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**Skýrsla um gagnasöfnun
vegna hugsanlegrar mengunar
af völdum járnblandiverksmiðju**

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Skýrsla um gagnasöfnun vegna hugsanlegrar mengunar af völdum
Járnblendiverksmiðju

eftir

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1. Gögn um járnblandiverksmiðju á Grundartanga í Hvalfirði
Yfirlit þetta er unnið úr þeim heimildum sem tiltækar voru
í júní 1975 um málmblendiiðnað og verksmiðju á Grundartanga.
Skýrslunni er ætlað að veita innsýn í þá þætti sem um er að
ræða og helst ber að varast í sambandi við iðnað af þessu tagi.
Skýrslunni er skipt niður í 3 aðalkafla:

1.1. Jarðrask vegna byggingar verksmiðju

1.2. Meðferð hráefnis.

1.3. Úrgangsefni frá verksmiðjunni.

Tölur innan sviga tákna númer þeirra heimilda sem vísað er til.
Sjá heimildaskrá.

1.1. Jarðrask.

Ætlað er að uppgröftur úr verksmiðjulóð nemi um það bil
230.000 m³.

Þessu efni á að koma fyrir í hólum við norðvestur og norðaustur-
hliðar lóðarinnar. Þetta verður þó einungis framkvæmanlegt ef
þurrviðrasamt verður á jarðvegsflutningatímanum.

Talið er fullvíst að flytja verði nokkuð magn af uppgreftri
lengra frá lóðinni og er ætlunin að hylja klapparholt og mela
2 km vestan verksmiðjulóðarinnar með efninu og sá síðan gras-
fræi í holtin (2).

Vert er að geta þess að ríkjandi gróður á klapparholtunum
eru mosar og fléttur.

Gróðurfarslegar athuganir munu fyrst og fremst beinast að
þessum gróðurfélögum þar sem meiri hluti landsins umhverfis
verksmiðjuna er framræst mýrlendi eða ræktað land og þess vegna
háð ýmsum breytingum sem erfitt yrði að aðgreina frá hugsanlegum
breytingum vegna verksmiðjurekstursins.

Mosar og fléttur eru einnig mjög heppilegur gróður ef það er
haft í huga að fljótlega ætti að koma í ljós hvort einhver
skaðvænleg loftmengun orsakast af verksmiðjurekstrinum.

Það verður því að teljast mikilvægt að klapparholtin í næsta
nágrenni verksmiðjunnar fái að halda sér, svo unnt verði með
sem mestri nákvæmni að meta áhrif verksmiðjurekstursins á
náttúrlegt gróðurfarsvæðisins.

1.2. Meðferð hráefnis

1.2.1. Geymsla hráefnis

Allt hráefni sem verksmiðjan þarfnast, þ.e. kvarts, kol og brotajárn, verður flutt til landsins með skipum.

Við uppskipun verður efnið flutt með bílum í sérstaka hráefnisbingi sem standa munu óvarðir á verksmiðjulóðinni.

Talið er að í Bandaríkjunum fari um það bil 0.1% hráefnis þessa iðnaðar sem ryk út í andrúmsloftið við móttöku og geymslu.

Samsvarandi tölur fyrir járnblendiverksmiðjuna á Grundartanga yrðu 140-180 tonn á ári. Hér er aðallega um að ræða kol og kvartsryk. Að sjálfsögðu hefur veðráttta hér mikið að segja. Raki minnkar rykmyndun en vindar auka hana (1., 12.).

1.2.2. Kvartspvottur

Nauðsynlegt er að þvo það kvarts sem notað verður í framleiðsluna. Þetta verður gert með því að sprauta vatni í gegnum kvartsið í sérstökum síum. Leir og þess háttar verður síðan látið setjast til í sérstökum þróm áður en þvottavatninu verður hleypt til sjávar.

Síðan verður að losna við úrgangsefnin úr þrónum á einhvern annan hátt. Magn þessa úrgangs er ekki þekkt (1., 12.).

1.2.3. Kvartsmölun

Mestur hluti þess kvarts sem notað verður hér kemur í hæfilegri stærð, samt sem áður verður að mala einhvern hluta þess. Mölunin fer fram í sérstakri mölunarstöð. Þar mun eiga sér stað allmikil rykmyndun, en allt það ryk sem þarna myndast verður leitt í sérstakar pokasíur þannig að ekki á nema lítil hluti þess að losna út í andrúmsloftið (1., 12.).

1.2.4. Blöndun hráefnis

Sérstök blöndunarstöð verður í verksmiðjunni. Allmikið magn af ryki myndast óhjákvæmilega um leið og blöndun fer fram. Þetta ryk verður leitt í gegnum sérstakar síur á sama hátt og rykið frá mölunarstöðinni (1., 12.).

1.3. Úrgangsefni frá verksmiðjunni

Í járnblandiverksmiðjunni á Grundartanga er ætlunin að framleiða 47000 tonn af 75% kísiljárni, FeSi. Langstærsti hluti úrgangsefna frá verksmiðjunni er svonefnt kísilryk sem myndast í bræðsluofnunum. Reiknað er með því að 21000 tonn af kísilryki myndist við framleiðslu á 47000 tonnum af 75% FeSi.

Auk ryksins myndast ávallt eitthvað af brennisteinsildi (SO_2) og kolsýringi (CO) í ofnunum. Magn SO_2 fer eftir brennisteinsinnihaldi kolanna sem notuð eru. Ef notuð eru kol með 1% brennisteinsinnihaldi verður magn SO_2 80-120 kg/klst að meðaltali eða 30-40 ppm sem verður að teljast fremur hátt.

Kolsýringur (CO) sá sem myndast í ofninum ætti að brenna svo til fullkomlega við yfirborð ofnhleðslunnar þar sem hann kemst í snertingu við ildi og hitastigið er mjög hátt. Það verður því væntanlega lítið sem ekkert af CO sem berst út í andrúmsloftið með útblæstri.

Fastur úrgangur annar en ryk er áætlaður um 2300 tonn á ári. Hér er um að ræða 1000 tonn af járnblandi sem myndast ofan á ofnhleðslunni en þetta magn er talið að unnt sé að selja úr landi til málmbræðslna. Þau 1500 tonn sem eftir eru, aðallega kerbrot og brot úr ofnunum er ekki unnt að nýta og verður því að losna við þennan úrgang út í umhverfið.

Um magn eiturefna í þessum úrgangi er lítið vitað. Engar grundvallarrannsóknir hafa farið fram á magni eiturefna til dæmis cyaníð sambanda á þeim stöðum þar sem þessi efni eru geymd. Í heimildum þeim sem tiltækar eru stendur fullyrðing gegn fullyrðingu. Sumir telja þennan úrgang algjörlega hættulausan en aðrir eru á gagnstæðri skoðun (8,12, 13, 14, 15, 26, 50, 52).

Svo vikið sé aftur að vandkvæðum sem óhjákvæmilega skapast vegna hins mikla rykúrgangs frá verksmiðjunni (21000 tonn á ári), ber að geta þess að á Grundartanga er ætlunin að nota svonefndar pokasíur til að fanga rykið frá ofnunum.

Tæknilegir ráðunautar verksmiðjunnar fullyrða að með þessum hreinsibúnaði megi ná 99% ryksins. Þess ber að geta að hér er átt við þyngd en ekki kornafjölda.

Hreinsibúnaður af þessari gerð nær best stærstu og smæstu rykögnunum en hæfni tækjanna er minnst gagnvart kornum af millistærð.

Ýmsir hafa orðið til þess að efast um hæfni þessara hreinsitækja og einnig að gagnrýna það að hæfni skuli vera gefin upp með tilliti til þyngdar ryksins en ekki fjölda rykkorna af ákveðnum stærðarflokkum sem sleppa (13, 26, 48, 51).

Miðað við það að 1% ryksins sleppi í gegnum pokasíurnar, losna um það bil 210 tonn á ári út í andrúmsloftið frá verksmiðjunni á Grundartanga.

Þá kemur upp sú stóra spurning hvað gert verður við allt það magn sem pokasíurnar ná að fanga?

Tæknilegir ráðunautar verksmiðjunnar hafa skrifað undir yfirlýsingu þess efnis að að minnsta kosti 80% ryksins verði endurnýtt það er sett aftur inn í ofnana og notað í stað kvarts, en eins og gefur að skilja byggist þessi möguleiki á því að meginefni ryksins er kísilsýra (Si O_2).

Þessir sömu menn telja ennfremur að ef til vill megi ná því takmarki að endurnýta allt að 90% ryksins (8, 15, 50).

Þrátt fyrir þetta verður þó að losna við 2000-4000 tonn af ryki á ári frá verksmiðjunni.

Uppi eru ýmsar hugmyndir um það hvernig best sé að koma þessu efni fyrir. Segja má að hæst hafi borið tvo möguleika í sambandi við verksmiðjuna á Grundartanga:

- 1) Að losa rykið á sérstaka staði í umhverfi verksmiðjunnar og jarða það þar.
- 2) Að reynt verði að komast að samkomulagi við Sementverksmiðju ríkisins á Akranesi að hún nýti rykið í sína framleiðslu. Talið er sennilegt að Sementverksmiðjan gæti nýtt allt að 7000-8000 tonn á ári (8,12,15,26).

Þrátt fyrir gefin fyrirheit um endurnýtingu ryksins hafa ýmsir leyft sér að efast um gildi þess.

Samkvæmt norskum heimildum má telja fullvíst að afkastageta verksmiðjunnar minnki um allt að 8% ef til endurnýtingar kemur. Einnig er talið að gæði framleiðslunnar minnki þar sem rykið hefur ekki sömu eiginleika og kvartsið (5).

Þá er einnig talið að endurnýting muni leiða til þess að mun meira verði af þungmálum í rykinu sem myndast.

Um magn þungmálma í ryki frá FeSi verksmiðjum er mjög lítið vitað. Það hafa ekki verið framkvæmdar margar efnagreiningar á rykinu.

Samkvæmt heimildum frá E.P.A. í Bandaríkjunum getur verið um allmikið magn þungmálma að ræða til dæmis var cadmiummagn í einu sýni sem getið er um 100-1000 ppm.

Það getur enda ekki talist óeðlilegt að nokkurt magn þungmálma sé í ryki sem þessu. Brotajárn inniheldur ávallt eitthvert magn þungmálma. Þar sem suðumark þessara málma er yfirleitt mun lægra en hitastigið í ofnunum hljóta þeir að gufa upp úr ofnhleðslunni og munu þá annað hvort þéttast utan um kísil-kornin eða berast beint upp úr verksmiðjunni út í andrúmsloftið.

1.4. Heimildir

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2. Undirbúningur lóðar - Útboðsgögn.
3. Appraisal study of industrial plant sites - Straumsvík - Geldinganes - Grundartangi - Galtarlækur
4. Engineering and cost study of the ferroalloy industry - EPA-450/2-008-74-008-May 1974
5. Røykrensing ved ferrolegeringsverk - Oslo janúar 1973
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Volume 1: Proposed standards EPA 450/2-74-018a.
Volume 2: Test data summary EPA 450/2-74-018b.
7. Viðræðunefnd um orkuferkan iðnað.
 - a) Bréf til Iðnaðarráðuneytisins 29.5.1974
 - b) Bréf til Heilbrigðis- og tryggingamálaráðuneytis 7.5.1974
 - c) Bréf til Heilbrigðiseftirlits ríkisins 29.5.1974
8. Málblendiverksmiðjan - Fundir með Union Carbide og EPA í USA 14.-17. jan. 1975. Skýrsla frá Steingrími Hermannssyni.
9. Skýrsla um sama efni frá Eyjólfri Sæmundssyni.
10. Bréf til Heilbrigðis- og tryggingamálaráðherra, Matthíasar Bjarnasonar, dags. 18.2. 1975
11. Umræður um málblendiverksmiðjuna, Cadmium o.fl. dags. 13.2. 1975. Baldur Johnsen (svar við skeyti frá Valgarði Egilssyni).
12. Greinagerð um hugsanlega mengun og mengunarvarnir, vegna fyrirhugaðrar járnblendiverksmiðju í Hvalfirði: Baldur Johnsen og Eyjólfur Sæmundsson.
13. Spurningalisti frá Heilbrigðiseftirliti ríkisins til Union Carbide.
14. Svör við þessum spurningum.
15. Bréf frá undirbúningsnefnd málblendiverksmiðju til Náttúruverndarráðs, dags 28.4. 1975.
16. Fundargerð frá fundi verkefnisstjórnar umhverfissrannsókna vegna járnblendiverksmiðju frá 13.5.1975.
17. Bréf frá Náttúruverndarráði til Líffræðistofnunar vegna umhverfissrannsókna dags. 5.5.1975.

18. Bréf frá Náttúruverndarráði til Viðræðunefndar um orkufrekan iðnað, dags. 4.7.1973.
19. Bréf frá Náttúruverndarráði til Heilbrigðiseftirlitsins, dags. 9.4.1975.
20. Fundargerð frá fundi í undirnefnd um málblendiverksmiðju, dags. 29.4.1975
21. Fundargerð frá 2. fundi verkefnisstjórnar 6.5. 1975.
22. Bréf frá Náttúruverndarráði til Iðnaðarráðuneytis, dags. 9.4.1975
23. Skýrsla um heimsókn til Norsk Hydro: Hjörleifur Guttormsson og Vilhjálmur Lúðvíksson.
24. Skýrsla frá sömu aðilum (H.G. og V.L.) um heimsókn í ferromangan verksmiðju (Elkem-Spiegerverket).
25. Skýrsla frá sömu aðilum (H.G. og V.L.) um heimsókn í Lista-álverið.
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27. Who is afraid of small particles?: Stanton S. Miller.
Small particles in air pose a big control problem: Sheldon K. Friedlander.
28. Skrá yfir framleiðslu og hráefnisnotkun verksmiðjunnar.
29. Control of emissions from ferroalloy furnace processing: R.A. Parson.
30. Forurensningsproblemer i norsk ferrolegeringsindustri: Helge Fredriksen Kjemi nr. 1/1972.
31. Trace metal pollution in the environment: Robert E. Zee and Darryl J. von Zehnden. Journal of the Air Pollution Control Association, Oct. 1973, Vol. no. 10.
32. a) The Significance of Particulate Emissions: John K. Burchard. Journal of the Air Pollution Control Association Dec. 1974. Vol. 24, no. 12.
b) Emission standards for particulates: George W. Walsh. Sama tímarit og 32a.
33. Bréf frá A/S Fesil & Co., Sverre Årseth, til Hjörleifs Guttormssonar, Náttúruverndarráði, dags. 15.4.75.
34. Bréf frá EPA (Randy D. Seiffert) til Steingríms Hermannssonar dags. 22.1.75

35. Bréf frá C.R. Allenbach (Union Carbide) til Eyjólfis Sæmundssonar, dags. 22.4.75
36. Federal register Vol. 39, no. 204, Part III -EPA- Ferroalloy Production Facilities - Proposed Standards of Performance for New Stationary Sources.
37. C.R. Allenbach - Efnagreiningar.
38. Upplýsingar til Elkem-Spiegerverket A/S - Bremanger Smelteverk frá Statens Foureensningstilsyn (Noregur - Röykskaderádet).
39. Efnagreiningar frá Union Carbide.
40. Elkem Silica - Main components.
41. Gjenvinning af rökstöv frá åpne FeSi og Si-metallovner. Foredrag ved N.I.F.'s konferanse 16.12.74 i Sarpsborg.
42. Statens Naturvårdsverk, Lars O. Schalin. Reserapport från besök vid Smältverken i Fiskaa, Kristiansand, Norge - etc.
43. Statens Naturvårdsverk, Lars O. Schalin. Särskild utredning om reningsanordningar vid smältungar för tilverkning av kisel.
44. Forurensningsproblemer ved drift af elektriske reduksjonsovner Aage Lömo.
45. Röykskaderádet 8.9.72 CK/mb. Myndighetenes behandling av ferrolegeringsindustrien i U.S.A. og Canada etc.
46. Almennar upplýsingar. Ferrosilikon, framleiðsla þess, notkun og markaður.
47. NLVF - Norges Landbruksvitenskaplige Forskningsråd. Utredning om bruk av Silica-stöv i landbruket.
48. Grein Einaris Vals Ingimundarsonar í Morgunblaðinu 10. jan. 1975.
49. Grein Baldurs Johnsen í Morgunblaðinu 18. jan. 1975.
50. Grein Steingríms Hermannssonar í Tímanum 8. feb. 1975.
51. Grein Valgarðs Egilssonar í Morgunblaðinu 21. mars 1975.
52. Grein Einaris Vals Ingimundarsonar í Þjóðviljanum, 12. apríl 1975.
53. Athugasemd frá Hjörleifi Guttormssyni varðandi rannsóknaráætlunina.

2. Heimildir um mengun með sérstöku tilliti til þungmálma og brennisteinstvíldis.

Heimildir þær sem hér um ræðir eru að mestu leiti fengnar þannig að keypt voru ljósrit af völdum greinum á "The British Library, Science Reference Library", en þar vann undirritaður í 10 daga í lok ágúst 1975 við öflun upplýsinga.

Eins og fram hefur komið í fyrri hluta skýrslunnar verður að telja allmiklar líkur á því að talsvert magn þungmálma losni út í umhverfi verksmiðjunnar á Grundartanga. Þar af leiðandi var lögð megin áhersla á að safna upplýsingum um mismunandi áhrif þungmálma á lífverur.

Vegna anna við sýnatöku á verksmiðjusvæðinu reyndist ekki unnt að eyða lengri tíma en 10 dögum í þessa upplýsingaöflun. Eins og gefur að skilja þá er þetta allt of stuttur tími til þess að gera úttekt á jafn yfirgripsmiklu efni og hér er um að ræða. Segja má þó að tekist hafi að fá allgott yfirlit yfir cadmium og blý en minna um aðra þætti.

Hafa verður einnig í huga að hér er í mörgum tilfellum um að ræða mjög sérfræðilegt efni og því varla á færi eins og sama aðila að gera þessu fullnægjandi skil.

Þessum síðari hluta skýrslunnar er skipt niður í fimm kafla: Cadmium, blý, aðrir þungmálmar, brennisteinstvíldi og heimildaskrá.

Kaflarnir eru þannig uppbyggðir, að fremst er stutt yfirlit um helstu atriði en þar á eftir fara ljósrit af titli og samantekt hverrar heimildar.

Heimildum er raðað þannig á kaflana að þær sem einungis fjalla um cadmium koma í kafla 2.1., um blý í kafla 2.2. Þær heimildir sem fjalla um aðra þungmálma koma í kafla 2.3. í þessum kafla eru einnig þær heimildir sem fjalla um cadmium og/eða blý ásamt öðrum þungmálmum. Heimildir um brennisteinstvíldi koma í kafla 2.4. einnig eru í þessum kafla tvær heimildir sem fjalla um mælingar á magni ryks frá FeSi-verksmiðjum.

