalurgico Planta y helio 368 22 00 vectores directos 2000</i>	CAM. A MELIPILLA 8920	MAIPU	HORNO GALVANIZADO (QUEMADOR N°4 Y N°1)	0.062	9.0	200
			TINA DE GALVANIZADO (QUEMADOR N°3)	0.007	9.5	260
			HORNO DE GALVANIZADO (QUEMADOR N°4-1-3)	0.126	9.0	200
			HORNO DE GALVANIZADO (QUEMADOR N°4)	0.048	5.0	200
			HORNO DE GALVANIZADO (QUEMADOR N°4-1-3-2)	0.103	9.0	200
CIA. MANUF. DE METALES LTDA. (CAMET)	CAM. A MELIPILLA 5489	CERRILLOS	HORNO DE FUNDICION	0.075	9.5	260
			HORNO DE FUNDICION	0.020	9.5	262
DANIEL OSMAN OCHOA	CAM. LAMPA PARC.1 LOTE 2	LAMPA	HORNO ROTATORIO	0.392	24.0	286
GOODYEAR DE CHILE S.A.I.C.	CAM. A MELIPILLA KM. 16	MAIPU	REACTOR OXIDO DE PLOMO (BATERIAS)	0.017	24.0	280
			HORNO DE FUNDICION DE PLOMO DYNACAST Y MARK V	0.120	24.0	280
			CRISOL FUNDICION REACTOR OXIDO	0.009	24.0	280
FCA. DE MATERIALES DE COBRE LTDA.	CAM. LA PRIMAVERA SITIO 1	LAMPA	HORNO CRISOL N° 1 Y N° 2 - (EX HORNO CRISOL 500)	0.027	6.5	262
FUNDICION AMERICA S.A.	STA. ELENA 1287	SANTIAGO	HORNO MORGAN/GRANALLADORA	1.600	10.0	240
FUNDICION RICARDO LEON	LLANO DE LAMPA - PARCELA 2	LAMPA	HORNO ROTATORIO, RECUPERADOR DE PLACAS DE PLOMO	0.043	7.0	220
IND. NAC. DE PLOMO INDEPP LTDA.	PADRE TADEO 4871	Q.NORMAL	HORNO CON OLLA DE ACERO	0.017	9.0	92
INDS. GRALES. Y COMPLEMENT. DEL GAS S.A.	LOGRONO 3871	E.CENTRAL	HORNO DE PLOMADO	0.066	10.0	227
INDS. METAL. SORENA S.A.	RODRIGO DE ARAYA 96	S.MIGUEL	GRANALLADORA(16)	0.110	3.0	200
			GRANALLADORA(43)	0.053	3.0	144
			FILTRO DE MANGAS N°1	0.260	10.0	0
			FILTRO DE MANGAS N°2	0.410	10.0	0
			FILTRO DE MANGAS N°3	0.060	24.0	365
			FILTRO DE MANGAS N°4	0.230	24.0	365
NIBSA S.A.	JUAN GRIEGO 4429	S.JOAQUIN	HORNO DE INDUCCION CHATARRA N°1 (CP-2) (HORNO)	0.119	9.0	247
			HORNO DE INDUCCION ELECTRICOS (CP-7) (HORNO)	0.050	9.0	227
			HORNO DE INDUCC. CHATARRA N°2(CP-10)CAP.CP-11/CP-2	0.011	9.0	247
			HORNO DE INDUCCION CHATARRA N°3 (CP-11)	0.121	9.0	247
			LINEA MOLDEO - FUNDICION 3 (CP-3)	0.274	9.0	247
			HORNO DE INDUCCION CHATARRA (CP-9)	0.147	9.0	227
MEDIDORES LAUTARO S.A.I.C.	HERRERA 1127	SANTIAGO	HORNO DE INDUCCION BRONCE	0.140	10.0	231
			TUNEL COLADA	0.077	1.5	230
MANUF. METALES OFFERMANN'S FLOOD	VARAS MENA 865	S.MIGUEL	HORNO DE FUNDICION (LATON)	0.008	0.0	220
PLOMETAL	GRAL. BRAYER 1774	Q.NORMAL	HORNO CRISOL DE FUNDICION PLOMO CHICO	0.037	4.0	144
			HORNO CRISOL DE FUNDICION PLOMO GRANDE	0.020	3.0	96
SERGIO CACERES MUNOZ	RIQUELME 843	PUDAHUEL	HORNO PARA GALVANIZADO	0.013	0.0	240
SGS CHILE LTDA.	LAS ESTERAS 2441	QUILICURA	HORNOS DE COPELACION	0.420	13.5	365
SOC. NAC. METALURGICA LTDA. (SONAMET)	ISABEL RIQUELME 560	S.JOAQUIN	HORNO DE INDUCCION N°2	0.014	0.0	252

Particular

OBS:

COMERCIAL HUAL LTDA.	BERLIOZ 5760	S.JOAQUIN	NO REGISTRA FUENTES FIJAS
GEOLAB	LOS EBANISTAS 8521	L.REINA	NO REGISTRA FUENTES FIJAS

¿SOPLENIA?