2.1. Cadmium.

Með aukinni iðnvæðingu hefur magn ýmissa þungmálma í umhverfinu farið hratt vaxandi. Einn þessara þungmálma er cadmium. Það hefur lengi verið vitað að cadmium málmurinn er mjög eitraður, en það er þó fyrst fyrir tiltölulega stuttu að menn fara að hafa verulegar áhyggjur af samsöfnun þessa efnis í umhverfinu.

Það má segja að áhugi manna á líffræðilegum áhrifum cadmiums hafi fyrst vaknað fyrir alvöru þegar fram kom sjúkdómurinn itai-itai í Japan (þetta er sjúkdómur í lifur, nýrum og beinum).

Rannsóknir sýndu að þennan sjúkdóm mátti rekja til óeðlilega mikils cadmium magns í ákveðnum líkamsvefjum sjúklinganna. Sjúklingarnir áttu það sameiginlegt að hafa dvalist lengi í cadmium menguðu umhverfi og líkami þeirra hafði smám saman safnað í sig allmiklu magni af cadmium. Leið cadmiums inn í mannslíkamann liggur um meltingarfæri og öndunarfæri, þ.e. úr fæðu og drykkjarvatni eða úr andrúmslofti. Vitað er að margar lífverur, bæði plöntur og dýr, safna cadmium í vefi sína.

Plöntur taka cadmium úr jarðvegi og er magn efnisins mun meira í plöntum á menguðum svæðum en á ómengduðum. Í jarðveg getur cadmium borist með jarðvatni, úr andrúmslofti og með áburði.

Af þessu leiðir að ræktun nytjaplantna t.d. hrísgrjóna og hveitis á cadmium menguðum svæðum er stórvarasöm.

Styrkur cadmiums í dýravefjum er mestur í lifur og nýrum þar sem málmurinn virðist vera bundinn uppleystu eggjahvítu efni.

Skeldýravefir innihalda einnig oft allmikið magn af cadmium. Athuganir á tilraunadýrum hafa leitt í ljós að cadmiumgjöf veldur ýmsum breytingum á starfsemi líkamans t.d. hækkar blóðþrýstingur og skemmdir koma fram á eistum, nýrum og lifur.

Athuganir á japönum hafa sýnt að cadmium sem safnast fyrir í líkamanum er í lang mestu magni í nýrum og lifur (50-75% af heildar cadmiummagni líkamans).

Cadmium veldur skemmdum og truflun á starfsemi nýrna (proteinuria). Í tengslum við þetta er einnig talið fullvíst að cadmium valdi breytingum á kalsíum og fosfórefnaskiptum líkamans sem orsakar minnkandi kalkmagn í beinum (osteomalacia). Blóðsjúkdómar og

lifransjúkdómar hafa einnig komið í ljós hjá tilraunadýrum og mönnum. Sjúkdómar í öndunarferum hafa einnig fundist (lungna-
bjúgur, lungnapemba).

Þekking á hegðun cadmiums úti í náttúrunni er af mjög skornum skammti. Gerðar hafa verið einstakar athuganir á lífverum en segja má að langtíma rannsóknir á hegðun cadmiums innan vistkerfis hafi ekki farið fram. T. d. skortir nær algjörlega vitneskju um það í hve miklu mæli cadmium safnast fyrir í fæðukeðjum. Talið er þó að aukning cadmiummagns upp eftir fæðukeðjum eigi sér ekki stað í jafnríkum mæli eins og t.d. þegar kvikaslifur á í hlut. Ástæðan fyrir þessum mismun er fyrst og fremst sú að cadmium er lausar bundið en kvikasilfur innan vefja lífvera.

Telja verður mjög brýnt að afla nánari vitneskju um hringrás þessa efnis innan vistkerfa.



Heimild nr. 1

Cadmium in the Environment

Second Edition

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with technical and editorial
assistance from
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Chapter 1

INTRODUCTION

The second edition of *Cadmium in the Environment* updates the earlier review on cadmium carried out under a contract (No. CPA 70-30) between the U.S. Environmental Protection Agency and the Department of Environmental Hygiene of the Karolinska Institute, Sweden. The earlier report to the EPA, with modifications, formed the basis for the first edition of *Cadmium in the Environment*, which was published by CRC Press in 1971. The collaboration between the two institutions continues (contracts 68-02-0342 and 68-02-1210) and has resulted in a second report to the EPA in 1972. The project officer from the U.S. Environmental Protection Agency has been Robert J. M. Horton, M.D.

The second edition of *Cadmium in the Environment* presents and in some cases reevaluates all information contained in the first edition, in the second EPA report, and subsequent findings, published as well as unpublished, up to and including part of 1973. Like the first edition, the present work focuses upon information essential to the understanding of the toxic action of

cadmium and the relationship between exposure and effects on human beings and animals.

Through repeated personal contact with several Japanese researchers, including a 5-week visit to Japan by one of the authors (Dr. Tord Kjellström), it has been possible to obtain and evaluate much data from Japan which would not have been accessible otherwise. Papers published in Japanese could be taken into account as well since Dr. Kjellström speaks and reads Japanese.

We express our gratitude to the Environmental Agency of Japan, particularly to Dr. Yoshimasa Yamamoto, Chief of the Section of Environmental Health and Public Hazards, as well as to the Prefectural Institutes of Hygiene and Departments of Public Hazards in Fukushima, Gumma, Hyogo, Nagasaki, Miyagi, and Toyama as well as the Japanese Association of Public Health. Valuable information and assistance have been received from several independent researchers. Kenzaburo Tsuchiya, M.D., Professor of Preventive Medicine and Public Health, School of Medicine, Keio University, assisted us in planning and executing valuable visits in Japan.

Heimild nr. 2

A FOOD CHAIN MODEL OF CADMIUM IN WESTERN LAKE ERIE

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(Received 12 January 1974)

Abstract—The simple food chain model illustrated here could prove useful in large scale planning applications provided additional data are collected on the various trophic levels. The model demonstrates the increase in concentration of potentially toxic substances, such as cadmium, as one proceeds up the food chain. The food chain model also illustrates how interactive modeling between complex non-linear and linear compartment model can be accomplished. The problem of verification and data availability are highlighted by the model: estimates of transfer rates and biomass of different trophic levels must be on hand. This model therefore is an example of a modeling structure that is still in an early stage of development; hence the reliance on linear kinetics rather than possibly more realistic non-linear mechanisms. Nevertheless, the spatial-trophic level structure of the model indicates the general behavior of a toxicant such as cadmium when released into the water environment.

Heimild nr. 3

THE CHEMISTRY OF CADMIUM IN NATURAL WATER—I A STUDY OF CADMIUM COMPLEX FORMATION USING THE CADMIUM SPECIFIC-ION ELECTRODE

J. GARDINER

Water Pollution Research Laboratory, Department of the Environment, Stevenage, England

(Received 16 June 1973)

Abstract—The extent of formation of labile complexes of cadmium has been investigated in synthetic solutions and in real samples. A substantial proportion of the total cadmium in river and lake water will usually be present as the free cadmium ion, and this proportion will be larger the lower the pH value and the lower the proportion of sewage effluent present in the water. Humic substances usually account for most of the complexation, followed in importance by carbonate, the complex of which with cadmium has not been reported previously.

Heimild nr. 4

THE CHEMISTRY OF CADMIUM IN NATURAL WATER—II. THE ADSORPTION OF CADMIUM ON RIVER MUDS AND NATURALLY OCCURRING SOLIDS

J. GARDINER

Water Pollution Research Laboratory of the Department of the Environment,
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(Received 24 September 1973)

Abstract—The adsorption of cadmium on mud solids and particles of clay, silica, humic material and other naturally occurring solids has been studied. Radiochemical methods were employed so that cadmium concentrations in the $\mu\text{g l}^{-1}$ range could be used. The variation of the extent of adsorption with many of the large number of factors involved was investigated, concentration factors (distribution coefficients) were determined, and in the course of the work, loss of cadmium by adsorption on container surfaces and filters was investigated.

Rates of adsorption and desorption were shown to be rapid. Concentration factors for river muds varied between 5000 and 50,000 and depended mainly on the type of solid, its state of subdivision, the concentration of metal ion present, the time of contact and the concentration of complexing ligands. Humic material appeared to be the main component of river mud responsible for adsorption. Adsorption and desorption processes are likely to be major factors in controlling the concentration of cadmium in natural waters and will tend to counteract changes in the concentration of the metal ion in solution.

Aust. J. mar. Freswat. Res., 1974, 25, 97-104

Heimild nr. 5

Toxicity Bioassays of Cadmium on Selected Freshwater Invertebrates and the Interaction of Cadmium and Zinc on the Freshwater Shrimp, *Paratya tasmaniensis* Riek

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Abstract

In acute toxicity bioassays with cadmium sulphate at 15°C in soft water (total hardness 10 mg/l as calcium carbonate), the concentrations fatal to 50% of the test animals were determined for five freshwater invertebrate species. The 96 hr median lethal concentration (LC50) of cadmium was 0.04 mg/l for the amphipod *Austrochiltonia subtenuis* Sayce, 0.06 mg/l for the shrimp *Paratya tasmaniensis* Riek, 0.84 mg/l for the ephemeropteran nymph *Atalophlebia australis* Walker, 250 mg/l for the zygopteran nymph *Ischnura heterosticta* (Burmeister) and well over 2000 mg/l for a trichopteran larva of the Leptoceridae. The bioassays on *Paratya* indicated that there may be seasonal differences in sensitivity to cadmium. The 96 hr LC50 for zinc for *Paratya* was 1.21 mg/l. Zinc and cadmium appeared to interact less than additively at concentrations below 1 toxic unit. Above this concentration, their interaction was strictly additive.

The Effect of Cadmium on Population Growth
of the Green Alga *Scenedesmus quadricauda* Heimild nr. 6

by EVAN KLASS, DONALD W. ROWE, and EDWARD J. MASSARO

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Increasing industrial utilization has led to increasing levels of bioavailable cadmium (Cd) in the environment (Kopp and Kroner, 1969; Lucas et al., 1970; Uthe and Bligh, 1971). The United States Department of Health, Education and Welfare has set the acceptable upper limit of Cd in drinking water at 10 ppb. This level is exceeded in many municipal water supplies (Flick et al., 1969, Kopp and Kroner, 1969; Durum and Hem, 1972; Cheremisinoff and Habib, 1972) and natural water bodies (Taylor, 1971; Kobayashi, 1972; Piley and Taylor, 1972; Abdullah et al., 1971; Ritchie, 1973). Moreover, Yamagata and Shigematsu (1970) state that even if Cd is undetectable in the water phase, large concentrations may be found in suspended particulate matter and sediment.

Little information is available regarding the effect of Cd²⁺ on aquatic plants, particularly at the primary producer level. Cadmium has been found to accumulate in the Southern Naiad *Najas quadulepensis* (Cearly and Coleman, 1973). At a concentration of 7 ppb, exposure for 21 days resulted in accumulation of 7.1 ppm ($\mu\text{g Cd/g}$ ashed tissue). At concentrations of 90 and 830 ppb, tissue concentrations of 4357 and 5429 ppm were attained. Witkamp et al. (1971) reported that ¹¹⁵Cd was rapidly sorbed (5-15 min) by algae (species not specified) and that the concentration factor for ¹¹⁵Cd was approximately 1000.

Herein, we report preliminary observations on the toxicity of cadmium to the freshwater alga *Scenedesmus quadricauda*.

Heimild nr. 7

Cadmium Accumulation in Rat Liver

Anthony V. Colucci, ScD; Dennis Winge; James Krasno, MD

The biochemical accumulation and clinical pathological conditions induced by intraperitoneal administration of cadmium was studied in Sprague-Dawley rats. Injected doses of cadmium ranging from 0.5 to 3 mg/kg of body weight were administered. Distribution studies of Cd

in the liver indicated the metal was bound to a soluble protein, and that the amount of metal present increases with increasing dosage.

The pathological changes were found to correlate better with hepatic concentration of metal than with the injected dose.

Cadmium Toxicity and Bioconcentration in Largemouth Bass and Bluegill

by

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Cadmium is one of the heavy metals of current interest in environmental contamination, primarily because of its highly toxic properties, its common occurrence in industrial discharges, and its existence in natural waters as a very high potential pollutant (BOWEN 1966). In addition to the direct toxicity of cadmium to fish, another and possibly more serious threat exists through the ability of these organisms to concentrate this metal. For example, an adult organism may accumulate a quantity of metal that does not cause death, but may be deleterious to some other stage of the life cycle (BRUNGS 1969).

The purpose of the present study was to detect and evaluate the effects of subacute exposure to cadmium in the largemouth bass and bluegill. Evaluation of toxicological effects was based on observations of behavioral effects, rate of growth, survival, and tissue and organ accumulation of cadmium.

Summary

The exposure of juvenile largemouth and bluegill to cadmium (0.0005 to 0.85 mg/liter) resulted in accumulation of this metal in concentrations greater than those of the water. The quantity of metal accumulated increased as the exposure concentration increased. An equilibrium developed between the concentrations of the metal in the water and in the tissues after approximately 2 months. Metal accumulations on the bass tissues were higher in the internal organs, followed by the gills and the remainder of the body.

The bass were more sensitive to cadmium than the bluegill. Abnormal behavior patterns observed in both species suggested that the nervous system was the site of damage.

Cadmium and Zinc in Pregnancy and Lactation

*Ojars J. Lucis, MD, PhD; Ruta Lucis, PhD; and
Zahir A. Shaikh, PhD, Halifax, Nova Scotia, Canada*

Radioactive cadmium (^{109}Cd) and zinc (^{65}Zn) were injected subcutaneously into pregnant rats. More cadmium than zinc was found in the placenta. After birth, newborns showed detectable ^{109}Cd only in liver, gastrointestinal tract, and in the brain tissue. Zinc 65 was present in all newborns' tissues. During lactation, highest output of ^{65}Zn was in colostrum and, on subsequent days, ^{65}Zn in milk declined rapidly. Cadmium 109 in milk was present in low concentration throughout the lactation period. Rats injected

with ^{109}Cd and ^{65}Zn after parturition excreted these isotopes in milk in a similar pattern. Newborns nursed on radioactive milk showed rapid absorption of ^{65}Zn , whereas ^{109}Cd accumulated primarily in the intestinal tract; a lesser quantity of ^{109}Cd was deposited in the liver. In other organs, only ^{65}Zn was found. The lactating mammary gland contained more ^{109}Cd than ^{65}Zn ; after lactation, ^{65}Zn was depleted, whereas ^{109}Cd remained in mammary tissue.

Cadmium-Binding in Human Liver and Kidney

Heimild nr. 10

Tore L.M. Syversen, MSc

Autopsy specimens of liver and kidneys from 40 patients have been analyzed for cadmium and zinc. Sephadex chromatography was performed on soluble extracts from these tissues. In samples from 19 patients a cadmium-binding protein was found.

The mean cadmium content of kidney in this group was higher than the corresponding value for all 40 patients. A molecular weight of 10 to 12,000 was estimated for the cadmium-binding protein by Sephadex chromatography. Isoelectric focusing resolved two peaks with pI 4.8 and

pI 6.0, the OD_{254}/OD_{280} ratio for both peaks being about 5.

These data indicate that humans without known occupational exposure to cadmium do have a cadmium-binding protein similar to metallothionein in their liver and kidney.

Factors Affecting Plant Uptake and Phytotoxicity of Cadmium Added to Soils

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Heimild nr. 11

For a set of 30 surface soils, addition of 50 mg of cadmium, from $CdCl_2$, to 500 grams of soil reduced yields and sharply increased cadmium levels in analyzed portions of radish and lettuce plants when compared with those plants grown on control soils. For the treated soils, plant cadmium was significantly related to cadmium extracted from soil by neutral N ammonium acetate. The N HCl and N HNO₃ extractions did not indicate plant availability but removed most of the soil cadmium. From among 18 potential independent variables, stepwise linear regressions to predict cadmium found in plant parts harvested from treated soils included a measure of the relative ability of soils to adsorb cadmium, acetate-soluble cadmium in the soil, soil reaction, and organic matter as significantly contributing independent variables. Plant cadmium levels were significantly correlated with amounts of Ni, Fe, Zn, and Cu in the same plant portion.

Summary and Conclusions

Among studies of factors influencing the assimilation of heavy metals by plants, investigation of cadmium uptake may be most important. The cadmium content of treated soils in this study exceeded levels which occur in surface agricultural soils. John et al. (1972) found cadmium content of 33 such soils averaged 0.88 ± 0.79 ppm HNO₃-soluble cadmium and ranged from undetectable amounts to 4.67 ppm. However, localized contamination of soils attributed to agricultural chemicals or metallurgical and other industrial sources could, and are shown to (John et al., 1972), attain the level of soil contamination studied. When 50 mg of cadmium was added to 500 grams of soil, the cadmium concentrations in the edible portions of radishes and lettuce harvested from 30 different soils averaged 387 ppm and 138 ppm in dry tissue, respectively. The allowable level for foodstuffs, arbitrarily set at 0.5 ppm of cadmium on a wet-tissue basis, may be exceeded easily when certain soils are contaminated. Results of this study indicated that the cadmium pollutant may readily be taken up from the soil and may result in potentially hazardous accumulation of cadmium in plants. Besides its effect on the cadmium levels, the treatment produced toxicity symptoms and reduced yields.

The cadmium content of plant parts was related to amounts of exchangeable cadmium in the contaminated soil (measured by extraction with normal ammonium acetate) rather than to total amounts of cadmium added to the soil (estimated closely by N HCl and N HNO₃ extractions). The ability of the soils to adsorb cadmium was inversely correlated with plant cadmium levels and was the most important single factor in explaining variations in cadmium in radish plant parts. Increased soil acidity was associated with higher plant levels of cadmium while increased organic matter content provided added capacity for adsorption of cadmium by the soil and was therefore related inversely to cadmium in the plant parts.

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Heimild nr. 12

CADMIUM: BIOLOGICAL EFFECTS AND OCCURRENCE IN THE ENVIRONMENT

♦6628

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It is only in recent years that there has been concern with cadmium as an environmental contaminant. Although the acute toxic properties of the soluble salts were known over one hundred years ago, the total usage was small, mainly as insoluble pigments. The recognition of its valuable metallurgical properties, such as corrosion resistance, led to increased metal production after 1910 from about 100,000 lb per year to 31,000,000 lb per year in 1968. Exposure of workers to the fumes of the oxide was recognized to be the cause of an acute and sometimes fatal pulmonary edema.

In 1950, Friberg (1) called attention to renal disease and emphysema in workers exposed to cadmium oxide dust over long periods in a battery plant. About this time, Japanese physicians were studying a unique disease in elderly women who had borne many children. The disease was characterized by osteomalacia, proteinuria, and glycosuria. These women had lived for many years in an area contaminated by mine drainage. It was concluded that the disease had been caused by a greatly increased intake of cadmium and possibly other metals in water and rice, plus a low calcium and Vitamin D intake, stresses of pregnancy and lactation, etc. The disease was reported in the English literature about 1969 by Tsuchiya (2) and was called Itai-Itai (ouch-ouch) disease, because of the severe bony pain.

In the meanwhile, biochemical and toxicologic studies had shown that the very small amount of cadmium (Cd) normally absorbed tended to be retained for long periods, particularly in the kidney, and proteinuria was noted when kidney concentrations reached a certain level. The discovery of a specific Cd and Zn binding protein in the liver and kidney and of various interactions between Cd, Zn, and Cu led to a great interest in cadmium toxicology and to consideration as to the role it might play in diseases such as hypertension.

As a consequence of all the above complex and interesting findings, a very large literature on cadmium has appeared in the past few years. Much of it has appeared

Heimild nr. 13

Cadmium in Plants

By HANSFORD T. SHACKLETTE

CONTRIBUTIONS TO GEOCHEMISTRY

GEOLOGICAL SURVEY BULLETIN 1314-G

*An account of the concentrations of cadmium
in plants from areas that have normal or
anomalous amounts of this element
in the air or soil*



DISCUSSION AND SUMMARY

Reliable estimates of typical cadmium concentrations in plant tissues are difficult to make because of the great variability in cadmium content among the different plant species and plant organs. Moreover, reports in the literature use different bases for computing cadmium concentrations in plants. For example, Malyuga (1964, p. 15) gave the cadmium concentration in plant ash but did not give the percentage of ash obtained from the dry tissue; Schroeder and Balassa (1963) gave cadmium values based on the wet weight of vegetables but gave neither the percentage of water nor the percentage of ash in the samples, and Hanna and Grant (1962), among many others, gave cadmium concentrations on a dry-weight basis but did not give the ash yield of the samples. Data on cadmium in plants that are presented for the first time in this report include cadmium concentrations in both ash and dry tissue, or give the concentrations in ash and the ash yield of the dry material with an equation that can be used to determine approximate cadmium concentrations in the dry tissue.

Another source of inconsistency in the reported data on cadmium in plants is the difference in methods of analysis that were used to obtain the data. Methods that were used included acid digestion and atomic absorption, acid digestion and polarography, X-ray emission, neutron activation, and ashing by heat followed by emission spectrographic analysis of the ash. Some reports do not specify the analytical method that was used. This report does not attempt to judge the relative accuracy and precision of analyses determined by these different analytical methods.

To summarize data from the numerous reports of cadmium in plants, a table has been prepared that gives estimates of cadmium concentrations in plants or plant parts from environments presumed to have the normal low levels of cadmium, and in those from environments reported to have greater than normal levels of cadmium (table 3). Because most reports give cadmium on a dry-weight basis but do not give ash weights, the data from other reports were converted to parts per million in dry plant material. Some data based on ash weight, but without the ash yield being given, were converted to approximate concentrations in dry weight by assuming a reasonable ash yield for the particular kind of plant tissue that was analyzed. In instances of conflicting data, personal judgment was used in selecting the data to include in the table.

The values given in table 3 must be used with caution in evaluating specific problems of cadmium content in plants. The categories of plants and plant parts used in this table were, of necessity, often very broad and doubtless included certain species or varieties and plant parts whose normal cadmium contents differ greatly from the value given for the category. It should be noted that some of the cadmium values in the table were based on very few samples. Furthermore, for some kinds of plant materials, the cadmium concentrations in the environments where the plants grew were only loosely characterized, or were unknown.

Concentrations of cadmium in Spanish moss can be used to give estimates of the relative amounts of airborne cadmium at different localities within the regions where this plant occurs. Samples that contained the highest concentrations of cadmium were from locations where greater than normal levels of cadmium in the air were expected to occur as a result of industrial, domestic, and vehicular emissions. In contrast, samples that contained the lowest concentrations were from locations apparently remote from sources of significant cadmium pollution. Samples having cadmium concentrations in the central range of values could not be adequately evaluated without more detailed studies of the environments from which the samples came.

The yield of ash obtained by burning Spanish moss plants provides an estimate of the relative total particulate contamination of the air at the different localities where the samples originated.

TABLE 3. — Estimates of cadmium concentrations (parts per million in dry material) in some plants and plant parts

[....., no data available; <, less than the value stated]

Kind of plant or plant part	Reported or estimated cadmium concentrations, or ranges in concentrations	
	In environments presumably having normal cadmium levels	In environments having greater than normal cadmium levels
Marine algae.....	0.1-1	.....
Mosses (bryophytes).....	0.7-1.2	8-340
Lichens (fruticose type).....	0.1-0.4	1
Grasses.....	0.03-0.3	0.6-40
Alfalfa.....	0.02-0.2	¹ 0.2-2.4
Grains:		
Corn (<i>Zea mays</i>).....	0.1	2
Rice (polished).....	.....	0.5
Barley, wheat, and oats.....	0.1-0.5	² 0.1-1.5
Vegetables:		
Asparagus.....	.....	8
Beet root.....	.05	0.24
Cabbage leaves.....	.05	6-12
Carrots.....	<.35	8
Chinese cabbage.....	.....	41
Eggplant fruit.....	.....	8
Kale.....	1	.....
Leafy vegetables used as pot herbs or salads.....	0.3-0.5	3-50
Leeks.....	.....	14
Lettuce.....	0.3-0.5	4-16
Potatoes.....	0.05-0.3	0.6-2
Spinach.....	0.6-1.2	.....
Turnip roots.....	.....	5
leaves.....	.....	15
Tomatoes.....	.....	2
Trees, deciduous:		
Leaves.....	0.1-2.4	4-17
Stems (branches).....	0.1-1.3	0.14-1.5
Trees, coniferous:		
Leaves.....	0.1-0.9	0.05-1
Stems.....	.....	0.03-1.5
Epiphytes (Spanish moss).....	0.1	1
Floating aquatic plants (duckweed).....	.....	17
Marine flowering plants (<i>Zostera marina</i>).....	0.23	.....

¹Original data given in wet weight; converted to concentration in dry material by assuming 25 percent water in original sample.

²Original data given in wet weight; because the water content of grains is very low, these values were not converted to a dry weight basis.

Excessive contamination of the plants by particulate soil materials reduces the reported cadmium values in the plant ash, whereas if the particulate material originated from combustion of hydrocarbons or from certain industrial processes, increased surficial contamination is thought to increase the reported cadmium values in the plant ash.

CONCLUSIONS

Cadmium in low concentrations most likely is a normal constituent of all plant tissues. The concentration in the tissue is determined by the inherent ability of a plant species to absorb cadmium and by the cadmium concentration in the environment. At low levels of cadmium in soils, differences in cadmium content among plant species commonly are greater than differences in amounts of cadmium in the soils where the plants grew. Beyond certain background amounts of cadmium in soils, the cadmium content of plant tissue tends to increase with increased concentrations of cadmium in the soil.

Airborne cadmium, originating in emissions from the combustion of hydrocarbons or from certain industrial processes, may enter the soils and be absorbed by plants, or may be deposited on the surface of plants in particulate matter, until very high levels of cadmium are accumulated by the plant. There appears to be no natural means by which cadmium is eliminated from plant tissue, and no cultural practice has been found effective in reducing or preventing the absorption of cadmium by plants.

Heimild nr.14

Lithium in Surficial Materials of the Conterminous United States and Partial Data on Cadmium

By Hansford T. Shacklette, Josephine G. Boerngen,
James P. Cahill, and Ramona L. Rahill

GEOLOGICAL SURVEY CIRCULAR 673

bounded on the east and west by the typically low to medium values of the Atlantic Coastal Plain region—a pattern characteristic of most metals in soils (Shacklette, Hamilton, and others, 1971, p. D6). Areas having high values are apparent in the Appalachian Highland region, in Nevada, and on east-west routes across the central part of the Cordilleran Mountain region.

Because lithium has many industrial uses, contamination of soils by this element may be expected. Lithium-type greases, for example, are widely used on industrial and agricultural machinery. The United States produced more than 200 million pounds of these greases in 1958 (Kolfenbach and Morway, 1959, p. 22). Bradford (1966, p. 221) listed and discussed practices which may produce lithium toxicity as follows: "Acidification of some neutral or alkaline soils; irrigation with water containing lithium; and contamination of soils or irrigation waters from industrial wastes containing lithium. The production of lithium and its compounds has increased enormously since the development of atomic energy, and consequently these materials are finding many valuable applications in science and industry." He stated further that lithium compounds are used in the rubber, ceramic, and cement industries.

CADMIUM

ANALYTICAL METHOD

The procedure used for cadmium analysis is an adaptation of the method described by Nakagawa and Harms (1968). Transfer a 1-gram dry sample into a 20x200-mm pyrex culture tube. Moisten the sample with water and place a 1-cm teflon magnetic stirring bar in the tube. Add 5 ml HNO₃ and boil and stir the sample for 20 minutes. Wash the tube walls with approximately 10 ml of water and boil the sample for an additional 10 minutes. Remove the tube and cool the sample, then dilute the sample to a

final volume of 20 ml. Measure the cadmium content of the sample solution by aspirating part of the solution into an atomic-absorption spectrometer using a wavelength of 2,288 microns. Other instrumental parameters include an air-hydrogen oxidizing flame and a laminar single-slot burner 10 cm long.

All samples in this study were scanned by use of the HNO₃ atomic-absorption method. A few samples contained large amounts of calcium; these samples were analyzed also by an organic extraction-atomic absorption procedure because high concentrations of calcium are known to interfere with the determination of cadmium. This extraction procedure, developed by Cahill, consists of HNO₃ dissolution and adjustment to pH 8 with NH₄OH. The cadmium is then extracted with 10 ml of *n*-butyl acetate made to contain 2 percent 2-mercaptobenzothiazol (MBT). Measure the cadmium content of the organic phase by atomic absorption, using an air-hydrogen flame and the previously mentioned instrumental parameters. The lower detection limit of this method is 1 ppm.

RESULTS OF ANALYSES

Because of insufficient sensitivity (1 ppm) of the analytical method, cadmium concentrations could be measured in only 11 of the 912 samples analyzed. Cadmium concentrations in the other 901 samples were determined to be less than 1 ppm. The location and description of sample sites where surficial materials contained measurable amounts of cadmium, and the cadmium concentration measured, are given in table 2.

DISCUSSION

Underwood (1971, p. 276) stated:

Data on the sources of cadmium to man and domestic animals are exceedingly meager. The factors that affect the magnitude of normal intakes and the movements of cadmium from soils and plants to animals and man have also been little studied. This is a serious gap in knowledge, in view of the geographical differences

TABLE 2.—Location and description of sample sites where surficial materials contained measurable amounts of cadmium and the cadmium concentration measured, in parts per million.

Sample No.	State	County	Locality and description of sample	Cadmium, in dry material
GC 0422 ..	Ohio	Auglaize	U.S. Highway 33, 1 mile northwest of Lakeview; brown silty loam, cultivated	1.0
0560 ..	Wisconsin	Polk	State Route 35, 2 miles south of Luck; yellow sandy loam	1
0602 ..	California	Kern	Junction of State Route 33 and unnumbered road, 10 miles northwest of Button Willow; B horizon soil	1
1521 ..	Texas	Harris	U.S. Highway 90, 2 miles east of Addicks; dark alluvial clay	1
1558 ..	Kansas	Bourbon	U.S. Highway 54, 10 miles west of Fort Scott; dark prairie soil over limestone	1.5
1851 ..	Colorado	Moffat	U.S. Highway 40, 8 miles east of Massaduna; brown clayey silt	1
1913 ..	New Mexico	Chaves	U.S. Highway 70, 18 miles southwest of Roswell; very dry tan soil with many chert fragments	1.5
2427 ..	California	Nevada	Junction of U.S. Highway 40 and State Route 20, near Cisco; B horizon soil	1
2431 ..	California	Santa Clara	U.S. Highway 101 at State Route 152 exit, Gilroy; B horizon soil	10
2671 ..	South Dakota	Brown	State Route 37, 1 mile south of Grotton; gray-mottled B horizon lacustrine clay, in grassland	1
2706 ..	California	Shasta	In Lassen Volcanic National Park, 3 miles southeast of Mamamita Lake; B horizon soil	1

in human renal cadmium levels and their increase with age, the toxicity of this element, and the possible association of cadmium with human hypertension. The interactions of cadmium with zinc, copper, iron, and selenium also indicate the need for more information on sources of cadmium to man and animals.

Cadmium concentrations in various plants, including food plants, were given by Shacklette (1972). Analyses of cadmium concentrations in soils have been hampered because of insufficient sensitivity of available analytical methods. The concentrations commonly found in ordinary soils are at or below the detection limit of the methods that are used. Swaine (1955, p. 20) wrote: "It is unlikely that normal soils would contain more than c.[circa] 1 ppm Cd." Vinogradov (1959) gave 0.5 ppm as the "average" concentration of this element in soils; the same value was given as a "suggested" average by Warren, Delavault, and Fletcher (1971, p. 2).

Miesch and Huffman (1972, p. 76-77) reported cadmium concentrations in upper and lower soil horizons from the Helena Valley area, Montana, where pollution from smelters is widespread. In regard to soils just outside the immediate Helena Valley area they stated: "The mean is estimated to be approximately 0.8 ppm, and the range is from less than 0.5 to 2 ppm." Within the Helena Valley area they observed that:

The highest cadmium content was found in soils collected near the smelter stack; approximately 150 ppm cadmium was found in samples collected from the upper 4-inch soil layer 0.67 mile northwest of the stack along traverse C. The cadmium content of the upper 4-inch soil layer, like the lead and zinc content, decreases systematically with distance from the stack, but no soils taken beyond a distance of about 5 miles from the stack were found to contain more cadmium than those soils sampled outside the Helena Valley. This does not necessarily mean that cadmium contained in smelter stack emissions is less widely dispersed than lead or zinc; cadmium is more difficult to assess because it is less abundant. The cadmium content of soils collected at a depth of 6 to 10 inches is one-fifth to one-tenth of that in soils of the upper 4-inch layer, indicating that the chemical mobility of cadmium in the soils is somewhat greater than that of lead, but less than that of zinc. This is in accord with the observed general behavior of cadmium in soils as reported from studies in geochemical prospecting.

In the present study, regional trends in cadmium concentrations in soils cannot be demonstrated by the very few reported cadmium values. Likewise, the "average" soil cadmium value of 0.5 ppm, as given by Vinogradov (1959) and by Warren, Delavault, and Fletcher (1971), cannot be evaluated by using our data because of the limitation in sensitivity of the analytical method that was used for samples in this study. The depth at which these samples were collected (about 8 in.) most likely precludes airborne industrial contamination of most samples, if judged by the results of Miesch and Huffman (1972), who reported greatly reduced cadmium levels with increasing depth of soil sampling. Nonetheless, the high value of 10 ppm cadmium in the Santa Clara County, Calif., sample probably represents contamination from some unidentified source.

Hypertension induced in rats by small doses of cadmium¹

HEMILDA nr. 15

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SCHROEDER, H. A., AND W. H. VINTON, JR. *Hypertension induced in rats by small doses of cadmium.* Am. J. Physiol. 202(3): 513-516. 1962. Female rats on a cadmium-free diet exhibited fluctuating systolic hypertension when given cadmium in drinking water at subtoxic levels (5 ppm) from the time of weaning for 180-240 days. Relatively small accumulations of cadmium in kidney and liver were present, and hypertension was the only sign of toxicity. Male rats failed to show more

than a tendency to hypertension when treated similarly. When rats were given choices of sodium chloride in drinking water, females took more water and two to three times as much salt as did males. Animals exposed to sodium chloride drank more water than did those not exposed, whether given cadmium or not. The presence of cadmium and/or hypertension at these concentrations did not affect the intake of salt or water.

INFLUENCE OF CADMIUM IONS ON THE TRANS- MEMBRANE POTENTIAL AND CONTRACTILITY OF ISOLATED RABBIT LEFT ATRIA

Heimild nr. 16

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Accepted for publication March 21, 1973

ABSTRACT

TODA, NOBORU: Influence of cadmium ions on the transmembrane potential and contractility of isolated rabbit left atria. *J. Pharmacol. Exp. Ther.* 186: 60-66, 1973.

In isolated rabbit left atria Cd^{++} (0.02-0.5 mM) caused a marked depression of the action potential and a slight decrease in the resting potential and the 10% duration. In more than half of the atria exposed to 0.5 mM Cd^{++} , action potentials were totally abolished with a slight reduction of the resting potential. Parameters of the transmembrane potential recorded from control preparations were not affected by cysteine (1 mM). The inhibitory effect of Cd^{++} was partly reversed by cysteine, excess Ca^{++} and ethylene glycol bis(aminoethyl ether)- N,N,N',N' -tetraacetic acid. In atria in which action potentials were totally abolished by 0.5 mM Cd^{++} , these agents restored the action potentials. Cysteine was the most effective. The contractile force-rate curve of left atria was significantly depressed by Cd^{++} (0.02 and 0.1 mM). The inhibitory effect of Cd^{++} was reversed by cysteine in concentrations insufficient to alter contractility in control media and also by excess Ca^{++} . It appears that the Cd^{++} -induced depression of action potentials and contractions is due to binding with sulfhydryl groups in membranes and contractile proteins as well as interference with availability and inward movements of Ca^{++} . It is concluded that membrane sulfhydryl groups may relate closely to the permeability of atrial cell membranes to Na^+ and Ca^{++} during excitation.

Heimild nr. 17

Effects of Acute and Subacute Cadmium Administration on Carbohydrate Metabolism in Mice

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Effects of Acute and Subacute Cadmium Administration on Carbohydrate Metabolism in Mice. GHAFGHAZI, T. AND MENNEAR, J. H. (1973). *Toxicol. Appl. Pharmacol.* 26, 231-240. The administration of single doses of cadmium acetate (2.0-6.0 mg/kg, ip) produces hyperglycemia and glucose intolerance in intact mice. Adrenalectomy prevents the hyperglycemic effect but not the glucose intolerance. Glucose intolerance is associated with a decreased pancreatic secretory activity as evidenced by decreased insulinogenic indices in Cd-treated mice. The administration of 4.0 mg/kg of Cd daily for 14 days produces tolerance to Cd-induced hyperglycemia. The subacute treatment did not produce changes in resting blood glucose levels, nor did it produce a decrease in glucose tolerance. A significant reduction in circulating serum insulin was detected after subacute Cd administration. It is suspected that a Cd-induced decrease in renal threshold to glucose masks the effect of lowered serum insulin concentrations.