	Plume Samples ^a Smelter Number					Ore ^b
	1 (ng/m ³)	2 (ng/m ³)	3 (ng/m ³)	4 (ng/m ³)	5 (ng/m ³)	Smelter 2 (μg/g)
Carbon (total)						
Carbon (organic)						
Carbon (elemental)						
N						
F						
294 Na	550 ± 80	700 ± 300	230 ± 70	210 ± 50	240 ± 40	17,000 ± 4,000
Mg	370 ± 260	<800	<90	210 ± 80	<200	7,600 ± 700
Al	220 ± 290	1,000 ± 800	480 ± 120	350 ± 180	170 ± 100	62,000 ± 2,000
Si						
P						
S	280,000 ± 32,000	120,000 ± 24,000	54,000 ± 12,000	45,000 ± 7,000	<6,000,000	<50,000
Cl						
K	1,300 ± 240	900 ± 450	720 ± 110	290 ± 90	510 ± 190	47,000 ± 14,000
Ca	1,600 ± 300	780 ± 500	1,700 ± 110	1,200 ± 210	100 ± 800	11,700 ± 500
Ti	180 ± 50	700 ± 100	<80	<20	<10	3,600 ± 800
V	59 ± 8	4.8 ± 1.2	2.4 ± 1.8	3.2 ± 0.6	0.60 ± 0.31	69 ± 2
Cr	6.5 ± 2.6	35 ± 15	5.9 ± 2.3	77 ± 70	14 ± 5	67 ± 2
Mn	39 ± 3	28 ± 7	11 ± 6.5	6.8 ± 1.5	3.2 ± 0.9	190 ± 10
Fe	1,800 ± 100	2,500 ± 500	2,700 ± 100	1,100 ± 100	1,100 ± 100	53,000 ± 1,000
Ni						
Cu	3,200 ± 300	6,800 ± 1,300	9,500 ± 900	4,200 ± 420	2,000 ± 200	5,500 ± 500
Zn	340 ± 110	4,500 ± 400	22,000 ± 2,000	7,200 ± 5,100	7,600 ± 600	540 ± 20
As	2,000 ± 100	2,000 ± 100	1,900 ± 100	1,400 ± 100	4,300 ± 100	5.6 ± 0.4
Se	920 ± 10	880 ± 20	49 ± 2	170 ± 10	42 ± 10	11 ± 1
Br	17 ± 4	33 ± 10	10 ± 6	<50	<10	
Rb						
Sr						
Zr						
Cd						6 ± 2
Sn						
Sb	80 ± 5	140 ± 10	210 ± 10	58 ± 5	370 ± 20	5.9 ± 0.2
I	6 ± 6	6.8 ± 3.5	47 ± 5	53 ± 6	2 ± 2	8.4 ± 0.2
Cs	0.45 ± 0.20	1.5 ± 0.2	0.41 ± 0.21	0.28 ± 0.15	0.34 ± 0.20	
Ba	14 ± 8	<10	50 ± 50	<3	<7	
La	1.9 ± 0.3	1.8 ± 0.4	0.76 ± 0.07	0.27 ± 0.07	0.50 ± 0.30	45 ± 1
295 Ce	1 ± 1	0.12 ± 0.02	2 ± 1	0.6 ± 0.5	<0.3	78 ± 5
Eu						1.49 ± 0.04
Hf						
Ta						
Hg						
Pb	5,100 ± 1,000	3,000 ± 600		2,600 ± 500	1,900 ± 400	50 ± 5
Th	0.34 ± 0.02	0.31 ± 0.20	<0.2	<0.1	<0.1	
U						

^aSmall et al. (1981a).^bSmall et al. (1981b).

REPÚBLICA DE CHILE
MINISTERIO DE SALUD
SERVICIO SALUD VIÑA DEL MAR-QUILLOTA
DEPTO. PROGRAMAS SOBRE EL AMBIENTE

F.:37 L.:14 22.03.99.-

ORD.: N° 808.-/000317

COMISION NACIONAL DEL MEDIO AMBIENTE
OFICINA GENERAL DE ARCHIVO
FAX:
N° IN.: 1208
FECHA: 26 MAY 1999
DESPACHO:
OBS.:
P MATUS

ANT.: - Su Ord.Of. N° 501157 del
08.03.99.-

MAT.: Da respuesta que indica.-

VIÑA DEL MAR

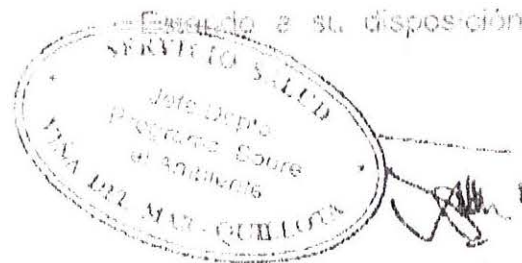
26 MAY 1999

DE: JEFE DEPTO. PROGRAMAS SOBRE EL AMBIENTE
SERVICIO DE SALUD VIÑA DEL MAR-QUILLOTA

A: SRA. PATRICIA MATUS
JEFE DEPTO. DESCONTAMINACION, PLANES Y NORMAS
CONAMA

De acuerdo a su solicitud sobre antecedentes para Norma de Calidad Primaria para Plomo en Aire, y en relación a puntos 4, 5, 6 del ant., comunico a Ud. que lamentablemente en este Departamento no contamos con datos sobre esta contaminación. Si bien existen redes de monitoreo en distintos sectores, no se han realizado estudios de los filtros provenientes de las mediciones de PIM. Por otro lado, cabe mencionar que se está instalando una red en el sector de La Calera - Hijuelas, como consecuencia del proyecto "Utilización de Combustible Alternativo en el Horno 8 de Cemento Melón" en el cual se contempla el análisis de metales pesados.

En caso de su disposición para nuevas consultas, le saluda atentamente



DR. FRANKLIN SÁNCHEZ GARCÍA
JEFE DEPTO. PROGRAMAS SOBRE EL AMBIENTE
SERVICIO DE SALUD VIÑA DEL MAR-QUILLOTA

Jhb.
ING. C. Q. MLZ./DRA. IMV./tmf.

DISTRIBUCIÓN:

- CONAMA
- Depto. Programas Sobre el Ambiente



RECTOR

UNIVERSIDAD CATOLICA DEL NORTE ⁰⁰⁰³¹⁸

70 # 7234,
 COMISION NACIONAL DEL MEDIO AMBIENTE
 OFICINA DE PLANES Y NORMAS
 5904 / 45 85
 20 MAY 1999
 FECHA: _____
 DEPARTAMENTO: _____
 C.D.: _____
 P. Matus
 P/ Wano

RECT. U.C.N. N° 077/99

MAT.: Antecedentes Norma de Calidad Primaria para Plomo en Aire.

REF.: ORD. N° 991157 de CONAMA.

ANTOFAGASTA, mayo 17 de 1999.