INHIBITION BY CADMIUM IONS OF THE ELECTRICAL
ACTIVITY OF SINUATRIAL NODAL PACEMAKER FI-
BERS AND THEIR RESPONSE TO NOREPINEPHRINE

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Accepted for publication October 2, 1972

ABSTRACT

TODA, NOBORU: Inhibition by cadmium ions of the electrical activity of sinoatrial nodal pacemaker fibers and their response to norepinephrine. J. Pharmacol. Exp. Ther., 181: 357-365, 1973.

In rabbit sinoatrial (SA) node pacemaker fibers, the overshoot, the maximal diastolic potential and the threshold potential were decreased and the 10% and 90% durations were prolonged by Cd^{++} (0.1 and 0.5 mM). The slope of diastolic depolarization was decreased, which results in bradycardia. In most of preparations exposed to 0.5 mM Cd^{++} , pacemaker activities were totally abolished. The inhibitory effects of Cd^{++} were reversed by cysteine in a concentration insufficient to produce changes in the membrane potential of pacemaker fibers exposed to control solutions. Calcium ions (4.4 mM) did not effectively reverse the effects of Cd^{++} . Cadmium-induced changes were prevented by cysteine and Ca^{++} . The positive chronotropic effect of sympathetic nerve stimulation, norepinephrine and histamine was inhibited by Cd^{++} (0.02 and 0.1 mM). The chronotropic effect of histamine was not influenced by 10^{-6} M propranolol. The maximum rate increase by norepinephrine (5×10^{-6} M) and histamine (5×10^{-4} M) was markedly attenuated by Cd^{++} . Cysteine and Ca^{++} reversed the Cd^{++} effect. From these results, it can be concluded that membrane constituents containing sulfhydryl groups may play an important role in the maintenance of the spontaneous pacemaker activity, associated possibly with the permeability of membranes for Na^+ . It is postulated that Cd^{++} interferes either with the amine-receptor binding or with an increase in the permeability of pacemaker membranes for Na^+ during diastole thus inducing tachycardia.

Cadmium-induced Testicular Injury
and Alterations of Androgen Synthesis
in Brook Trout

NON-LETHAL doses of cadmium salts can cause specific injury to the testis of various mammalian species^{1,2}. There is some evidence that the spermatogenic process can be adversely affected by Cd, possibly through its injurious effects on the vasculature of the testis^{3,4}, but little is known of the effects of Cd on androgen synthesis⁵. In view of the well-documented reports of a direct relationship between androgens and maintenance of spermatogenesis in several vertebrate species including fish⁶ we investigated the effects of Cd on the testis of a freshwater-maintained salmonid fish, the brook trout *Salvelinus fontinalis*.

Environmental Impact of Cadmium: A Review by the Panel on Hazardous Trace Substances

by Michael Fleischer*, Adel F. Sarofim,[†] David W. Fassett,[‡]
Paul Hammond,[§] Hansford T. Shacklette,^{**}
Ian C. T. Nisbet,^{††} and Samuel Epstein^{‡‡}

Introductory Note

This report is the result of a review by a Panel on Hazardous Trace Substances, as part of a report to an *ad hoc* Committee on Environmental Health Research whose chairman was Dr. David Rall, Director of the National Institute of Environmental Health Sciences, NIH.

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The Panel undertook as one of its charges an in-depth examination of several groups of chemicals. This examination was aimed at defining sources of environmental contamination by these chemicals, their distribution in the environment, their transport and alteration, and their biological effects on humans and on other components of the biosphere.

The Panel has also taken the view that it will be important to develop quantitative means for understanding the patterns of the movement of these materials into, and their alteration and persistence within the biosphere; tentative models aimed at these objectives have been developed.

The first report by the Subpanel on polychlorinated biphenyls has been published (1). The present report on Cadmium is an extensive review of this element, prepared by the Subpanel on Cadmium, identified above. It has been reviewed in detail both by the Subpanel and by the entire Panel on

Hazardous Trace Substances. A number of suggestions that emerged from this review have been incorporated into the report. To this extent, the report is a collective effort. However, the chapters or parts of chapters were each the direct responsibility of one or more authors.

The sections on General Properties and Uses and Environmental Forms and Sources were contributed primarily by M. Fleischer; the section on Cadmium Material Flows was contributed primarily by A. F. Sarofim; the section on Effects on Man and Animals was prepared mainly by D. W. Fassett and P. B. Hammond; the sections on Cadmium in Plants and Animals and Ecological Effects were contributed by H. T. Shacklette and I. C. T. Nisbet; The section on Analysis for Traces of Cadmium was prepared by S. Epstein and M. Fleischer. In addition, we are deeply indebted to many colleagues who contributed valuable advice and suggestions.

NORTON NELSON, *Chairman*
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General Summary

Cadmium was recognized many years ago to be a highly toxic element, and the need for precautions in industrial operations in which workers were exposed to dusts and vapors of the element or its compounds had long been known. It was not, however, until comparatively recently that concern began to be expressed over the possible effects on human health of exposure over long periods to low concentrations of cadmium, in part because of its steadily increasing consumption and consequent increase in the general environment, and in part because of the outbreak of the itai-itai disease in Japan in the late 1940's and early 1950's. Exposure to cadmium, originating from smelter wastes and concentrated by the rice plant to levels far above those of the normal environment, has been shown to have been one of the causative factors in this disease.

The present report reviews and assesses the information available to November 1972 on the environmental occurrence, transport, and biological effects of cadmium with special attention to significant gaps in our knowledge, and recommends areas of research for future studies.

Occurrence, Transport, and Biological Effects

Cadmium is a relatively rare element that is rather uniformly distributed in the most abundant rocks of the Earth's crust, which has an average content of 0.15-0.2 ppm Cd. It is slightly concentrated in shales, especially in those rich in organic matter, in lacustrine and oceanic sediments, in manganese nodules, and in marine phosphorites; the latter average about 25 ppm Cd. The only natural concentrations of commercial interest are those in sulfide deposits, especially those containing zinc, lead, and copper, from which it is recovered as a by-product. Total production in the United States and in the world reached all-time highs in 1969 of 5,736 and 17,576 metric tons, respectively. Production decreased in 1970 and 1971, but it has been estimated that consumption in the United States will nearly double by the year 2000 to a level of about 13,600 metric tons.

Cadmium metal has an appreciable vapor pressure, higher than that of zinc, at the temperatures used in smelting ores, in the manufacture of metallic alloys, and in the reprocessing of cadmium-containing alloys and of cadmium-plated materials. These processes account for about 90% of the cadmium of atmospheric emissions, estimated by Davis et al. (2) to be about 2300 metric tons annually in the United States. The only other major sources of atmospheric emissions of cadmium are the burning of coal and oil, the burning of cadmium-weighted plastics, and the burning of sewage sludge. This estimate of total emission of cadmium to the atmosphere is in qualitative accord with published measurements of the cadmium content of the air in various parts of the United States, although data on

residence time in the atmosphere are very scanty. The data on the contents of cadmium in soils near point sources of cadmium emissions, such as smelters and metallurgical plants, show that the fall-out has resulted in high concentrations of cadmium close to those sources.

Most fresh waters contain less than 1 $\mu\text{g}/\text{l}$. Cd; sea water averages about 0.15. Data on the transport of cadmium in aqueous systems are too fragmentary to permit reliable balances of the flow of cadmium to be constructed, but they suggest that erosion and weathering of rocks and soils contribute far less cadmium to streams in the environment than that contributed by man's activities. Sewage sludge contains notable concentrations of cadmium, and the leaching of such sludge that has been used for land fill could contribute appreciable amounts of cadmium to the drainage system. Information is lacking on the behavior in soil and in drainage systems of the appreciable amounts of cadmium added to the soil in superphosphate fertilizers.

Plants exposed to concentrations of cadmium above those of normal background contain higher than normal concentrations of cadmium. Mosses appear to be especially good indicators of exposure to high concentrations. Damage to plants from excess cadmium has been reported, but the concentrations of cadmium required were higher than even those in soils of contaminated areas.

Only scattered data are available on levels of cadmium content in wild or domestic animals. The levels found in animals are generally much lower than those found in adult humans. No clear geographical correlation has been demonstrated between levels in herbivorous animals and levels in vegetation. In marine animals, the highest concentrations recorded have been in pelagic zooplankton (13 ppm, dry weight), molluscs (locally up to 73 ppm, wet weight), and plankton-eating birds (20-53 ppm, wet weight, in livers). There is no evidence that cadmium concentrates in marine food chains. Adverse effects on reproduction of fish have

been reported at concentrations of cadmium similar to those of moderately polluted waters.

The average intake of cadmium by humans is generally estimated to be about 20-50 $\mu\text{g}/\text{day}$, mostly from food. Intestinal absorption is low, probably about 3-8%; the cadmium is notably concentrated in the kidneys and liver, which contain 50-75% of the total body burden. A higher proportion of the cadmium reaching the respiratory tract is absorbed, but the total amount so absorbed is less than that from foods, except perhaps for smokers. The high content of cadmium reported for tobacco may cause smokers to have considerably higher body burdens of cadmium than nonsmokers. The total burden of cadmium in humans increases with age from very little at birth to an average of about 30 mg in the age range 40-50; it may decrease slightly after that.

Exposure to fumes or dusts of cadmium metal or cadmium oxide is known to cause acute pulmonary edema. Chronic exposure to cadmium through the respiratory tract produces a number of toxic effects, the most important of which is chronic emphysema, accompanied by renal disturbance. The effects noted in the itai-itai disease in Japan differ in many respects from the foregoing. The victims were almost all women over 50 who had borne several children; the disease was characterized by osteomalacia and osteoporosis, as well as renal damage. Although cadmium has been implicated as a causative agent, it seems probable that there was profound disturbance of calcium metabolism and that deficiencies of calcium, vitamin A, and vitamin D played important roles in the disease.

It has repeatedly been suggested that build-up of cadmium in the body (or perhaps an increase of the ratio cadmium/zinc) is related to the occurrence of hypertension in man. Experimental studies of rats and rabbits indicate that these animals develop hypertension after intake of cadmium orally or by injection. However, epidemiological studies of persons occupationally exposed to

cadmium and post-mortem studies of cadmium levels in the kidney have not yielded unequivocal statistical evidence of a relation between cadmium content or cadmium/zinc ratio and hypertension.

Carcinogenic effects of cadmium have not been recognized in humans.

In summary, cadmium has not yet been proved to be a hazard to the average individual exposed to the average levels now present in the environment. The data from Japan, however, strongly suggest that part of the population is more sensitive to these hazards because of dietary deficiencies. Further research is needed on the hazards of average levels of cadmium to such individuals and on the hazards due to higher than average intakes of cadmium by persons who live in areas of high emission, who are heavy smokers, or who eat much shellfish. In the meantime, precautions are necessary to decrease emissions from the major sources and to insure that present levels of cadmium in the environment are not increased.

General Recommendations

One of the major purposes of this review was to identify gaps in our knowledge of the impact of cadmium in the environment and to suggest researches aimed at filling such gaps. Specific recommendations are made at the end of each chapter of this report. More generally, however, the Subpanel has found, as have other groups that have made similar reviews, that assessments of this kind are greatly hampered by a notable lack of interdisciplinary coordination of research on environmental pollutants. This is, of course, a natural consequence of the fact that so many disciplines and special fields of research, commonly with very limited contact with one another, are involved in such research, thus greatly increasing the difficulty of assembling the results into a coherent picture.

The Subpanel concurs with the Subpanel on Polychlorinated Biphenyls that there is a need for the development of general systems models to describe the transport of environmental pollutants. It proved to be

difficult to prepare a model for the transport of cadmium which satisfactorily explained ambient concentrations of cadmium, particularly in surface run-off. However, new technological developments—such as the large increase in recent years of the production of cadmium-weighted plastics—emphasize the need for generalized models applicable to a variety of substances, yet flexible enough to meet changing conditions.

Our review has also emphasized the need to study environmental problems as a whole, rather than in piecemeal fashion. Thus, the effects of emissions from metal smelters, a major source of emissions of cadmium, are the sum of the effects due not only to cadmium, but also to zinc, lead, arsenic, and sulfur dioxide, and possibly also to other elements such as copper and thallium, so that conclusions based on the study of a single element must be extremely uncertain. It is therefore important that such problem be considered as a whole, not only in systems models, but also in generalizing monitoring systems and in designing experiments.

As with the PCB problem, a major gap in our understanding of the cadmium problem is that we do not know how to apply data from laboratory studies on the toxicity of cadmium to its effects on animal populations in the natural environment. The difficulty of showing that adverse effects are occurring in the field indicates the need for fuller studies of the effects of environmental contaminants on animal communities, both in model ecosystems (microcosms) in the laboratory and in real ecosystems in the field. Similar difficulties in evaluating the consequences of low-level exposure of humans over long periods of time emphasize the urgent need for improved epidemiological studies of these effects.

General Properties and Uses

Chemical, Physical, and Geochemical Properties

Cadmium is a chemical element, atomic number 48, atomic weight 112.40, consisting

Environmental Health Perspectives

Cadmium in Plankton: Elevated Concentrations off Baja California

Abstract. One hundred thirty-five plankton samples were collected in the northeast Pacific Ocean and analyzed for their cadmium content. Concentrations were generally low (2 to 5 micrograms of cadmium per gram, dry weight) in all samples, except for the plankton collected off Baja California, where high values (10 to 20 parts per million) were consistently found on two cruises.

Plankton are well known for their ability to concentrate trace elements and, provided certain criteria are met, amounts in association with these organisms may reflect ambient levels in the environment. We have measured the concentration of cadmium in plankton from the northeast Pacific Ocean and, in almost all areas sampled, we have found relatively low concentrations of this element. However, on two cruises off Baja California we consistently observed elevated amounts of cadmium in the plankton collected south of San Diego.

The data for the first Baja cruise and from previous studies (1) are shown in Fig. 1. South of San Diego, eight of ten samples contained more than 10 μg of Cd per gram, dry weight (range, 8.9 to 19.5; mean, 13.2); in contrast, only 1 of the 86 samples collected on two Hawaii-California transects, off Oregon, and in Monterey Bay, California, had a Cd concentration greater than 10 parts per million (ppm). The mean concentrations for these areas were always below 5 ppm. The single high value (16 ppm) was found at the last station of the

portance since Cd is known for its toxicity (2) and high concentrations in the primary producers and consumers (plankton) could represent a potential problem for organisms at higher trophic levels, where high concentrations of this element are sometimes found (3).

However, since trace element concentrations in plankton are highly variable, and since the collection methods usually employed can cause severe contamination problems, it was necessary that we have many more data before drawing any conclusion. Thus, we collected additional samples off Baja California in January and February 1974 (Fig. 2). Once again, high Cd concentrations were observed in almost all the collections south of San Diego. Values were especially high south of Punta Eugenia, where four samples contained 17.8 to 20.9 ppm. That this was not strictly a coastal phenomenon was also illustrated by concentrations of 16.2 and 17.2 ppm noted approximately 500 km southwest of Punta Eugenia. For all 32 samples collected south of San Diego, the range was 4.2 to

Diego. Low values were also observed at the five remaining northerly stations (3.5 to 7.5 ppm) (4).

With the confirmation of our original findings, it now appears that Cd concentrations in the plankton off Baja California are approximately three times higher than in the plankton collected in other areas (5). However, scientists familiar with the problems of analyses of trace metals in plankton can view these results with justifiable skepticism. For example, paint and rust chips fall off almost all research vessels and are frequently caught in plankton nets towed in the vicinity of the ship, and high trace metal concentrations in plankton can result from this source of contamination. To avoid this problem, all of the samples on the second Baja cruise and half of those on the first cruise were collected from an inflatable dinghy rowed several hundred meters away from the main research vessel. The net employed (aperture, 64 μm) and other parts of the sampling gear were constructed of nylon or plastic materials, with the exception of the brass net rings and grommets, which were heavily coated with fiber glass. Precautions were also taken while digesting the samples in redistilled nitric acid and peroxide and while analyzing them by atomic absorption (6).

Another reason for the pattern we have observed could be natural variability due to differences in species composition

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Cadmium in New Zealand Dredge Oysters: Geographic Distribution

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(Received September 15, 1973)

High Cd levels of up to 9 ppm wet wt. have been found in the dredge oyster, *Ostrea lutaria* (Hutton), from Foveaux Strait, New Zealand. Average Cd levels in the oysters were determined at 24 stations in order to obtain a pattern of the geographic distribution of Cd. These data, in combination with a consideration of the prevailing currents, indicate that the source of the Cd must lie to the west of Foveaux Strait, possibly in Fiordland. These high Cd levels are naturally occurring since there is no industrial pollution in the area. Compared with other oyster species, *O. lutaria* may have a predilection for accumulating Cd.

2.2. Blý.

Magn blýsambanda í umhverfinu hefur aukist mjög mikið á þessari öld m.a. vegna aukins fjölda bifreiða og aukinnar notkunnar á blýblönduðu eldsneyti.

Með athugunum á blýinnihaldi og aldursgreiningum á ís Grænlandsjökuls hefur komið í ljós að fyrir 1750 voru 20 ug af blýi í hverju tonni af ís, 1860 voru 50 ug/tonn, 1940 voru 80 ug/tonn, 1950 voru 120 ug/tonn og 210 ug/tonn árið 1965.

Hér gildir það sama og fyrir cadmium að blý kemst eftir tveimur leiðum inn í líkama manna og dýra þ.e. um meltingarfæri og öndunarfæri.

Blý getur safnast fyrir í vefjum lífvera, plantna og dýra.

Hjá mönnum og öðrum svipuðum lífverum safnast blýið smám saman í beinvefjum og getur geymt þar. Þegar Ca-efnaskipti eru hröð getur einhver hluti af þessum birgðum losnað og borist í mjúka vefi lífverunnar og valdið eitrun (þ.e. eitrun þarf ekki að eiga sér stað á sama tíma og söfnun í líkamann fer fram), en það er magn blýs í mjúkum vefjum sem veldur eitruninni. Afleiðingar blýeitrunar eru sjúkdómar í blóði, nýrum og taugakerfi, og hafa sjúkdómar þessir verið mikið rannsakaðir.

Ekki er mikið vitað um áhrif blýs á gróður. Tilraunir á einfrumu grænþörungum hafa þó sýnt að 2.5 ppm og 10 ppm blýmagn í umhverfi orsakar hægari vöxt en 60 ppm drepa þennan þörung. Vitað er að margar plöntur safna blýi í vefi sína t.d. mosar og ýmsar gras- tegundir. Með því að athuga magn blýs í vefjum plantna má fá vísbendingu um magn blýs í umhverfi viðkomandi plantna.