Señora
 Patricia Matus C.
 Jefe Depto. Descontaminación, Planes y Normas
 Comisión Nacional del Medio Ambiente
 Obispo Donoso 6 - Providencia
Santiago

De mi consideración:

De acuerdo con su requerimiento de antecedentes relacionados con ORD. de Referencia, emitido el 08 de marzo de 1999, comunico a usted que nuestra Institución no posee información referida a los puntos 4, 5 y 6 de dicho documento.

Debido a que los estudios sobre Norma de Calidad Primaria de Plomo en el Aire han sido encargados, por CONAMA, a otras instituciones; la Universidad Católica del Norte no ha realizado aportes publicados sobre los temas citados.

Sin otro particular, saluda atentamente a usted,

JUAN ANDRÉS MUSIC TOMICIC
RECTOR

BASELINE STUDIES AND METAL CONTAMINATED SOILS**Estudios de líneas de base y suelos contaminados
con metales****BRIAN E. DAVIES¹****C O N T E N T****ABSTRACT****INTRODUCTION****IMPORTANCE OF REPRESENTATIVE FIELD SAMPLING AND LABORATORY
ANALYTICAL QUALITY CONTROL****STATISTICAL INTERPRETATION OF TRACE METAL DATA****CARTOGRAPHICAL INTERPRETATION OF DATA****CASE STUDIES****Example of the extraction of baseline values****Example of the use of multivariate statistics****Example of patterns around a point source A smelter or refiner is a point
source of contamination****Examples of patterns around multiple point sources****REFERENCES****ACKNOWLEDGEMENTS**

¹ Environmental Geochemistry Research Unit, Department of Environmental Sciences, University of Bradford. Bradford, West Yorkshire, BD7 1DP England

ABSTRACT

This paper describes systematic approaches to interpreting results from surveys of metal contaminated soils. Since contaminating metals are present naturally in soil, anthropogenic accumulations are recognised through statistical analysis of the data. Distinctive spatial patterns may also be generated and these are evaluated using computergraphic techniques. Case studies are described briefly to support the general narrative.

INTRODUCTION

There are eighty four naturally occurring and detectable elements. Nearly all the mass (98%) of silicate rocks and soils is accounted for by only eight of them: O, Si, Al, Fe, Ca, Na, K and Mg. The remainder are the "trace elements", some of which are essential for plant growth and are also called micronutrients. If present in excess concentration both micronutrients and non-essential trace elements have undesirable or lethal effects on plant and animal growth. Some of these elements are now present in excess concentration in some soils as a consequence of man's industrial or urban activities. Much research has been carried out on the polluting 'heavy' metals, especially cadmium, copper, lead, mercury and zinc. The qualifier 'heavy' is not rigorously defined but most authors use it to describe metallic elements having a density greater than 6000 kg m^{-3} .

Whenever an element or its compounds are heated, dissolved or pulverised they become environmentally labile and may escape from the working environment. Having escaped, contaminants follow normal environmental pathways until they reach a geochemical sink, such as soil or sediment, and there accumulate. When the accumulation of a contaminant reaches a level at which biological injury is seen for a particular organism the contaminant becomes a pollutant. Thus, a distinction is made between contamination, anthropogenically induced accumulation above the local background level and pollution, biological injury resulting from contamination. Pollution is species-specific, e.g., excess zinc in soil can injure plant life but is relatively innocuous for animals.

There is no unequivocal way of recognizing when a soil has been contaminated or polluted by trace elements since all the naturally occurring elements are present in all soils, albeit at very low concentrations. The problem of recognizing whether contamination by metals has taken place becomes one of deciding whether the measured concentration of a particular element is within the range of what could occur naturally for that soil or whether the measured concentration is anomalous. If the anomaly is not of natural occurrence but is of anthropic origin it is a neoanomaly and the soil is contaminated. This paper is concerned with some techniques for establishing baseline concentrations in soil and recognizing anomalies and neoanomalies.

IMPORTANCE OF REPRESENTATIVE FIELD SAMPLING AND LABORATORY ANALYTICAL QUALITY CONTROL

In the environmental sciences research is often conducted by sampling, chemical analysis and data evaluation rather than by controlled experimentation in the laboratory. A carefully prepared sampling protocol will ensure that samples are representative. Known or suspected influences can be recorded and quantified. The final data represent the sample analysed, they do not necessarily represent the environment sampled. If the sampling was not representative or if the sample was contaminated after collection then the results are worse than worthless since they may be completely misleading and lead to quite unjustifiable conclusions or remediation policies.

A sample may be representative but the data derived from it may be neither precise nor accurate. In environmental surveys many hundreds of samples may be analysed and the work load may therefore preclude replication of every sample. It is essential to replicate (usually duplicate) some proportion (e.g. 20%) of the samples chosen at random. Every batch should include one or more samples of a certified reference material and samples selected for the batch should be drawn at random from the sample collection. The classical "garbage in, garbage out" pitfall of computer treatment of data can be avoided only by adhering to a strict and well prepared sampling protocol and by ensuring the best possible analytical quality assurance programme.

STATISTICAL INTERPRETATION OF TRACE METAL DATA

Typically, a survey may yield metal concentrations for three to five hundred samples. The size of such a database will preclude its publication in full in most journals and it is therefore necessary to summarize the data both for evaluation and publication.

Quantitative approaches to the description and evaluation of trace element data for soils are still in their infancy and it is not clear what is the best model to describe the variability of soil metal concentrations. **Ahrens (1954)**, has proposed that the distribution of elements in igneous rocks approximates to a log-normal distribution. This model does not necessarily apply to soils but the available evidence suggests it may. Data from contaminated soils are usually strongly skewed and therefore need to be normalised by, e.g., a log transformation.

The simplest descriptive statistic is the mean and computer packages also provide the standard deviation of the mean, i.e., a measure of the spread of values around the mean. It is also helpful to tabulate the minimum and maximum values. But data assessment should not stop at this point since these parameters do not fully summarize the data. It is important that the median value be calculated. Many statistical packages will also provide the skewness or third moment statistic. A positive value indicates a clustering of samples to the left of the mean.