H. R. L. S. I.
BRITISH MUSEUM
25 FEB 1972

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feature

Heimild nr. 23

pollution and poisoning

High lead levels are dangerous to man, and ambient concentrations are presently rising

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Lead has been mined and used by man for many years. Widespread early applications of lead are readily understood in light of its many desirable properties—relatively easily refined from natural ores, ductility, high resistance to corrosion, and other properties.

In both Greek and Roman culture, lead was used for manufacturing cooking utensils of the wealthy and in the lead pipes for the extensive plumbing systems of their homes. Studies indicate that Roman civilization deteriorated largely as a result of extensive lead poisoning (high incidence of infant mortality, mental retardation, and sterility) in the ruling class. This theory is supported by data showing a high lead concentration in the bones of their remains.

Of the nonferrous metals, lead is one of the most widely used in industry and everyday life. The annual consumption in the U.S. alone is well above one million tons. The storage battery industry is the largest consumer, about 40%, and the petroleum industry consumes about 20%, producing lead alkyls as gasoline additives. These 300,000 tons of lead are, of course, added directly into the ambient air. By contrast, only about 45% of the total lead consumed is recovered from metal products and batteries.

Today lead is an ubiquitous element present in food, water, and air. Lead aerosol is a common air contaminant. Dated samples of snow in northern Greenland indicate that up to 1750, there were about 20 µg of lead per ton of ice until the Industrial Revolution. By 1860, this had increased to 50 µg/ton. The proliferation of the automobile since World War II also resulted in sharp increases—in 1940, 80 µg; in 1950, 120 µg; and in 1965, 210 µg. In the past two decades, man's continuing use of lead has produced an

environmental level far above that which would exist naturally, and this could have grave consequences on human health.

Sources of lead

Lead is a natural constituent of soil, water, vegetation, animal life, and air. Significant sources of naturally occurring lead include dust from soils and particles from volcanoes. In contrast to certain other metals such as mercury, lead in its elemental form is not a major source of poisoning.

In medieval times, the practice of "sweetening" wine with lead or lead acetate became a serious toxicological problem. Even today, alcoholic beverages of illicit origin are occasionally incriminated as the source of lead poisoning. Old automobile radiators are often used as the condenser component in illicit stills and contain enough solder to cause dangerous contamination of the "moonshine." Lead encephalopathy (disease of the brain), nephritis (disease of the kidneys) with gout, and other lead-related conditions have been reported in moonshine consumers.

Until the 1950's, most interior paints contained lead pigments which were a major source of childhood lead poisoning. Since then, lead oxide has been replaced by titanium dioxide. However, some old houses were painted countless times with leaded paint, and thick chips of leaded paint fall off as the walls and ceilings peel. Putty also contains lead and is even more likely to be found in substandard dwellings. Since children between the ages of one and four or five ingest nonfood particles of all types, about 8% of children in ghetto areas suffer from some degree of lead poisoning.

Another major lead source is earthen-

ware pottery improperly glazed with lead. Large amounts of lead may be leached out of the glaze into certain foods. Today, man continues to pollute his environment with lead from other sources such as manufacturing, use of pesticides, incineration of refuse, and combustion of coal and leaded gasoline. Available data indicate that combustion of leaded gasoline is the major source of atmospheric lead in urban areas.

Atmospheric lead

Antiknock agents of lead alkyls, in the form of tetraethyllead (TEL) or tetramethyllead (TML), have been added to most gasoline since 1923. Their use rapidly became a cause for concern because lead intoxication and even death occurred among those occupationally exposed. In 1925, the U.S. Surgeon General appointed a committee to investigate possible public health hazards in the manufacture, distribution, or use of leaded gasoline. In the following year, the committee proposed a set of regulations which were concerned only with precautions in manufacture and distribution. The proposed regulations were adopted voluntarily by the petroleum industry.

About 1930, an attack on the significance of lead as a hazard to the general public began, but for the following 30 years, there was little interest in the potential environmental pollution problem of lead. Then in 1958, the Ethyl Corp. sought and was granted an increase in the concentration of lead in gasoline by the Surgeon General. Today, the amount of TEL ranges from 2 to 4 g/gal of gasoline.

A survey in 1964 indicated only 88 cases of TEL poisoning reported in the U.S. and Canada, subsequent to adoption of the regulations in 1926,

Subclinical lead poisoning (bók)
Waldron, H.A. and Stöfen, D. 1974

Efnisyfirlit.

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Effects of Dietary Mercury and Lead on Eggshell Thickness in Mallards

by
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and R. H. HUDSON

Heimild nr. 27

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In recent years, brown pelicans (*Pelecanus occidentalis californicus*) attempting to reproduce on Anacapa Island off the California coast have laid thin-shelled eggs, almost all of which have collapsed during early incubation (JEHL 1969, and RISEBROUGH et al. 1971). Laboratory exposure of other species to DDE (HEATH et al. 1969, LONGCORE et al. 1971, and WIEMEYER and PORTER 1970), the suspected cause of this phenomenon (HICKEY and ANDERSON 1968, KEITH et al. 1970, and RATCLIFFE 1967), has not produced the extreme eggshell thinning exhibited by Anacapa pelicans. The greater eggshell thinning in wild pelicans could be the result of this species being innately more sensitive to DDE as suggested by BLUS et al. (1971, 1972), or possibly it could be due to an additional effect on shell thickness of other pollutants in the marine environment. Two pollutants which may be capable of this type of synergistic or additive effect are mercury and lead compounds, which are biologically active and common in the environment (KLEIN and GOLDBERG 1970, KNAPP 1970, LAZRUS et al. 1970, and TEJNING 1967). The following tests were conducted to determine whether mercury and lead in the diet of captive mallards (*Anas platyrhynchos*) would increase the eggshell thinning above that caused by DDE alone.

Lead

Arch Environ Health/Vol 30, June 1975

Heimild nr. 28

Possible Toxicity in Urban vs Rural Rats

David Mouw, PhD; Kenneth Kalitis; Miriam Anver, DVM, PhD; Joyce Schwartz; Anna Constan; Rolf Hartung, PhD; Bennett Cohen, DVM, PhD; Dan Ringler, DVM

The degree of lead poisoning in wild rats from two environments has been studied. Wild rats captured in an urban area had markedly elevated tissue lead compared with values in rural rats. This elevation may have been caused by differences in factors affecting absorption of ingested lead or an elevated respiratory

exposure to airborne lead, or both, and lead in precipitated dust.

Changes in several biologic indexes (depression of Δ -amino levulinic acid dehydratase in kidney and red blood cells, presence of renal intranuclear inclusion bodies, and increased kidney weight) confirmed lead poisoning in urban rats.

The Blood Lead Threshold

Heimild nr. 29

Harry A. Waldron, MB

Arch Environ Health/Vol 29, Nov 1974

There is much evidence to support the view that threshold limits exist for toxic chemicals below which they exert no overt harmful effects. In the case of lead, however, there are grounds to believe that the present widely accepted threshold levels are too high and new upper per-

mitted limits for adults and children are proposed.

It is suggested that the main value of blood lead concentrations is to monitor abnormal exposure in a population, rather than to serve as a major diagnostic tool.

Heimild nr. 30

RECENT PROGRESS IN THE STUDIES OF LEAD POISONING

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INTRODUCTION

Lead intoxication has been a well recognized entity since old days. Although lead is widely used in many types of industry, and occasionally causes acute intoxications in those workshops where the fume-and-dust control is insufficient, classical plumbism is thought to occur infrequently in modern industries.

On the other hand, interest in the deleterious effects of lead has recently shifted from the industrial field to that of the potential hazard to the community at large. We are constantly being exposed to lead in our environment, in the form of air contamination from lead smelting, and the combustion of gasoline containing lead alkyls. We are exposed to lead in various other ways as well - via pesticides, paints, solder used to seal food cans, lead piping, abraded particles of lead containing ceramics, glassware, etc.

The deleterious effects of increased environmental lead contamination usually take a chronic form. Chronic lead poisoning is not only different from acute poisoning, but is also difficult to diagnose.

AN EVALUATION OF THE USE OF BIOLOGICAL INDICATORS IN AN ATMOSPHERIC LEAD SURVEY

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(First received 23 July 1974 and in final form 5 December 1974)

Abstract—Atmospheric lead deposition was monitored in the vicinity of a battery factory by an integrated survey of lead levels in indigenous moss and grass samples and by a short-term study of weekly increments in lead deposition at selected sites around the source using the mossbag technique. A highly significant correlation (coeff = 0.95) between the lead content in indigenous mosses and grass can be demonstrated, and the lead levels closely reflect the proximity to the source and the long-term wind pattern. The suspended mossbags adequately monitor the input to ground moss and grass given sufficient exposure time for slow accumulation rates. The spatial variation in mossbag lead content after one month correlates significantly with wind direction and speed and with calculated mean long-term ground level concentrations from stack emissions at each site; however, only 40 per cent of the temporal (weekly) variation in lead accumulation in the mossbags can be explained by correlation with the wind direction and speed and rainfall at each site.

THE EFFECTS OF LEAD ON ALGAE

I: *Effects of Pb on Viability and Motility of 'Platymonas Subcordiformis'* (Chlorophyta: Volvocales)

ANITA HESSLER

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(Received 1 May, 1974; in revised form 5 July, 1974)

Abstract. The effects of lethal and sublethal concentrations of $PbCl_2$ on reproduction, viability, and motility of a marine unicellular green flagellate alga, *Platymonas subcordiformis*, were studied under controlled laboratory conditions. The severity of the effects depended primarily upon the concentration of Pb^{++} and the duration of treatment. Log phase cells were more sensitive than stationary phase cells. Sublethal amounts of Pb (2.5 and 10 $mg\ l^{-1}\ Pb^{++}$) tended to retard population growth by delaying cell division and daughter cell separation. A lethal amount of Pb (60 $mg\ l^{-1}\ Pb^{++}$) caused inhibition of growth and cell death. Various intracellular abnormalities resulted from Pb treatment. The flagella were shed or altered in a variety of ways, depending on Pb concentration; motility was least affected by low Pb and completely impaired by high Pb. Normal wild-type cells appeared to be more sensitive to Pb than mechanically sheared (flagella-less) cells and cells of a non-flagellate mutant of *Platymonas*. Exposure of cells to Pb in non-growth conditions of dark and cold (2°C) had little negative effect.

Lead Poisoning in a Bird of Prey

by

Heimild nr. 33

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Lead poisoning has long been recognized as a serious disease of waterfowl (PHILLIPS and LINCOLN, 1930; GRINNEL, 1901; BOWLES, 1908; BELLROSE, 1959). Birds feeding in areas of heavy waterfowl shooting ingest spent lead shot which is mistaken for seeds or grit. The shot is then ground up in the gizzard which makes the lead more absorbable from the intestinal tract. Although most of the lead is excreted in the feces, some is absorbed into the brain, muscles, and feathers, with the highest deposition in bone tissues (BAGLEY, LOCKE and NIGHTINGALE, 1967), etc. Lead absorption from shot which lodges in the body tissue is minimal (MACKLE, 1940).

Food habits of non-aquatic birds in the wild precludes their ingesting spent shot. Consequently, lead poisoning from food is not too likely. This report deals with a probable case of fatal lead poisoning in a bird of prey. Source of the exposure is presumed to be from feeding duck heads having detectable levels of lead within their brain and muscle tissues and from shot lodged within the head itself.

Heimild nr. 34

Lead Concentrations in Native Trout

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*Bozeman, Mont. 59715*Bulletin of Environmental Contamination & Toxicology,
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The background levels of lead in the environment, as evidenced by snow samples from Greenland, have been increasing at an exponential rate (BRYCE-SMITH, 1971). A base level of 20 $\mu\text{g}/\text{ton}$ was observed up to 1750. By 1860 it was 50 $\mu\text{g}/\text{ton}$; in 1940, 80 $\mu\text{g}/\text{ton}$; in 1950, 120 $\mu\text{g}/\text{ton}$ and by 1965 the concentration was 210 $\mu\text{g}/\text{ton}$. In the past 30 years the increasing use of lead has culminated in an environmental level far above that which would normally exist, with possible harmful effects on health (PATTERSON, 1965 and PATTERSON, et al., 1966). The major sources of lead contamination are leaded gasolines and pesticides, manufacturing, combustion of coal, incineration of refuse, leaded paints, and earthenware pottery that has been improperly glazed.

Tetraethyl lead and tetramethyl lead are added to gasolines to increase their octane ratings. The national average is 2.40 grams of TEL/gallon or 1.54 grams of lead per gallon. The amount of lead discharged to the atmosphere in exhaust gases varies from 25% to 75% depending upon driving conditions (HALL, 1972 and MILLS, 1971). As a consequence the atmospheric concentrations near highways are an exponential function of distance from the roadway (DAINES, et al., 1970). The lead level near the highway is relatively high, but drops off rapidly during the first 150 feet from the highway. The concentration is reduced 50% within the first 10 to 30 feet from the highway.

Soils and plants along heavily traveled highways show that lead concentrations increase with traffic volume and decrease with distance from the highway (MOTTO, et al., 1970). Much of the lead was a removable surface contaminant on the plants and the increase in the soil was limited to the surface material.

The West Gallatin River in southwestern Montana flows adjacent to U.S. Highway 191 for forty miles. As a consequence, the automobile traffic will increase the lead concentration in this region. In this paper we report the lead concentrations found in native trout taken from the river and compare them to similarly obtained values for fish from the Federal Fish Hatchery in Bozeman, Montana and from Yellowstone National Park.

2.3. Aðrir þungmálmur.

Eins og sjá má þegar heimildir þessa kafla eru skoðaðar er það nokkuð algilt að lífverur geta safnað í sig allmiklu magni af þungmálum. Að sjálfsögðu er hér mismunur á milli lífvera og jafnframt hefur magn þungmálma í umhverfinu mikið að segja. Tilraunir hafa sýnt að yfirleitt eru fyrstu áhrif aukins magns þungmálma tiltölulega væg. Koma áhrifin t.d. fram hjá ýmsum einfrumu þörungum sem minnkaður vaxtarhraði en með auknu magni verða áhrifin alvarlegri t.d. algjör stöðvun á vexti og að lokum dauði.

Styrkleikamögnun þungmálma upp eftir fæðukeðjum er einnig talin líkleg a.m.k. fyrir sumu þungmálma, en slík mögnun getur haft mjög alvarlegar afleiðingar í för með sér fyrir lífverur á efri fæðuþrepunum.

Rannsóknir á zinki hafa sýnt að í magninu 2.4 ppm í umhverfinu minnkar það vaxtarhraði hjá grænþörunginum *Chlorella vulgaris* um 50% á 96 klst. Zink veldur hækkaðri dánartölu hjá seiðum ýmissa fiska þó magn þess í umhverfinu sé mjög lítið (t.d. 0.08 ppm fyrir "minnow"). Ef styrkur zinks er mikill getur það orsakað skemmdir á tálknum fullorðinna fiska og minnkað þannig hæfni þeirra til ildisnáms út vatninu.

Heimild nr. 35

GROWTH RESPONSE OF THE GREEN ALGAE *CHLORELLA VULGARIS* TO SELECTIVE CONCENTRATIONS OF ZINC*

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Abstract—A modification of a previously published fish cell culture technique (Rachlin and Perlmutter, 1968) has been successfully employed in this study to evaluate the effects of a metal toxicant on the growth response and therefore productivity of the green algae *Chlorella vulgaris*. The results of this study indicate that the concentration of zinc which reduces the growth rate of a test population of this alga, during a 96 h exposure, by 50 per cent, is 2.4 ± 0.02 ppm. The test design has advantages in that it concerns itself with productivity reduction rather than standard survival (LC_{50}) of the test organisms. In addition the data generated is readily treated by the system of probit analysis for ease of evaluating the results. The use of this technique and test system, allows for the design of parallel studies in which the effects of toxicants on both animal and plant cell systems can be evaluated in terms of a more unified cellular approach.

Heimild nr. 36

The Effects of Zinc on Rainbow Trout (*Salmo gairdneri*) in Hard and Soft Water

by JAMES R. SINLEY, JOHN P. GOETTL, JR.,

and

PATRICK H. DAVIES

Colorado Division of Wildlife

Bulletin of Environmental Contamination & Toxicology,
Vol. 12, No. 2 © 1974 by Springer-Verlag New York Inc.

This research was performed to determine the effects of zinc sulfate on rainbow trout (*Salmo gairdneri* Richardson) in hard and soft water. Acute bioassays were used to determine TL_{50} values for zinc, i.e., that concentration of zinc lethal to 50% of the exposed fish. Chronic flow-through bioassays, in which exposure data collected over at least one generation of the test organism reflects the effects of a toxicant on growth, reproductive capacity, spawning behavior, viability of eggs, and the growth of fry, were used to evaluate the effects of zinc on rainbow trout throughout its life cycle. The results of these bioassays are expressed as "maximum acceptable toxicant concentrations" (MATC's). Well water (hardness = 330 mg/liter as $CaCO_3$) was used for the hard water experiments and dechlorinated tap water (hardness = 25 mg/liter as $CaCO_3$) was used for the soft water experiments.

The hard water chronic bioassay began with two-gram fingerlings and continued through sexual maturity as two-year-old fish. The soft water chronic bioassay began with eyed eggs and continued until, but not through, sexual maturity of the fish. Survival of fish from eggs and fry acclimated to sub-lethal concentrations was compared with survival of non-acclimated fish.

Because of the importance of zinc in the environment, toxicological information on zinc is available in the literature. BRUNGS (1969) developed an MATC for zinc using fathead minnows (*Pimephales promelas*, Rafinesque). However, most other work has dealt with the short-term, acute effects of zinc (LLOYD, 1960; GOODMAN, 1951; and MOUNT, 1966). There is a lack of information in the literature concerning chronic exposure of rainbow trout to zinc.

Heimild nr. 37

THE EFFECT OF SUBLETHAL CONCENTRATIONS OF COPPER AND ZINC ON VENTILATORY ACTIVITY, BLOOD OXYGEN AND pH IN RAINBOW TROUT (*SALMO GAIIRDNERI*)*

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(Received 4 June 1974)

Abstract—Changes in buccal and opercular pressure amplitude, as well as ventilation and coughing frequency were monitored in rainbow trout using catheterization of respiratory cavities and pressure transducers. One or more of the ventilatory parameters measured were found to change under toxicant stress at concentrations of copper or zinc at or below the LC 50. Possible synergistic effects were indicated when the two metal ions were tested together.

Serial analyses of arterial P_{O_2} and pH in fish exposed to copper and zinc individually at concentrations approximating the LC 50 showed that environmental zinc produced a sharp decrease in both P_{O_2} and pH. Copper, however, caused little effect other than a transient increase in pH. The toxic action of the two metals in low concentrations thus may not be the same.