Table 1 illustrates soil metal concentrations from a typical survey (**Davies and Roberts, 1978**). The arithmetic data are characterised by a feature which is common in this kind of data, namely that the mean is greater or very much greater than the median. The most common inference drawn from the value of the mean is

"typicality", the "average" (in its colloquial sense) value. But the median is also a measure of central tendency. The two statistics are seen to differ in **Table 1**, e.g., the mean Pb concentration is 5.2 times greater than the median. This distribution is positively skewed and the median is a far better representation of central tendency than the mean.

The most commonly used statistical evaluation techniques (analysis of variance, regression analysis or correlation analysis) are 'parametric' tests which require the test populations to be normally distributed, i.e., they should not be skewed. Populations can be normalised by transforming the data and

a common transformation is to convert each value to its logarithm (the common log₁₀ or the natural log). **Table 1** shows the result of a log₁₀-transformation. The geometric mean (234 $\mu\text{g Pb g}^{-1}$) is now only 1.4 times the median (167 $\mu\text{g Pb g}^{-1}$). As a general rule, all soil trace element data should be log-transformed before statistical analysis.

The simplest way of identifying contaminated soils is by collecting reference or control samples from apparently similar but uncontaminated areas (e.g., those remote from urban or industrial influences). After analysis the geometric means and deviations are calculated. A threshold value is then calculated being the value lying two or more standard deviations above the mean, depending on the probability level required. An anomalous value is one which lies above the threshold. The range mean + two or three standard deviations can also be reported as the "probable range". This is often more useful than the actual range which may overemphasize an extreme outlier value. Where more than one sample is apparently anomalous then the differences between the two groups (control and anomalous) can be assessed by standard statistical tests such as the familiar t-test.

It should not be assumed that anomalous concentrations necessarily indicate contamination. **Bolviken and Lag (1977)** have described areas in Norway where the absence of vegetation is due to the toxic effects of high concentrations

Table 1. Summary data for soils (mg kg^{-1}) in the Halkyn Mountain area of North Wales (Davies and Roberts, 1978)

	Pb	Zn	Cu	Cd
Arithmetic data:				
Number of samples	288	288	288	288
Mean	870	685	18	5.63
Median	167	111	13	1.1
Standard Deviation	3268	4185	20.8	38
Minimum	35	10	2.3	0.1
Maximum	47955	49393	252	540
Kurtosis	156	127	60	156
Skewness	11.5	11.1	6.5	288
Log₁₀ transformed data:				
Mean	234	155	14	1.3
Standard Deviation	3.99	3.19	1.90	2.81
Kurtosis	0.35	4.5	2.61	7.6
Skewness	0.91	1.69	0.91	1.94

of metals in soils as a result of weathering of sulphide ores close to the surface. This is a natural process having nothing to do with contamination. Identification of a geochemical anomaly should, in the first instance, be considered as only that, an anomaly.

Very often it is not possible *a priori* to separate contaminated and uncontaminated soils at the time of sampling. The best that can be done in this situation is to assume the data comprise several overlapping log-normal populations. A plot of percentage cumulative frequency versus concentration (either arithmetic or log-transformed values) on probability paper produces a straight line for a normal or log-normal population. Overlapping populations plot as intersecting lines. These are called broken line plots and they can be partitioned so as to separate out the background population and hence estimate its mean and standard deviation (Tennant and White, 1959; Sinclair, 1974; Davies, 1983).

CARTOGRAPHICAL INTERPRETATION OF DATA

Isotopic analysis is becoming more widely available and is inherently superior for identifying sources but is still beyond the reach of many laboratories. Valuable inferences concerning source apportionment may be drawn from the spatial distribution of soil metal concentrations.

Contaminating sources are generally classed as point or line. A smelter stack is a typical point source and highways are typical line sources due to the movement of motor vehicles and their exhaust emissions along them. A cluster of point sources forms an area source. But whatever the geometry of the source, as contaminants are carried away they become diluted. Fallout from a stack tends to decline exponentially away from the source. Similarly, overbank inundation in polluted river systems leads to greatest contamination nearest to the river channel. Distinctive depositional patterns are thereby created and much can be inferred about the presence and nature of contamination by studying these patterns. Cartographical interpretation of data is an essential component of many contamination projects.

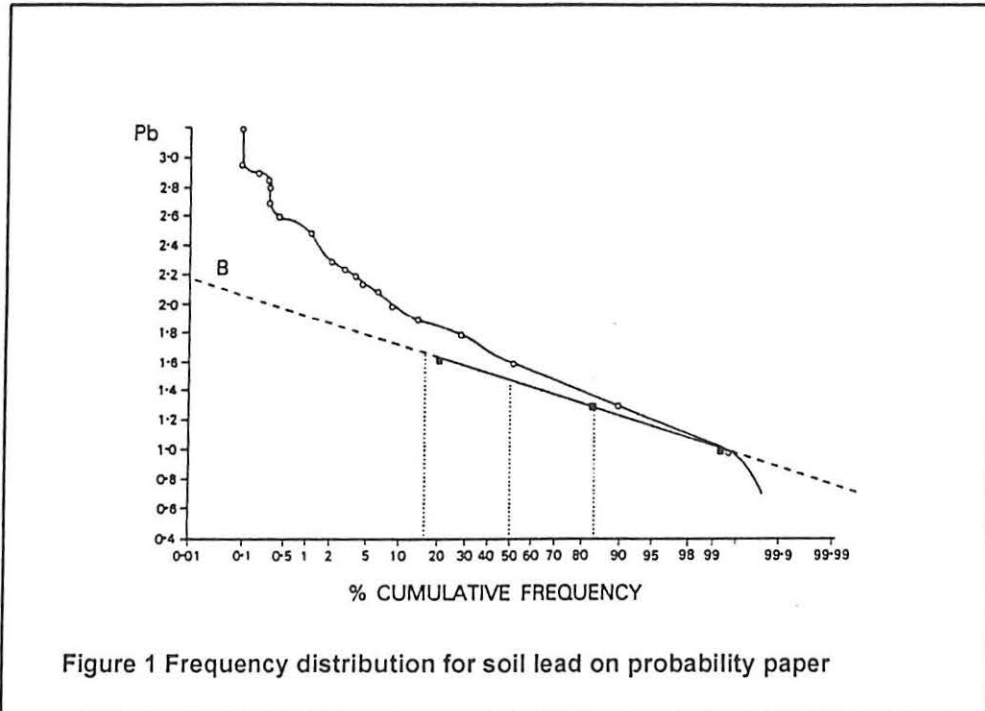
Many ways are possible for representing the spatial distribution of trace metal data ranging from sized or coloured symbols based on the relative concentration at the sample locality to complex statistical surfaces such as trend surface plots. Whatever style of representation is chosen an essential step in the data reduction is the manner in which the concentration values are classified to produce a relatively few groupings of the data from the minimum to the maximum. This can be done empirically by allocating class limits from previous experience but this approach involves too high a degree of subjectivity.