Archives of Environmental Contamination and Toxicology, Vol. 2, No. 4, 1974, © 1974 by Springer-Verlag New York Inc.

Heimild nr. 38

THE EFFECTS OF ZINC ON THE MORTALITY AND REPRODUCTION OF THE MINNOW, *PHOXINUS PHOXINUS* L.

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The long-term effects of zinc nitrate on the reproduction and on the mortality during different developmental stages of the minnow, *Phoxinus phoxinus* L., have been studied in fresh water. Mortality of newly-hatched fry was seen to be the most sensitive parameter as compared with factors such as number of deposited eggs, hatch-ability, and the mortality of underyearlings, yearlings, and mature minnows. The fry showed an increased mortality at a zinc concentration of 0.08 ppm, which is 1/40 of the 96-hr LC50 estimated for the adults.

Heimild nr. 39

Mercury Content of Mussels from West European Coasts

Mussels have been sampled from the east side of the North Sea from Arcachon in France to Cape Skagen in Denmark and on the west side from Lands End to Edinburgh. High levels of mercury occur in mussels taken from the vicinity of the Rhine and Eems Dollard, and values on the British coast are generally higher than on the east side of the North Sea.

-51-

Observations on the Distribution of Dissolved Mercury in the Ocean

Heimild nr. 40

The concentration of dissolved mercury in sea water has been determined in a number of areas in the northern and southern hemispheres and an attempt has been made to correlate the values found for certain areas with natural physical phenomena. The average concentrations found ranged from 11.2 ng l⁻¹ in the southern hemisphere to 33.5 ng l⁻¹ for the northern hemisphere; an increase suspected to be the result of dispersion of industrial pollution by jet streams. Local effects including upwelling, volcanic action, land run-off and heavy suspended matter loads are also discussed.

The Science of the Total Environment, 3 (1975) 279-287
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Heimild nr. 41

MERCURY AND SELENIUM IN MARINE MAMMALS AND BIRDS

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(Received September 22nd 1974)

ABSTRACT

Information is provided concerning the concentrations of mercury and selenium in tissues of marine animals. In marine mammals a 1:1 Hg/Se molecular increment ratio was found and an almost perfect linear correlation between mercury and selenium. It is suggested that marine mammals are able to detoxify methylmercury by a specific chemical mechanism in which selenium is involved. The results also indicate that the fate of methylmercury in fish-eating marine birds differs fundamentally from that in marine mammals.

Deep-Sea Research, 1974, Vol. 21, pp. 139 to 144. Pergamon Press. Printed in Great Britain.

Heimild nr. 42

NOTE

Total mercury in sea water in the northwest Atlantic Ocean

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(Received 12 June 1973; in revised form 2 August 1973; accepted 9 August 1973)

Abstract—Total mercury was determined using a shipboard method of analysis for sea-water samples collected on two identical cruises along a section between Halifax and Bermuda. Concentrations decreased seaward, but there were no significant vertical gradients. The concentrations, averaging 0.15 µg l⁻¹, are the highest yet reported for open ocean water. Experiments indicated that an average of 57% of the total mercury can be lost if samples are stored before analysis for 10 days at pH 1.

The Dynamics of Metals in the American Oyster, *Crassostrea virginica*. I. Seasonal Effects¹

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ABSTRACT: The seasonal dynamics of Mn, Fe, Zn, Cu and Cd were investigated in a genetically similar population of hatchery-reared American oysters, *Crassostrea virginica*, maintained in plastic trays in the Rhode River, a tributary of the Chesapeake Bay. Samples were collected monthly from September, 1971 through May, 1973. Annual cycles resulting in the turnover of large portions of the body burden were observed for all metals studied. Subtly different patterns of metal dynamics were observed as a result of the reduction in biological variations realized by employing genetically similar oysters. Metals are grouped into two classes according to their dynamics; (1) Mn and Fe concentrations in soft tissues are significantly correlated with shell deposition. A high rate of Mn turnover in soft tissues (approximately 2 times the body burden per day) occurs during the shell growth season. (2) Zn and Cu concentrations are not correlated with shell growth. Zn and Cu body burdens exhibit a gradual increase during the spring and early summer followed by a rapid loss during August-September in which 33% of the Zn and 50% of the Cu is lost in less than 4 weeks. Cd behavior is similar to Zn and Cu with a 50% reduction in body burden during an 11 week period between July and October.

Water Research Vol. 8, pp. 729 to 738, Pergamon Press 1974. Printed in Great Britain.

UPTAKE OF CADMIUM, ZINC, COPPER, LEAD AND CHROMIUM IN THE PACIFIC OYSTER, *CRASSOSTREA GIGAS*, GROWN IN THE TAMAR RIVER, TASMANIA

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(Received 15 September 1973)

Abstract--Hundreds of oysters and mud samples from 15 sites along the Tamar River were analysed for cadmium, copper, zinc, lead and chromium. The widely accepted concept of enrichment factors of up to several hundred thousand, describing accumulation by oysters of cadmium, zinc and copper from seawater has been found to be grossly misleading. Concentrations found for these three metals in oysters were only 10-40 times the concentrations in inhabited muds. Concentrations of metals in muds may be used to indicate whether a potential oyster bed would produce oysters that were grossly contaminated. Approximately 1 ppm cadmium in mud could result in oysters containing at least 25 ppm, i.e. 4-5 ppm wet wt. Similarly, 100 ppm zinc in mud could produce oysters containing at least 4000 ppm, i.e. 800-1000 ppm wet wt. Three heavy metal accumulation processes were discernible. Copper and chromium appeared to be absorbed up to a maximum weight that was limited by the size of the oyster and was independent of the amount of metal in the mud. Lead was not absorbed through any physiological demand, but was randomly incorporated at sites containing high concentrations in the mud. Zinc and cadmium were accumulated by a process that depended primarily on the concentrations of these metals in the mud at each site. Mean dry wt concentrations of metals in oysters and mud samples ranged from: 4.2-134 ppm and 0.4 to 5.7 ppm cadmium; 200-1700 ppm and 3-224 ppm copper; 0-135 ppm and 4-1500 ppm lead; 1-37 ppm and 2-88 ppm chromium; 1700-14,000 ppm and 20-500 ppm zinc, respectively.

Heimild nr. 45

THE DEPOSITIONAL ENVIRONMENT OF ZINC, LEAD AND CADMIUM IN RESERVOIR SEDIMENTS*

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(Received 24 September 1974)

Abstract—Despite low water retention dams and intervening reservoirs, reservoirs located downstream from a lead-zinc mining and milling area contain relatively higher concentrations of zinc, lead and cadmium than reservoirs in other areas. These metals are also concentrated in reservoir bottom sediments relative to surrounding soils. The zinc and lead content closely correlates to depth of water, organic content and percentage of clay-sized sediments. Zinc is preferentially weathered and transported from its source relative to lead. A model is developed in which the zinc and lead are transported by ionic and/or organo-metallic solution into reservoirs. Because of the relatively long residency time of water in reservoirs, the zinc and lead in the water is removed by clay minerals. Most of the zinc and lead content of the sediments is shown to be associated with sediments of specific gravity between 2.0 and 2.9. The efficiency of these reservoirs as a sink for zinc and lead results in the removal of an average 0.3 ppm zinc and 0.04 ppm lead from waters passing through Fort Gibson Reservoir.

Metal-induced hypertension following chronic feeding of low doses of cadmium and mercury*

Heimild nr. 46

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Groups of weanling rats, fed a low cadmium diet and deionized water fortified with essential metals, were exposed for 1 year to various concentrations of cadmium, mercury, or zinc in their drinking water. Insofar as possible, the experimental conditions duplicated those used by Schroeder and co-workers^{1-5, 8, 10-12} who have reported marked increases in indirectly measured systolic pressure following chronic ingestion of small amounts of cadmium. We found that rats given 1, 2.5, or 5 parts per million (p.p.m.) of cadmium had average increases in systolic pressure of 13 to 19 mm. Hg; these increases, although much smaller than Schroeder had observed, were statistically significant ($p < 0.005$) when compared to control animals. Rats given 10 and 25 p.p.m. cadmium had smaller increases in pressure, and rats given 50 p.p.m. of cadmium were sick and had significant decreases in pressure. Five and 10 p.p.m. of mercury were pressor, while 2.5 and 25 p.p.m. of mercury and 75 p.p.m. of zinc had no significant effect on blood pressure. In other and smaller groups of weanling rats, a suggestive ($p < 0.05$) increase in average systolic pressure was observed after 2 months exposure to 10 or 25 p.p.m. of cadmium.

DISTRIBUTION OF SOME HEAVY METALS IN ORGANISMS IN HARDANGERFJORD AND SKJERSTADFJORD, NORWAY

Heimild nr. 47

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(Received 15 April, 1974)

Abstract. Near Odda, in West Norway, metal-bearing waters enter the Sorsfjord, a tributary of the Hardangerfjord. Unusually high concentrations of Cd, Pb, and Zn are present in marine life over a considerable length of the fjord. Marine life near Odda also contained concentrations of Hg higher than normal. At Fauske, in North Norway, marine organisms contain high concentrations of Cu, but this contamination is confined to a small area of the Skjerstadsfjord system.

Acute Toxicity of Various Metals to Freshwater Zooplankton¹

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The discharge of heavy metals by industry represents a serious water pollution problem due to the toxic properties of these metals and their adverse effects on water quality.

Studies on the toxicity of heavy metals to freshwater organisms have concentrated on fish and have yielded only limited information concerning invertebrates. However, it has been shown that some zooplanktonic species are more susceptible to cations than fish are (ANDERSON, 1950; FREEMAN and FOWLER, 1953; BIESINGER and CHRISTENSEN, 1972). Since zooplankton is the main source of food for several species of fish, its destruction by heavy metals may result in the disappearance of some fish even though these latter may not be affected directly.

Therefore, more thorough knowledge of the effect of heavy metals on zooplankton would be very useful in two rather practical applications: 1) the establishment of water quality criteria that could make possible the conservation of aquatic life and 2) the use of zooplanktonic organisms in the bioassay of industrial wastes.

The present investigation was undertaken as a first step in the development of these studies, in order to determine the degree of toxicity of various metal salts to three species of freshwater zooplankton.

Aust. J. mar. Freshwat. Res., 1975, 26, 31-46

Heimild nr. 49

Heavy Metals in Cultivated Oysters (*Crassostrea commercialis* = *Saccostrea cucullata*) from the Estuaries of New South Wales

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Abstract

Results of a survey of metal levels in the Sydney rock oyster *Crassostrea commercialis* are reported. Concentrations of copper, zinc, cadmium, lead and arsenic in oysters sampled from the 19 important production areas in New South Wales are generally low, and in terms of the National Health and Medical Research Council recommendations for these metals there is little or no health risk to consumers.

Evidence is presented which indicates that metal concentrations decrease with increasing age and wet weight of oysters.

In oysters sampled from a single estuary, there is a gradient of increasing metal concentration with increasing distance upstream from the sea. Pollution may be the cause of the relatively high concentrations in oysters from this estuary, but further work will be required to verify this.

The variability of metal concentrations in oysters is discussed, and a sampling method is suggested for future monitoring of metals in this species.

Cadmium, Lead, and Zinc Distributions Between Earthworms and Soils: Potentials for Biological Accumulation

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Heimild nr. 50

Earthworms are one of the most important organisms responsible for mechanical mixing of the soil and play a major role in maintaining physical soil characteristics and processes such as aeration, water permeability, and mineral turnover (SATCHELL 1967). Earthworms are key components of natural food chains providing a food source for many small mammals and birds. Earthworms have been demonstrated to exert a significant effect on redistribution of cadmium, carbon, and cesium in soils (VAN HOOK et al. 1973, REICHEL et al. 1973). Due to this redistribution effect and the earthworm's ubiquitous occurrence in nature, these invertebrates may exert a significant influence on the distribution of trace elements in soils and in food chains by altering concentrations in tissues through bioaccumulation. In the present study, the differential accumulation by earthworms of Cd, Pb, and Zn from six soil series in east Tennessee was determined. These three trace elements were chosen because of their current importance in environmental contamination (FULKERSON et al. 1973, NRC-NAS 1971) and because of their high levels observed in earthworms (GISH et al. 1973). In addition, zinc is recognized as an essential element in plant and animal metabolism.

The six soil series included Bodine, Captina, Claiborne, Emory, Linside, and Tarklin (SWANN et al. 1942). Major earthworm genera included in our collections were Alabophora, Lumbricus, and Octolasion. Samples consisting of three replicates of 100 cm², taken 10 m apart, of soils and earthworms contained therein, were collected from the USAEC Reservation in east Tennessee from areas undisturbed for the past 30 years. Soil samples consisted of the top 10 cm with vegetation removed. These samples were mixed thoroughly and ashed for 24 hr at 450 C. Earthworms removed from these soils were placed in petri dishes on moist filter paper for 4 days to void their gut of soil. Earthworm genera from each sample were pooled and freeze-dried prior to ashing at 450 C for 24 hr. Ashed samples of soil and earthworms were boiled under reflux for 12 hr in nanograde aqua regia with known quantities of specific isotopes of Cd, Pb, and Zn. Electrodes were then prepared from the resulting material and determinations were made for total Cd, Pb, and Zn by isotope dilution spark source mass spectrometry. The estimated accuracy of the determinations was $\pm 5\%$ of the values reported.

*Research sponsored by the National Science Foundation's RANN Program and the U.S. Atomic Energy Commission under contract with the Union Carbide Corporation.

Heimild nr. 51

EFFECTS OF COPPER, ZINC AND CADMIUM ON *SELANASTRUM CAPRICORNUTUM*

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(Received 2 July 1973)

Abstract—The algicidal and algistatic effects of copper, zinc and cadmium on *Selenastrum capricornutum*, a unicellular green algae were analyzed by using a modification of the Algal Assay Procedures Bottle Test.

Algicidal concentrations of copper, zinc and cadmium were 0.30, 0.70, and 0.65 mg l⁻¹. Treatment of *Selenastrum* with various concentrations of the metals resulted in similar growth rates characterized by extended lag growth phases.

Combinations of copper, zinc and cadmium were similar in toxicity to equal concentrations of zinc. Combinations of copper and cadmium resulted in a greater growth rate than equal concentrations of copper suggesting that cadmium inhibits copper toxicity.

Selenastrum was able to exist in waters from the upper South Fork and North Fork of the Coeur d'Alene River where zinc and other metals were in low concentration. However, the algae was not able to tolerate zinc concentrations greater than 0.5 mg l⁻¹ from waters of other parts of the drainage. These observations were consistent with laboratory findings where 0.7 mg l⁻¹ zinc was algicidal and 0.1 mg l⁻¹ inhibited the growth of *Selenastrum*.

30 MAY 1975

Heimild nr. 52

BEHAVIOR OF Mn, Fe, Cu, Zn, Cd AND Pb DISCHARGED FROM A WASTEWATER TREATMENT PLANT INTO AN ESTUARINE ENVIRONMENT

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(Received 15 October 1974)

Abstract—To obtain information on the fate of trace metals discharged to an estuarine environment, analyses have been made on water and sediment samples from Back River, MD., and on effluent from the large wastewater treatment plant that discharges there. Within 2-3 km of the outfall, the concentration (in µg l⁻¹) of all metals decreases as follows: Mn, >120-90; Fe, >570-300; Cu, 53-7; Zn, 280-9; Cd, 3.5-0.5 and Pb, 31-<4. Except possibly for Mn and Fe, these decreases are much greater than can be ascribed to simple dilution, so physical, chemical or biological processes must be removing metals to the sediments. Correspondingly, sediment concentrations of Cu, Zn, Cd and Pb are approximately one order of magnitude higher than normally found in uncontaminated areas. After the initial decrease, concentrations of Mn and Cd in the water begin to rise again, suggesting remobilization from the sediments. Comparison of the estimated annual discharge of 8 trace metals to the Chesapeake Bay from wastewater treatment plants and from rivers suggests that the wastewater input may be within one order of magnitude of the fluvial input for Cr, Cu, Zn, Cd and Pb. Of the metals studied, Cd presents the greatest potential for serious pollution because its input from wastewater probably exceeds fluvial input, it appears to be readily remobilized from sediments, and it is known to be toxic to many organisms.

Trace Metals in Hong Kong Waters

Hong Kong has a population of between four and five million and is becoming increasingly industrialized. Already there are some 19,000 factories concentrated in a few densely populated areas and most of the effluent and sewage is discharged untreated into the sea. Elevated heavy metal concentrations have been recorded in the receiving waters. Lead has 160 times and cadmium 180 times the concentration found in the open ocean.

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Heavy Metals in Organic Phases of River and Estuarine Sediment

Analysis of sediments taken from various levels in the lightly polluted River Blyth in Northumberland shows that quite high concentrations of metals can be accumulated in sediments.

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Induction of Abnormal Polychaete Larvae by Heavy Metals

A little known observation that exposure to sublethal concentrations of detergent cause fatal abnormalities in the second generation of a polychaete has been followed up and similar abnormalities have been observed in the first or second generation of larvae exposed to sublethal concentrations of copper and zinc. Few toxicity tests extend beyond the responses of the exposed individuals. The discovery of a delayed reaction to sublethal concentrations of common contaminants of the sea has unknown but potentially important ecological implications.

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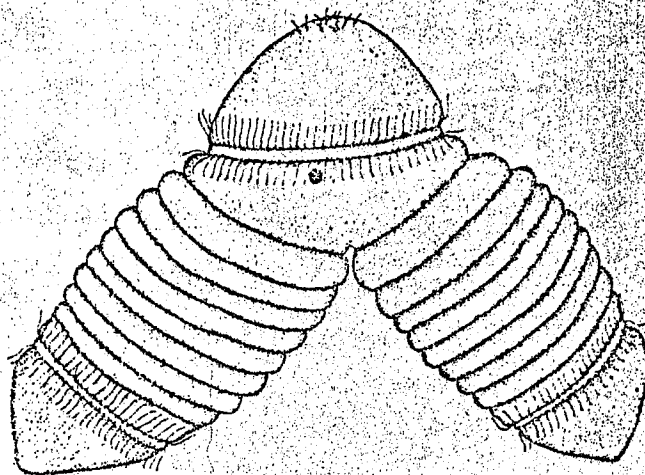


Fig. 1 Abnormal larva of *Capitella capitata*.

Factors Influencing Trace Element Needs and Tolerances in Man

Concern is voiced about the hazards of heavy metal pollution of the sea and trace elements in food. In fact many of these substances are essential for human health and occasionally the margin between minimum needs and maximum tolerance is a very slender one. The chemical form of the trace element and the interactions between different trace elements included in the diet are also often important in deciding between health and hazard. Monitoring foods and the environment for the effects of pollution therefore demands subtlety and an awareness of this complexity which is usually missing.

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A Trace Metal Problem in Pond Oyster Culture

Heimild nr. 57

Oysters reared in power station cooling water were found to have accumulated high concentrations of copper and zinc. The reasons for such elevated metal concentrations and the relevance of these observations to shellfish culture have been examined and emphasize the care that must be taken to avoid unwitting contamination of culture ponds.

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Dietary Habits and Heavy Metal Concentrations in Fish from the Severn Estuary and Bristol Channel

Heimild nr. 58

Comparisons of the rates of growth, feeding habits and heavy metal levels of flounders from Barnstaple and Oldbury-on-Severn have shown that at all ages the fish from the North Devon coast are larger than those from the middle Severn estuary and that there are marked differences in diet. These differences in diet may contribute to the much higher zinc levels of the Barnstaple flounder samples.

In the six other fish species which have been examined, there is a distinct correlation between the cadmium concentrations of the tissues and the proportion of crustaceans in the diet. Lead concentrations appear to follow a similar trend, but no relationship could be detected between diet and tissue zinc levels.

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Trace Metal Concentrations in *Fucus* from the Bristol Channel

Heimild nr. 59

Brown seaweeds are unable to regulate their uptake of trace metals and can therefore be used to provide a running average of metal contamination in the surrounding waters. There are many sources of error, however, and misleading results can be obtained if attention is not paid to factors that influence the metal concentrations in the weed. This becomes particularly important when comparing the results of different investigators.

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Heavy Metals in Organisms of the Atlantic Coast of S.W. Spain and Portugal

Heimild nr. 60

Very high concentrations of copper, lead, zinc, and to a lesser extent mercury, are present in the estuary of the Rio Tinto in South-West Spain. At the mouth of the estuary, the concentrations of these metals fall very sharply towards the natural levels of these metals in organisms living in this part of the Atlantic.

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R. D. STENNER
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FEB 1973 Heimild nr. 61

Heavy Metals in Somerset Marine Organisms

Several independent studies of heavy metal pollution in the Severn Estuary and Bristol Channel are in progress. The County Health Department and Public Analyst have been examining the accumulation of metals in marine shore animals and the food chain, and report their results and conclusions.

The release of industrial wastes into the estuarial

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Heimild nr. 62

Distribution of Cadmium, Lead and Zinc in the Bristol Channel

More news from the Sabrina Project on heavy metal pollution in the Bristol Channel, this time affecting the Welsh side. While most of the contamination probably originates in the Avonmouth area, a secondary source of zinc and cadmium pollution seems to exist in the neighbourhood of Swansea.

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Acute Toxicity of Heavy Metals to Some Marine Larvae

Heimild nr. 63

The toxicity of copper, mercury and zinc to the larvae of oysters, shrimp, crab and lobsters has been examined over periods of up to 64 hours. Mercury was found to be more toxic than copper and zinc, which had similar levels of toxicity. Over the experimental period, the relationship between toxicity and concentration was linear. Larvae were from 14 to 1,000 times more susceptible than adults of the same species. The median lethal concentrations (LC_{50}) of each metal to the most sensitive species of larvae, tested over a 48 hour period, exceeded the concentrations found in natural sea water by a factor of 100. For longer test periods, the LC_{50} would be considerably less and this factor would then be considerably reduced. Hence the continued addition of these metals to confined waters should give cause for concern.

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Effect of Heavy Metals on Mortality and Growth

Heimild nr. 64

Toxicity of heavy metals is usually measured in acute tests but in a natural situation their sub-lethal effects may be at least as damaging. The effect of heavy metals on the growth rate of a worm and a brine shrimp, as well as on their mortality are discussed here.

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Distribution of Heavy Metals in the Severn Estuary

Heimild nr. 65

There has been considerable agitation in recent months about heavy metal pollution in the Bristol Channel and Severn Estuary and on land around Bristol. Concentrations of zinc, cadmium and lead in water, sediments, seaweeds and shore animals are recorded from a number of sites on the southern shore of the estuary. Contamination is detectable ninety miles downstream of Avonmouth where the highest concentrations of these heavy metals are found.

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Migration and Redistribution of Zinc and Cadmium in Marine Estuarine System

Heimild nr. 66

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* A survey of trace-element levels in the estuarine sediments of Texas shows that Corpus Christi Bay has anomalously high concentrations of zinc and cadmium. Maps of elemental abundance within the bay indicate large concentration gradients, the highest values being near the harbor entrance. Seasonal determinations of metal levels in the harbor and bay waters also revealed variations with time. During summer, stagnation of the harbor water increases the concentration of metals so that significant quantities precipitate in the reducing environment of the bottom water. In winter, the exchange of water between the bay and the harbor increases, and metals are redissolved from harbor deposits, washed into the bay, and adsorbed by particles settling to the bottom.

During a survey of the trace-element distribution in the sediments of Texas bays and lagoons, anomalous zinc and cadmium levels were found in Corpus Christi Bay. Because zinc has been found to be detrimental to fish and other aquatic life (Pettyjohn, 1972) and because cadmium is a known toxin to man, these elements pose a threat to the estuarine system. Although zinc does not appear to be highly concentrated in the marine food chain (IDOE, 1972), it may pose a greater hazard in the dissolved state where it can interact freely with nectonic life. Cadmium, on the other hand, does become concentrated in the food chain and is therefore a hazard in any chemical state. This report presents data on the distribution of these elements in the sediments, their seasonal variations, and the pathways by which they move within the estuarine system.

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Pollution Effects on Micro- and Meiofauna of Sand

Although the concentrations of pesticides and heavy metals in potential sea-food is currently attracting widespread attention, the effects of pollution on lower trophic levels in the sea remain almost unknown. In the sediment ecosystem pollution could have far-reaching consequences at high trophic levels through for example alteration of the composition of important species at low trophic levels in food webs, or by irradiation of organisms fundamental to the breakdown processes of the carbon, nitrogen and sulphur cycles.

Toxic effects of pollutants have been assessed mainly at high trophic levels (Portman 1970), and only acute effects involving 48 or 96 h L.C.₅₀ tests have been considered. Of potentially greater long-term importance are the synergistic effects of low levels of pollutants on growth, respiration and fertility rates and the possible alteration of behavioural patterns caused by pollutants. The large size and relatively long life-span of commercially important marine species renders studies of the effects of pollutants on complete life-cycles difficult to accomplish. Thus, smaller animals have advantages in pollution research in having short life-cycles and being easy to manipulate experimentally. The effects of pollution on genetic stability is also of fundamental interest and rapidly reproducing species are of importance in this context.

Marine sand beaches contain an abundance of micro- and meiofauna which provide ideal experimental material for pollution studies. In addition to being small (by definition) most species have short life-cycles and undergo direct development, without planktonic larvae and a variety of trophic levels exists in accessible communities.

A large section of the sand-beach micro- and meiofauna feeds at the primary trophic level on bacteria and micro-algae. As no information exists on the effects of pollutants at this trophic level, a bacterivorous ciliate protozoan and a microalgalivorous archiannelid were studied. The ciliate, *Cristigera* spp. was isolated from beach sand at Robin Hood's Bay, using the seawater-ice extraction method

(Uhlig, 1964). *Cristigera* was cultured on a diet of bacterium *Pseudomonas* spp.), also isolated from beach sand. The growth characteristics of the bacterium in relation to salinity, temperature and some chemical pollutants were established. From this knowledge an excess of food was maintained in experiments measuring the growth rate of *Cristigera*. Growth rates of *Cristigera* were measured as increase in number of cells per unit time, using a Coulter Model A particle counter, with periodic direct microscopic examination of sub-samples to check accuracy of counting. The exponential growth phase alone was studied. (A more detailed description of methods is out of place in the present report and will be given in subsequent papers). A routine temperature of $15^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ and salinity of 34.5 ± 0.5 ‰ were maintained in culture vessels. Each experiment was done in duplicate with an unpolluted control.

The archiannelid *Dinophilus gyrociliatus* O. Schmidt was cultured on a diet of ground deep-frozen spinach (Åkesson, 1970), at a temperature of $16^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and a salinity of 34.5 ± 0.5 ‰, in solid watch glasses (2 ml. capacity). The increase in length of ten recently hatched juveniles was measured every two days when the food source and seawater were changed. Growth rate measurements were continued until the F₁ generation hatched.

The pollutants tested for their effect on growth rate were common North Sea pollutants (I.C.E.S. Cooperative Research Report Series A, 1969), namely heavy metals, phenol, and sulphuric acid. Concentrations used were below levels that caused complete inhibition of growth rates, as synergistic effects of low levels of pollutant were the main interests. Experiments followed a 2³ factorial design with replication, but will be extended to encompass a 3³ factorial design where interaction terms are non-linear. The 3³ factorial design will enable linear, quadratic and cubic components of the response curves to be established, if present. The design will be extended to explore three dimensional response surfaces (Box and Wilson, 1951).

Cadmium, Nickel, Lead, and Zinc in Earthworms from Roadside Soil

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Heimild nr. 68

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■ Cd, Ni, Pb, and Zn in soils and earthworms along two Maryland highways decreased with increasing distance (10, 20, 40, 80, and 160 ft) from the roadway. Metals were quantified by atomic absorption spectrophotometry. Metal residues were higher at the location along each highway where traffic volume was greater. Correlations between residues in earthworms and soil decreased with decreasing atomic weights (Pb > Cd > Zn > Ni). Metal residues in soils were positively correlated with quantities of soil organic matter. Earthworms accumulated up to 331.4 ppm of Pb and 670.0 of Zn, concentrations which may be lethal to earthworm-eating animals.

Certain Biological Effects of Lead Upon the Animal Organism

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In a comprehensive review of the scientific literature, all of the biological, for the most part biochemical, phenomena which are known to result from the absorption of lead in measurable quantities into the bodies of animals and men have been assembled. An attempt has been made to indicate the extent to which the quantitative measurement of certain of these reactions to the absorption of

lead might be employed, or developed to the point of employment, in order to recognize the likelihood of the occurrence of clinical lead poisoning in time to prevent its occurrence. Of greater import is the demonstration of the multiplicity of effects which sufficient concentrations of lead may induce in the biochemistry and physiology of animals.

TOXICOLOGY AND APPLIED PHARMACOLOGY 25, 84-93 (1973)

Heimild nr. 25

Effect of Chronic Lead Treatment on Renal Function¹

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Received July 21, 1972

Effect of Chronic Lead Treatment on Renal Function. HIRSCH, G. H. 1973. *Toxicol. Appl. Pharmacol.* 25, 84-93. When rats were fed diets containing 1% or 2% lead acetate for 10-40 weeks, the kidney weight: body weight ratio was increased. Renal tissue water content was not changed. Accumulation of PAH and TEA by renal cortical slices from treated rats was not altered, but the capacity of kidney slices to synthesize glucose and metabolize pyruvate was decreased. Doses of 200 ppm lead or less had no effect on these parameters. Rats treated with 1% or 2% lead acetate showed an increase in the percentage of an injected dose of PAH excreted in 2 hr. Treatment of dams at parturition with 2% or 4% lead acetate resulted in an increase in the kidney weight: body weight ratio in the offspring at 30 days of age, an increase in PAH uptake by renal cortical slices, and a decrease in renal gluconeogenesis. Histologic examination of kidneys after lead treatment showed varying degrees of vacuolar degeneration and cellular necrosis, and the presence of some lead inclusion bodies.

Heavy metal toxicities

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Effects of 15 Common Environmental Pollutants on Eggshell Thickness in Mallards and Coturnix

by

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Introduction

Eggshell thinning has been documented in several species of fish-eating and raptorial birds in recent years (ANDERSON et al. 1969, FYFE et al. 1969, HICKEY and ANDERSON 1968, KEITH et al. 1970). High residue levels of DDE, the principal metabolite of DDT, were found in the affected birds and their eggs. Most researchers believe that DDE is the causative agent in the shell-thinning phenomenon (ANDERSON et al. 1969, CADE et al. 1971, FYFE et al. 1969, HICKEY and ANDERSON 1968, KEITH et al. 1970, PEAKALL 1970 b). However, laboratory studies with birds given DDE have not shown shell thinning of the magnitude (as much as 50%) seen in some species of wild birds (RISEBROUGH et al. 1971). For example, studies with penned ducks (HEATH et al. 1969, LONGCORE et al. 1971) have shown that DDE can cause eggshell thinning of 13 to 23%. The lower degree of thinning in ducks may be due to species differences, or to the possibility that the responses of this and other species under laboratory conditions may not be representative of those of fish-eating and raptorial birds in the wild. However, it is also possible that additional chemicals are partly responsible for the greater shell thinning and reproductive failure seen in some wild birds. Long and extensive use of DDT has led to the ubiquitous occurrence of the stable metabolite DDE in the environment (HICKEY 1969), but other chemicals, such as mercury, lead, and polychlorinated biphenyls, have also been shown to be widespread environmental pollutants (KNAPP 1970, LAZRUS et al. 1970, PEAKALL and LINCER 1970). This study was conducted to investigate the capacity of some of these compounds to cause eggshell thinning. Fifteen common pesticides and environmental pollutants, including DDE, were tested by a rapid, short-term screening procedure in two common species of laboratory birds.

Procedure

Eighty-four unmated female coturnix quail (*Coturnix coturnix japonica*) were randomly distributed into 14 groups of 6 each and placed in individual indoor cages on a regimen of 14 hours of light and 10 hours of dark. Eighty female mallards (*Anas platyrhynchos*) in their first reproductive season were randomly distributed into 16 groups of 5 birds each and placed in outdoor cages. Eggs were collected from all birds for 6 days to obtain an average pre-treatment eggshell thickness. Each group was orally administered a single dose of one of the chemicals, by gelatin capsule through glass tubing to the level of the proventriculus. So that maximum shell-thinning potential for each chemical would be expressed, dosages were chosen to be high but

Heimild nr. 71

TOXICITY OF HEAVY METALS AND SALTS TO
EURASIAN WATERMILFOIL
(*MYRIOPHYLLUM SPICATUM* L.)

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The toxicity of various heavy metals and salts to Eurasian watermilfoil (*Myriophyllum spicatum* L.) was determined under controlled growth conditions. Toxicants were added to water or to soil in systems with and without woods earth in the substrate.

Fifty percent inhibition of root weight occurred with concentrations of 0.25 ppm Cu^{+2} , 1.9 ppm $\text{Cr}_2\text{O}_7^{-2}$, 3.4 ppm Hg^{+2} , 2.9 ppm AsO_2^{-1} , 7.4 ppm Cd^{+2} , 2.5 ppm Al^{+3} , 9.9 ppm Cr^{+3} , 41.2 ppm Ba^{+2} , 21.6 ppm Zn^{+2} , 13.3 ppm NH_4^{+1} , 22.4 ppm CN^{-1} , 143 ppm $\text{B}_4\text{O}_7^{-2}$, 363 ppm Pb^{+2} , 10,228 ppm Na_2SO_4 , and 8,183 ppm NaCl . Soil increased toxicity of Cr^{+2} and Ba^{+2} but decreased toxicity of $\text{Cr}_2\text{O}_7^{-2}$, Cu^{+2} , Cd^{+2} , Al^{+3} , and Hg^{+2} . In distilled water, CaCl_2 increased toxicity of Cr^{+3} but not $\text{Cr}_2\text{O}_7^{-2}$.

For most toxicants there was a consistent relationship between inhibition of length and inhibition of weight and between inhibition of roots and inhibition of shoots. However, $\text{Cr}_2\text{O}_7^{-2}$ disproportionately decreased dry weight, and Hg^{+2} and Na_2SO_4 disproportionately decreased stem length growth. With Cd^{+2} and Cu^{+2} stem length was greater relative to other measures of growth. Toxicity of Na_2SO_4 and NaCl was the same when concentrations were calculated as osmotic pressure but not when calculated as Na atoms or as total molecules/L.

Aquatic angiosperms are an important part of freshwater ecosystems. Some are considered beneficial for some water uses while others are considered generally detrimental. Despite the economic, ecological, and esthetic importance of this diverse group of aquatic plants, data on their response to toxic chemicals are fragmentary.

Most reported studies on toxicity have concerned copper and arsenic compounds because of their use as herbicides. Arsenite at ten ppm killed water hyssop and parrotfeather in Florida (Phillippy 1961) and at four ppm killed part of a population of *Potamogeton* and *Alisma* but did not kill *Sagittaria* (Cowell 1965). Arsenate at five ppm killed *Potamogeton*, *Najas*, and *Anucharis* but did not kill *Nymphaea* and *Scirpus* in hatchery ponds (Surber and Everhart 1950). At three ppm Cu^{+2} had no effect on *Potamogeton*, *Eriocaulon*, *Scirpus*, *Pontederia*, *Juncus*, or *Nymphaea* (Smith 1939) but at two ppm inhibited growth of parrotfeather (Sutton and Blackburn 1971).

THE DISTRIBUTION OF HEAVY METALS IN THE RED ABALONE, *HALIOTIS RUFESCENS*, ON THE CALIFORNIA COAST Heimild nr. 72

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The gills, mantle, digestive gland and foot muscle of 74 specimens of the red abalone, *Haliotis rufescens*, from five localities on the California coast were analyzed for eight heavy metals: Ag, Cd, Cr, Cu, Pb, Hg, Ni, and Zn. The distribution of these elements in the abalones appeared to be non-normal and the non-parametric Wilcoxon U statistic was used to compare sample concentrations. No correlation of metal concentration with size was found. High concentrations of Cd (up to 1400 ppm) were found in the digestive glands of all samples and are assumed to represent natural levels. Cu and Ag concentrations appear to be inversely correlated, with Cu decreasing and silver increasing from north to south. High Hg concentrations in the La Jolla-Long Beach area appear to reflect pollutant inputs; elsewhere Hg levels appeared to derive from natural sources.

Toxic Effects of Trace Elements on the Reproduction of Mice and Rats Heimild nr. 73

Arch Environ Health—Vol 23, Aug 1971

Henry A. Schroeder, MD, and Marian Mitchener, Hanover, NH, and Brattleboro, VT

Breeding mice and rats were exposed to low doses of six trace elements in drinking water in an environment controlled as to contaminating trace metals. Each group was carried through three generations. Compared to control mice given only doubly deionized water, selenate (3 ppm selenium) resulted in excess deaths before weaning, runts, and failures to breed. Lead (25 ppm) and cadmium (10 ppm) resulted in loss of the

strain in two generations with many abnormalities. Molybdate (10 ppm molybdenum) was slightly toxic in this respect, and arsenic resulted only in elevated ratios of males to females. In rats, lead was very toxic, and titanium and nickel moderately toxic, resulting in many early deaths and runts. This method provides fairly rapid estimates of innate toxicities of trace elements in doses tolerable for growth and survival.