A more systematic approach derives from the frequency distribution of the data. The log-transformed values are classified (a class width of 0.1 is often suitable) and the percentage frequency in each class is calculated. These are then summed to 100%. A plot of concentration versus cumulative percent frequency is drawn and a smooth, sigmoid curve is interpolated between the points. This curve is then used to estimate the concentrations corresponding to selected percentiles.

Modern computer spreadsheets allow the same task to be performed without the need for drawing graphs. For contamination studies it is often convenient to use the 50, 70, 80, 90, 95 and 99th percentiles. This was done for the Halkyn Mountain data and the results are given in **Table 2**. The 50th percentile is, of course, the median.

Table 2. Percentiles of the Halkyn Mountain data summarised in Table 1

Percentile	50	70	80	90	95	99
	----- $\mu\text{g g}^{-1}$ dry soil -----					
Lead	167	386	775	2015	3689	12321
Zinc	111	190	341	697	1274	16496
Copper	12.5	16.5	19.2	29.4	53.4	101
Cadmium	1.1	1.8	2.4	4.6	9.9	146



Broadly, there are two kinds of map. Where it cannot be assumed that there is any progressive change across a given area for the value of the parameter under investigation choropleth maps are constructed. Areas of equal value are separated by boundaries from adjacent areas of different values. Familiar examples are soil or geology maps. But where progressive change occurs isoline maps may be

used. Examples are topographical maps where contours connect points of equal elevation or weather maps where isobars connect points of equal atmospheric pressure. The familiarity of topographical maps compared with other isoline maps has often led to all isoline maps being loosely described as 'contour'. **Monmonier (1982)** has provided a comprehensive account of the fundamentals of computer-aided cartography although much better software is now available than when he was writing.

It is arguable whether geochemical data are satisfactorily representable by isoline maps. Since chemical composition depends on rock type and rock type can be depicted properly only by choropleth maps, isoline maps are not perhaps strictly suitable for depicting geochemical data. However, although soil composition is strongly influenced by parent material composition other processes are also significant, such as wind or water transportation of particles and compounds. Transportation over distance entails progressive change in deposition and therefore progressive change in soil composition. It has already been observed that the contamination effect is subject to such a diminution away from the line or point source. It is reasonable to conclude that isoline maps often are suitable for the study of metal contamination.

A number of computer program packages are available for constructing isoline maps. **Davies and Roberts (1978)** and **Davies and Wixson (1985)** used the older SYMAP system where isoline maps were printed on a line printer and the plots were redrawn for publication. Major mainframe computer packages now produce very high quality monochrome or colour plots with inkjet or thermal printers. Powerful packages are also available for desktop computers and the plots in this paper were produced using a PC microcomputer and the SURFER FOR WINDOWS system of Golden Software, Inc., Golden, Colorado. SURFER also produces block diagrams and these three dimensional perspective figures are most helpful in visualizing geographic patterns.

Whichever system is used there is an important first stage. The data are imported into the program as X, Y and Z values (two geographic coordinates and the metal concentration) and from these a uniform grid of values is created. This entails extrapolation between neighbouring values to calculate the concentration at the grid intersection. The most common involves searching over a defined radius around each sample point and averaging using a weighing factor e.g., one dependent on the inverse square of the distance between points. Another method depends on a moving average system called kriging. Since production of a regular grid is an essential preliminary then the more the distribution of the original data departs from regularity the more possibility there is of distortion of the eventual geographic pattern and the higher the likelihood of misinterpreting the pattern. Where the terrain permits it is much better to sample on an orthogonal grid basis rather than rely on the chosen computer algorithm to regularise an irregular grid.

CASE STUDIES

Example of the extraction of baseline values

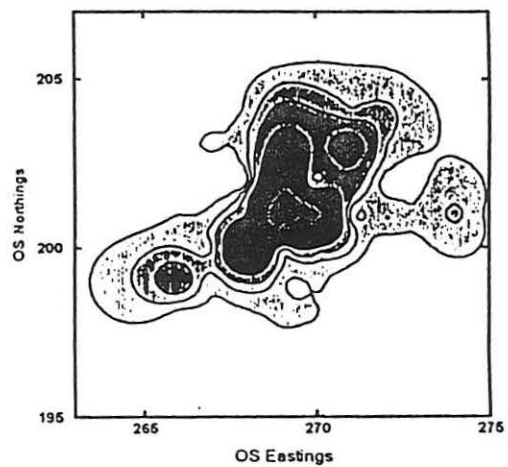
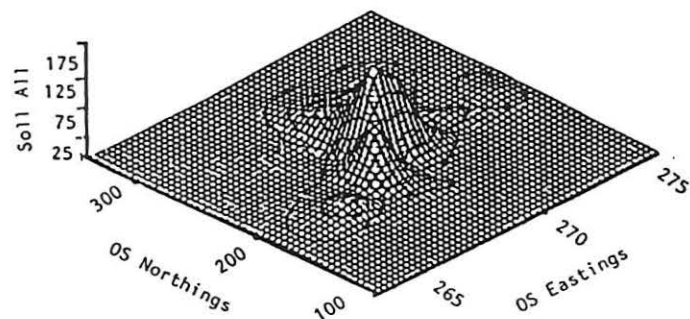
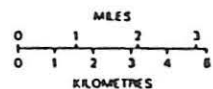


Base Map



MAP KEY

- SOIL SAMPLE POINT
- NICKEL REFINER
- RIVERS
- ▨ LAND ABOVE 500 FLOD.
- ▩ LAND ABOVE 1000 FLOD



Soil Ni ($\mu\text{g g}^{-1}$)

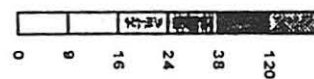


Figure 2 Distribution pattern of Ni in soils around a refiner at Clydach, south Wales, Great Britain

Davies (1983) was interested in trying to establish the background contents of lead in soils in England and Wales. Previous studies had identified areas where nineteenth century metal mining had caused extensive contamination but no systematic information was available for concentrations of lead in non-contaminated soils to assess the severity of soil contamination. Four of the author's own data sets were investigated

plus data from another author (**Archer, 1980**). The method of **Sinclair (1974)** was followed whereby, after a log₁₀ normalization of the data, the percentage cumulative frequency distribution was plotted on probability graph paper.

Figure 1 is derived from the **Davies (1983)** paper. The main plot is seen to comprise a series of intersecting, approximately linear sections, each representing an overlapping population of contaminated soils. The lower right hand section with a break at the 40th percentile, was identified as the element of the curve containing mostly uncontaminated soils. Curve B represent this section after compensation for the effects of higher lead concentrations (**Sinclair, 1974**). The 50th percentile corresponds to the geometric mean and was $30 \mu\text{g Pb g}^{-1}$; the geometric deviation is given by $(16\text{th percentile} - 84\text{th percentile})/2 = 1.53$ and the three standard deviation upper, threshold limit was therefore $108 \mu\text{g Pb g}^{-1}$ soil. This was in good

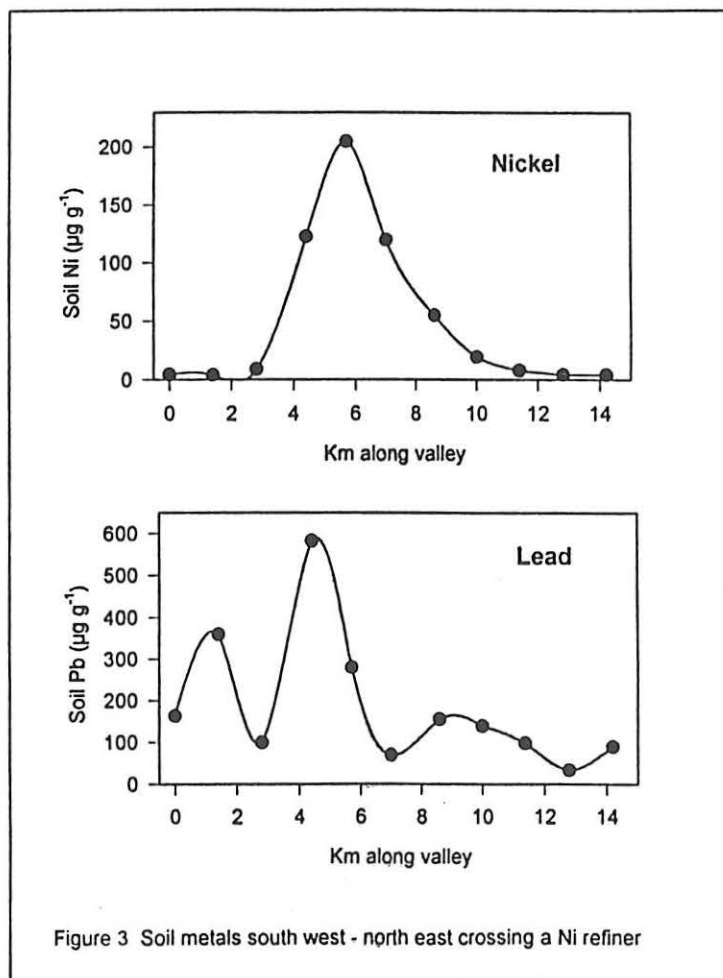
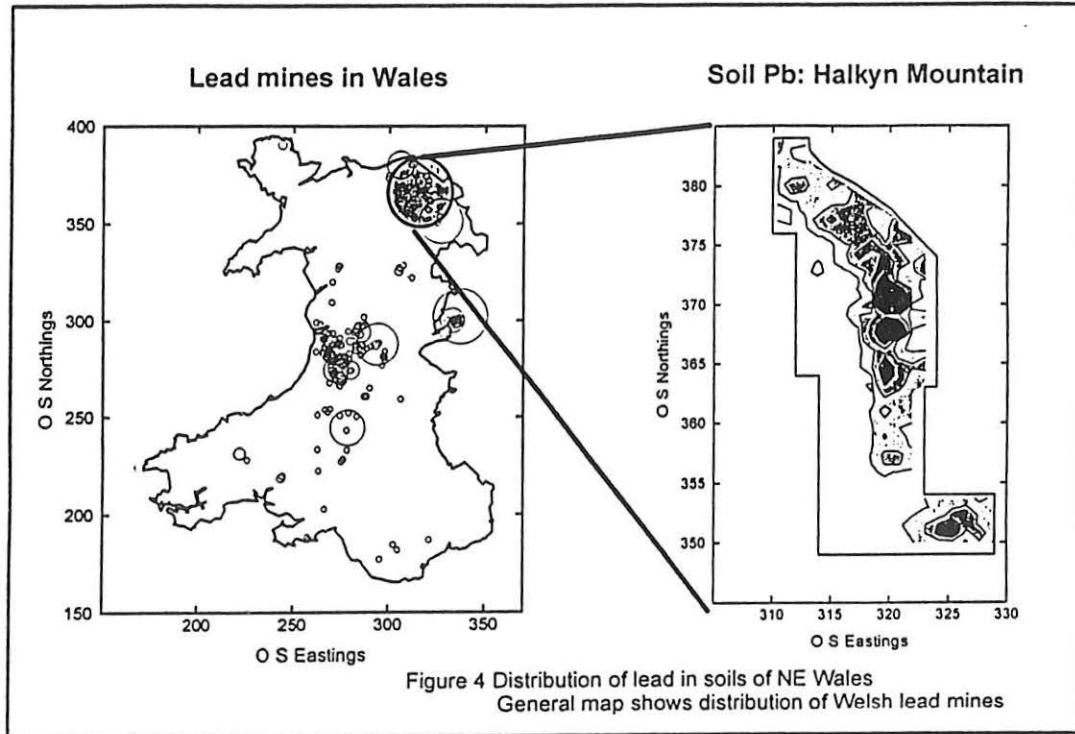