Cadmium, Zinc, Copper, and Lead in Human Renal Cortex Heimild nr. 74

Arch Environ Health—Vol 24, June 1972

Magnus Piscator, MD, and Birger Lind, Stockholm

Analysis of cadmium and zinc in the renal cortex of 67 Swedish subjects disclosed the same dependence on age as in US subjects. In the 6-50 year age group, cadmium content and the cadmium-zinc ratio were correlated to age; thereafter, there was a decrease in cadmium and zinc and in the cadmium-zinc ratios. The increase in zinc paralleled the increase in cad-

mium. The difference between total zinc and the amount of zinc equivalent to the amount of cadmium provides a measure of the physiological zinc content of the cortex; this fraction, 160 ppm (based on dry weight of renal cortex), did not vary with age. In the age groups over 60, cadmium content was significantly lower in women than in men.

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Heimild nr. 75

MUTAGENS AND POTENTIAL MUTAGENS IN THE BIOSPHERE

II. METALS—MERCURY, LEAD, CADMIUM AND TIN*

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(Received September 29th, 1973)

SUMMARY

Comparative data (wherever available) have been presented on the amounts and residues in the environment of a small number of mutagenic and potentially mutagenic metals focussing on mercury, lead, cadmium and tin (and their principal derivatives). Primary consideration has been given to aspects of their production and/or occurrence, reactivity, disposal, concentration, transfer, longevity, biochemical and toxicological nature of their residues in the various biosphere compartments.

Helgoländer wiss. Meeresunters. 20, 293-303 (1970)

Heimild nr. 76

Ophryotrocha labronica as test animal for the study of marine pollution

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KURZFASSUNG: *Ophryotrocha labronica* als Versuchstier für das Studium mariner Wasserverunreinigung. Der Polychaet *Ophryotrocha labronica* hat sich als geeignetes Testobjekt für Untersuchungen über Probleme der Verunreinigung von Meeresgebieten erwiesen. Als Kriterien für derartige Untersuchungen können herangezogen werden: Wachstumsgeschwindigkeit, Reproduktionsleistung, Dauer der verschiedenen Entwicklungsstadien, Sterblichkeit sowie Beobachtungen über Bewegungen und Nahrungsaufnahme. Die Größe des Polychaeten überschreitet kaum 4,5 mm. Er ist herbivor und kann in großer Anzahl in verhältnismäßig kleinen Gefäßen ganzjährig gezüchtet werden. Bei 20° C wird die Entwicklung in weniger als einem Monat abgeschlossen. Die Reproduktionsleistung ist sehr groß. Pro Weibchen werden durchschnittlich 120 Nachkommen produziert. Die Züchtungsmethoden werden beschrieben und die Ergebnisse einiger Versuche über den Einfluß von Nahrung, Temperatur, Salzgehalt sowie von industriellen Abfallstoffen (Schwefelsäure, Äthylenglykol) mitgeteilt.

2.4. Brennisteinstvíildi, SO₂

Tilraunir hafa sýnt að áhrif SO₂ í andrúmslofti á gróður virðast fyrst og fremst vera þau að CO₂-nám plantna minnkar, jafnvel við tiltölulega lágt SO₂ magn. Talið er að SO₂ sameinist aldehyðsambandi innan plöntunnar og myndi svonefnt alfa hydroxy sulfonat. Minnkandi CO₂-nám plöntunar stafar svo sennilega af því að alfa hydroxy sulfonat hindri nauðsynlega ensímvirgni innan plöntunnar.

Áhrif SO₂ mengunar á fléttur hafa verið mikið könnuð. Hefur mengun af þessu tagi haft gífurleg meikvæð áhrif á fléttugróður á víðáttumiklum svæðum á norðurhveli jarðar.

Athuganir á áhrifum SO₂ á menn hafa leitt í ljós að SO₂ hreinsast mjög vel úr loftinu í nefi en jafnframt hefur komið í ljós að öndunargangur um nef þrengist ef SO₂ er í loftinu. Þetta eykur líkurnar á því að öndun fari fram um munn þar sem mun meira magn af SO₂ myndi komast niður í lungun. Aukið magn SO₂ í andrúmslofti á loftmenguðum svæðum er án efa einn af þeim þáttum sem veldur aukinni tíðni lungnasjúkdóma hjá mönnum.

EXPERIMENTAL STUDIES ON SULFUR DIOXIDE

INJURIES IN HIGHER PLANTS Heimild nr. 77

I. Formation of Glyoxylate-Bisulfite in Plant Leaves Exposed to Sulfur Dioxide

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(Received 16 June, 1971)

Abstract. Reversible decrease in CO₂ fixation has been reported in rice plants exposed to low concentrations of SO₂ (Matsuoka *et al.*, 1969). Alpha hydroxy sulfonate is thought to form in leaves by an addition-reaction between plant aldehyde and SO₂, and to inhibit the process of the photosynthesis. However, the identification of this compound in the leaves has not been successful.

This report deals with the results of the radiochemical experiments to examine the occurrence of glyoxylate bisulfite, α -hydroxy sulfonate forms of glyoxylic acid in rice plant leaves exposed to radioactive sulfur dioxide. In plants exposed to SO₂, sufficient amounts of glyoxylate bisulfite could be formed and thereby inhibit the progress of the path from glycolic to glyoxylic acid.

EXPERIMENTAL STUDIES ON SULFUR DIOXIDE INJURIES

IN HIGHER PLANTS Heimild nr. 78

II. Disturbance of Amino Acid Metabolism in Plants Exposed to Sulfur Dioxide

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(Received in final form 25 April, 1972)

Abstract. Photosynthesis is reversibly inhibited by exposing plants to SO₂. The formation of α -hydroxy sulfonate in the exposed plants is suggested as one of the effects, because this compound inhibits glycolic oxidase which is necessary in the glycolic acid pathway. The suppression of the glycolic acid path should affect various aspects of metabolism in plants, particularly the reduction of the biosynthesis of glycine and serine. In this paper, the biosynthesis of these amino acids in plants exposed to SO₂ was investigated to estimate the significance of the formation of α -hydroxy sulfonate in the plants. The results show that photosynthetic formation of serine was reduced in the exposed plants, and that α -hydroxy sulfonate was formed.

Long-Term Continuous Exposure
to Sulfur Dioxide in Cynomolgus Monkeys

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Alex A. Krumm; and Harold N. MacFarland, PhD, Falls Church, Va

Cynomolgus monkeys were exposed to sulfur dioxide while a control group was exposed to filtered air. The exposure was for 24 hours a day, seven days a week, for 78 weeks. Frequent measurements were made to evaluate mechanical properties of the lung, distribution of pulmonary ventilation, diffusing capacity of the lung, and arterial blood oxygen tension. Hematological and clinical biochemical determinations were conducted. Microscopic evaluation of organs and tissues was conducted at termi-

nation of the exposure of the animals. No deleterious effect could be attributed to SO₂ exposure at concentrations of 0.14 to 1.28 ppm. Following 30 weeks of exposure to 4.69 ppm, an overexposure occurred in this group. This was followed by deterioration in pulmonary function which persisted during the following 48 weeks of observation, and alterations in pulmonary tissues were observed upon microscopic examination.

Human Response to Controlled Levels of Sulfur Dioxide

Arch Environ Health/Vol 28, Jan 1974

Ib Andersen, MD; Gunnar R. Lundqvist;
Preben L. Jensen, Aarhus, Denmark; Donald F. Proctor, MD, Baltimore

Nasal mucus flow rate, airway resistance, and subjective response was studied in 15 young men during six-hour exposures to 1, 5, and 25 ppm sulfur dioxide (SO₂). A significant decrease in nasal mucus flow rate during 5- and 25-ppm exposures was observed. This decrease was greatest in the anterior nose and in subjects with an initially slow mucus flow

rate. Pharyngeal air samples yielded less than 1% of the SO₂ inhaled, even after a six-hour exposure to 25 ppm SO₂. An increased nasal airflow resistance and a fall in forced expiratory volume in one second and forced expiratory flow during the middle half of expired volume was found at all exposure levels, but there was no change in "closing volume." Dis-

comfort was proportional to SO₂ concentration, but never excessive. Subjects with initially slow nasal mucus flow rates experienced the greatest discomfort. The acute effects of SO₂ exposure appear to justify reduction of the present threshold limit value of 5 ppm to 1 ppm, and provide support for a nasobronchial reflex bronchoconstriction.

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EXPERIMENTAL STUDIES ON SO₂ INJURIES IN HIGHER PLANTS

Heimild nr. 81

III: Inhibitory Effect of Sulfite Ion on ¹⁴CO₂ Fixation

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Abstract. Photosynthesis decreases reversibly in plants exposed to SO₂. Photosynthesis recovers when the exposure to SO₂ is discontinued. Inactivation of a photosynthetic enzyme, ribulose-1,5-diphosphate carboxylase, by sulfonation of its SH groups was investigated as a cause of the reversible reduction of photosynthesis. The relationship between the sulfite ion concentration in the reaction mixture and ¹⁴CO₂ fixation catalyzed by the enzyme which was prepared from alfalfa leaves was explored by using radioactive NaHCO₃.

About 50% and 85% inhibitions of ¹⁴CO₂ fixation were observed at 3 × 10⁻³ M and 3 × 10⁻² M concentration of sulfite ion in the reaction mixture, respectively. The accumulation of 3 × 10⁻⁴ M sulfite ion on the reaction site of the enzyme involved in the plants which were exposed to SO₂ could considerably reduce the CO₂ assimilation of the plant.

Heimild nr. 82

Bestemmelse av støvutslipp ved produksjon av ferrosilisium

Støvutslipp fra ferrosilisiumproduserende ovner kan bestemmes ved direkte støvemisjonsmålinger, av materialbalansen på silisium, eller av energi-forbruket pr mengde produsert metall. Artikkelen beskriver de tre metodene for bestemmelse av utslipp og anbefaler når de kan brukes.

Registrering av støvkonsentrasjon med automatisk tapesampling og radiometrisk støvmengdemåling



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Forfatteren er født 1944

Støvkonsentrasjonen er en viktig driftsparameter i industrielle prosesser, hvor støv enten blandes med eller utskilles fra en gass-strøm. Smelteovner, tørkeovner, oljekraftverk etc. hører inn under førstnevnte kategori, mens alle typer støvutskilingsanlegg hører inn under sistnevnte.

Begrepet registrerende støvemisjonsmålinger settes idag ofte i forbindelse med myndighetenes ønske om kontroll av utslipp. Bedrifters prosessutslipp er imidlertid ofte også et mål for produksjonstapet. Kvantitativ registrering vil da kunne gi bedre prosesskunnskap og mulighet for optimalisering.

Radiometrisk mengdemåling best egnet ved kvantitativ registrering

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Trace Analysis in Industrial Research†

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KEY WORDS: trace analysis, industrial methods, pollutants.

Public concern and legislative regulations governing environmental pollution have had a dramatic effect on chemists involved in industrial research. The need to establish both the presence and amounts of trace levels of pollutants in industrial products and wastes has become imperative. Since time and cost become important considerations in such analytical determinations, it is apparent that sensitive, rapid and reliable methods of trace analysis are required. Many experimental techniques have been employed to this end and active research programs exist to develop new techniques to make such analysis more efficient.

Techniques capable of determining many elements in a single examination of a sample are of particular interest. No single 'black box' approach is, or is likely to become, feasible for all species of interest. Nonetheless, certain multi-element approaches provide adequate information on some species and also provide important guidelines on the determination of other species by more specialized techniques. Problems encountered and progress achieved by the application of various spectroscopic, chromatographic, electrochemical and chemical methods to the trace analysis of industrial materials will be discussed.

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Air Pollution and Lichens

Edited by

B. W. FERRY, M. S. BADDELEY

and D. L. HAWKSWORTH

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I : Introduction

P. W. JAMES

Everyone wishes to abolish the damage which may be caused to man and to wild life by pollution from every source. As, however, we are not always agreed as to when damage is being caused, or how exactly some obvious damage arose, an easy solution will not be found. Man has always polluted his environment; he has always suffered from pests, but because of the 'population explosion', these problems have become more serious in recent years. The need for more research in these subjects is obvious, if irreparable damage to wild life, and to man, is to be avoided. Equally important, we must make sure that the results of such research are quickly and efficiently applied.

Mellanby (1967, p. 30)

Although the sensitivity of lichens to air pollution has been acknowledged since the observations of Grindon in south Lancashire in 1859 (Grindon, 1859), the lack of recording gauges effectively delayed all critical study in this field prior to 1958. However, since then, detailed research and surveys, carried out independently by scientists in the British Isles, Canada, Czechoslovakia, Germany, Scandinavia, USA and the USSR, have convincingly demonstrated that it is now possible to correlate the distribution of lichens around air pollution sources with mean levels of air pollutants and, in some cases, to utilize their behaviour as a means of monitoring the distribution and severity of the pollutant emissions. Sulphur dioxide has been proved to be the most important major pollutant adversely affecting lichen vegetation over wide areas of the northern hemisphere. Over two hundred papers dealing with lichen vegetation of areas affected by air pollution have now appeared in the scientific press (ch 3), and recent laboratory (ch 13 and 14) and transplant studies (ch 3) have corroborated the data obtained from field observations.

The compilation of the present book, the first on this aspect to have appeared, received its main stimulus as a result of the symposium devoted to *Lichens and Air Pollution* organized as part

2 Introduction

of the *First International Mycological Congress*, held in Exeter, England, in September 1971. At this meeting it was confirmed that there was a very substantial output of published but dispersed information, as well as important unpublished data on this aspect, a concise summation of which, it was felt, would considerably benefit future studies and research in the field of air pollution as well as advising on its recognition and control. Pertinent reviews of the behaviour of sulphur dioxide in the air (ch 2), the effects of air pollutants on plants other than lichens (ch 10) and the effects of other pollutants on lichens (ch 8 and 9) are included. The volume is not only designed for the specialist studying the effects of air pollutants on lichens, but also for those interested in the broader spectra of pollution studies. Several volumes on the latter topic, concerned at least in part with matters of air (atmospheric) pollution, have appeared in recent years. The recent publication of Bach (1972) is to be particularly recommended. The aims of the present book are to introduce and aid in an understanding of the wealth of data currently available on lichens and air pollution, and above all to stimulate the reader and suggest to him new and rewarding avenues of further research (ch 17).

There has been a general lack of the appreciation of the effects of long-term low levels of sulphur dioxide and fluoride on vascular plants, such as conifers, the corrosion rates for metals, the decay of stonework, and considerable concern is still being expressed on its effects on human health (Anon., 1970). Lichens are among the most sensitive organisms to sulphur dioxide pollution known and because different species are affected by different concentrations of this pollutant, it has been possible to construct scales for the estimation of the mean sulphur dioxide levels in an area, solely from the lichen vegetation present (*see* ch 3). The lichen scales are of particular value in areas with mean sulphur dioxide levels in the range 30-170 $\mu\text{g}/\text{m}^3$, and most sensitive in the range 30-70 $\mu\text{g}/\text{m}^3$. Representative scales have been compiled with the non-specialist in mind; these are quick and cheap to apply, and clearly not only of academic interest as they now cover a range of this pollutant at which, for example, coniferous trees are affected.

Nearly all lichens are composite plants, each basically com-

James 3

prising a fungal component, the mycobiont, and an alga, the phycobiont. The mycobionts are usually of Ascomycete affinity and are very rarely encountered in a non-lichenized state; the phycobionts are either green (Chlorophyceae) or blue-green (Cyanophyceae) and although many can thrive in a free-living condition, a few, such as *Trebouxia*, are rarely found to do so. Most of the pertinent literature on the group, including references to introductory texts, may be traced through Ainsworth (1971). The two bionts live in a symbiotic relationship forming a thallus whose morphology, anatomy and physiology are quite distinct from that of either of the two symbionts when separated and grown in axenic cultures. Lichens are extremely slow-growing plants, capable of living to a great age (up to 4500 years). They colonize natural substrata such as bark, lignum, rock, as well as man-made materials such as mortar, asbestos and glass on which they cause little harm. As a group, their extreme resistance to exposure, variation in temperature and degree of environmental desiccation are well known; their capabilities for enhanced uptake of radioactive and heavy metal fallout are less well studied. In recent years research into the physiology of the intact thallus and the interrelationships between the bionts, especially with regard to the transfer of carbohydrates, has proved to be important in the understanding of other symbiotic systems (ch 12).

That the lichen vegetation in areas which have become subjected to air pollution has become considerably depleted is seen from comparisons between the past and present floras of particular sites and changes in distribution of different species (see ch 16). Unfortunately, this decline is still continuing in many countries, the result of the increase in sources and consequently in the spread of sulphur dioxide emissions, existing to such an extent that in some cases certain species are in danger of extinction. This is a matter of considerable, urgent concern to those interested in conservation, and particularly to lichenologists. However, lichens are also important from other standpoints: they form, like most other organisms, an important integral part of the ecosystem, and any disruption in their communities affects other organisms dependent on them as food material or as protection in micro-habitats. Kuenan (1971) has stressed the

4 Introduction

need for detailed quantitative studies of the fauna of trees from which lichens are disappearing due to air pollution, and Schofield and Hamilton (1970) comment that damage by sulphur dioxide to the extensive lichen vegetation of the tundra would certainly lead to famine in areas of economically important reindeer and caribou husbandry which are particularly dependent on lichens for winter fodder.

Lichens produce an impressive array of secondary metabolic products (Culberson, 1969) many of which are unknown in other plant groups. Some of these have acclaimed antibiotic qualities and for this reason are commercially used in the pharmaceutical trade.

On environmental grounds, lichens add much to the aesthetic beauty of the landscape. Over most of western Europe much of the original lichen vegetation, composed of brightly coloured, grey or yellowish-green, large pendant bearded or leaf-like species, has now been replaced by a monotonous grey-green crust consisting of a single, particularly tolerant species (*Lecanora comizaoides*). Whilst visitors to parts of southern and western Britain still frequently remark on the richness of the lichen vegetation there, it is salutary to reflect that early in the last century similar communities were present in the London area (ch 6, 16).

The prospect of reducing sulphur dioxide levels to those at which lichens are completely unaffected is clearly unrealistic besides being prohibitive in cost; in any case their importance cannot justify such drastic action even on a European scale. It is, however, important that at least some areas are left unaffected for the reasons outlined above and all attempts should be made to limit the current trend of increasing sulphur dioxide emissions in Europe, especially along the Atlantic seaboard. The Swedish Royal Ministry for Foreign Affairs and the Royal Ministry for Agriculture (1971) recommend that mean sulphur dioxide levels of only $56 \mu\text{g}/\text{m}^3$ should be permitted in order to prevent damage to coniferous trees. If this standard were adopted, considerable improvements can be expected in the lichen vegetation in many areas of Europe.

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