Figure 3 Soil metals south west - north east crossing a Ni refiner

agreement with the threshold derived from the other data sets, namely $106 \mu\text{g Pb g}^{-1}$ soil.

Example of the use of multivariate statistics



Useful information can sometimes be gained concerning major sources of soil trace elements from extensions of correlation analysis. This is particularly useful for multielement surveys. **Davies and Wixson (1987)** used factor analysis to differentiate pollutants from other trace metals in surface soils of the mineralised area of Madison County, Missouri, USA. The ores around the city of Fredericktown MO have been mined since the eighteenth century. Early mining was confined to lead but in the nineteenth century interest switched to the deeper ores of copper and nickel. The last mine (the Madison mine) closed in 1961.

Data were available for 12 elements and 97 samples of surface soil sampled on a regular grid 8×11 km grid with a 1000 m sampling interval. After a \log_{10} transformation of the data highly significant correlations were found between some pairs of elements (e.g., Cu and Ni, $r = 0.903$) and significant correlations between elements not associated with local ores (e.g., Ba and Be, $r = 0.658$). These and other correlations suggested the possibility of grouping the trace metals in ways which were not obvious from a study of the original data without a time consuming evaluation and synthesis of all the correlations. The data were therefore examined

using common or R-mode factor analysis to attempt to identify rapidly clusters or associations within the data set.

Factor analysis is described by **Krumbein and Graybill (1965)**.

Essentially, it is a technique whereby a complex data set is simplified by creating one or more new variables or factors each representing a cluster of interrelated variables within the data set. The method starts with the computation of a correlation matrix and the validity of the subsequent transformations depends on the validity of this matrix. In this investigation

the data were normalised by a \log_{10} transformation. It is assumed that the variation in a variable is caused partly by a variation unique to itself and partly by the influence of underlying factors. Communality describes the proportion of the variance in the variable which is accounted for by common factors and uniqueness (i.e., communality) is therefore the inherent variability in the variable.

The analysis proceeds by transforming the correlation matrix and calculating eigen values and eigen vectors. Several sequential transformations (iterations) are made until the communality of one or more variables exceeds 1.0. The number of significant factors within the data are established by considering only those with an eigen value > 1.0 . The degree of association between each variable and each factor is given by its 'loading' on that factor. The loadings, which can be printed in either tabular or graphical form, then allow the recognition of clusters.

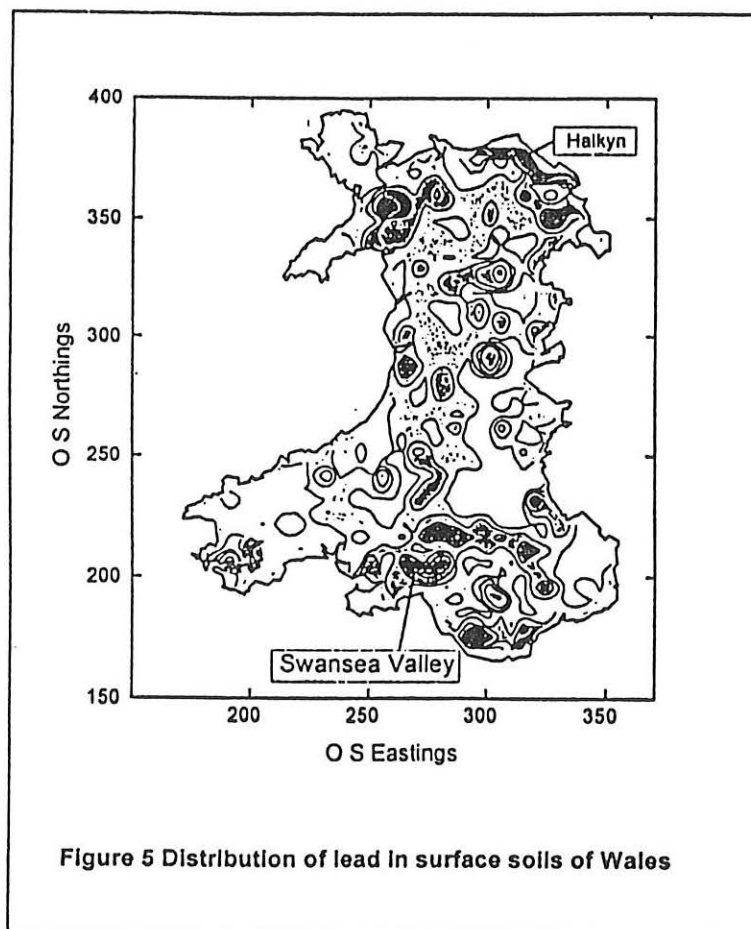


Figure 5 Distribution of lead in surface soils of Wales

Table 2 lists these loadings where Factor 1 accounted for 55.3% of the cumulative variance, Factor 2 accounted for a further 32.9% and Factor 3 accounted for the remaining 11.8%. The first factor contained elements which had contaminated the soil as a consequence of mining processes. The second factor contained those elements which had accumulated in local weathering residues. The third factor comprised elements which could be related to local rock type.

Example of patterns around a point source A smelter or refiner is a point source of contamination

Fallout decreases exponentially from the stack and the pattern of deposition is normally elongated in the direction of the prevailing winds as modified by topography. **Ashton (1972)** has described the pollution problem arising from a nickel refiner at Clydach in the Swansea Valley of Wales. **Figure 2** shows the depositional pattern around this refiner (**B.E. Davies, unpublished data**). The isoline levels are the 50, 70, 80, 90 and 95th percentiles of the soil nickel concentrations. The depositional pattern is seen to focus on the refiner and is elongated along the valley which itself is orientated with the prevailing southwesterlies.

Figure 3 is a transect south west to north east up the valley and crossing the refiner. The upper plot is of soil nickel and shows clearly the characteristic nature of the distance-decline curve away from any point source. The lower curve is of soil lead for which the refiner is not a source and lead-rich petrol fumes from traffic comprise a multiple source in nearby Clydach together with Swansea to the south west and Pontardawe to the north east. The plot of lead is therefore different as is the depositional pattern (not shown here).

Examples of patterns around multiple point sources

Lead and other ores have been mined in many parts of Wales and have given rise to extensive areas of contamination. **Davies and Roberts (1978)** have described the Halkyn Mountain area of north east Wales. This is a narrow plateau of limestone rising to about 260 m (mountain is a misnomer) which is scarred everywhere by small mines, trials and waste heaps. Soil samples were collected on a regular 1000 m grid over an area of 260 km². Contamination was widespread and was evident well away from the mines. Isoline class limits are given in **Table 3**.

The resulting plot is shown in **Figure 4** which also includes a map of the distribution of Welsh lead mines each depicted by a circle the diameter of which is proportional to recorded output of concentrates. The worst contamination occurs in the same area as the outcropping limestone and the main mines. The highest value (47955 $\mu\text{g Pb g}^{-1}$ soil) derived from a sample taken near the New North Halkyn Mine which ceased production in 1958. Isoline plots also allow an assessment of areas of land contaminated.

In the Halkyn area, **Davies and Roberts (1978)** showed that 1% (3 km²) of the study area contained soils with > 10,000 $\mu\text{g Pb g}^{-1}$ and a further 17% (44 km²) contained 1000 to 10,000 $\mu\text{g Pb g}^{-1}$ soil. More recent survey work has extended to the whole of Wales (**B.E. Davies, unpublished**). **Figure 5** is a lead map

for the whole country (class limits and isoline values = 50, 70, 80, 90, 95, 99th percentiles). The locations of the Swansea Valley and Halkyn Mountain are shown. It should be compared with the map of lead mines in **Figure 4**. The spread of contamination is more extensive however than the distribution of old mines and this is provisionally explained by washout over the hillier and wetter parts of Wales.

REFERENCES

- AHRENS, L. H. 1954. The lognormal distribution of the elements. *Geochimica et Cosmochimica Acta*, 5:49-73.
- AHRENS, L. H. 1966. Element distributions in specific igneous rocks. *Geochimica et Cosmochimica Acta*, 30:109-122.
- ARCHER, F. C. 1980. Trace elements in soils in England and Wales. In *Inorganic Pollution and Agriculture*: London, HMSO, v. MAFF Reference Book 326, p. 324.
- ASHTON, W. M. 1972. Nickel pollution: *Nature (London)* 237:46-47.
- BOLVIKEN, B. and LAG, J. 1977. Natural heavy-metal poisoning of soils and vegetation: an exploration tool in glaciated terrain. *Transactions of the Institution of Mining and Metallurgy*, 86(B), p. 173-180.
- DAVIES, B. E. 1983. A graphical estimation of the normal lead content of some British soils. *Geoderma* 29:67-75.
- DAVIES, B. E. and ROBERTS, L. J. 1978. The distribution of heavy metal contaminated soils in north east Clwyd, Wales. *Water, Air, and Soil Pollution* 9:507-518.
- DAVIES, B. E. and WIXSON, B. G. 1985. Trace elements in surface soils from the mineralised area of Madison county, Missouri, USA. *Journal of Soil Science* 36:551-570.
- DAVIES, B. E. and WIXSON, B. G. 1987. Use of factor analysis to differentiate pollutants from other trace metals in surface soils of the mineralized area of Madison County, Missouri, USA. *Water, Air, and Soil Pollution* 33:339-348.
- KRUMBEIN, W. C. and GRAYBILL, F. A. 1965. *An Introduction to Statistical Models in Geology*. New York, McGraw-Hill Book Company, 475 p.

Table 3. Grouping of elements by Factor Analysis (Davies and Wixson, 1987)

Variable	Factors		
	F 1	F 2	F 3
Cu	0.943	<	<
Ni	0.921	<	<
Co	0.910	<	<
Pb	0.808	<	<
Zn	0.637	<	0.461
V	<	0.971	<
Cr	<	0.949	<
Li	<	0.892	<
Ba	<	0.456	0.781
Mn	0.341	<	0.761
Sr	<	-0.326	0.748
Be	<	0.496	0.661

MONMONIER, M. S. 1982. Computer-assisted cartography: principles and prospects. Englewood Cliffs, NJ, Prentice- Hall, Inc., 214 p.

SINCLAIR, A. J. 1974. Selection of thresholds in geochemical data using probability graphs. *Journal of Geochemical Exploration* 3:129-149.

TENNANT, C. B. and WHITE, M. L. 1959. Study of the distribution of some geochemical data. *Economic Geology* 54:1281-1290.

ACKNOWLEDGEMENTS

Professor Davies' visit to Chile, and attendance at the conference, was supported under the British Council Chilean Academic Links Programmes. The arrangement is between the Department of Environmental Science, University of Bradford, England (Professor Brian E. Davies) and La Platina Agricultural Experiment Station, Instituto de Investigaciones Agropecuarias (INIA) (Sr. Sergio P. González). INACAP provided support, especially through arranging hotel accommodation. All who contributed to the success of the stay are warmly thanked.