References

At compiling data the conventions and styles set for the American Society of Agronomy (ASA Publications Handbook and Style Manual 1988) were followed as far as possible, although, in some cases, due to the indifferent use of conventions and styles in various sources, deviations from the SI system or other standards are still incorporated. References are cited mainly following the ASA guidelines, by one exeption: papers in conference/ symposium/ workshop proceeedings are cited only with the name-year system, and reference is made solely to the editor(s), ie only the editor and the textbook or proceedings title are mentioned in the List of References': For example:

citation in the main text is: Smedema in: van Hoorn ed. 1988.

further citation in the List of References: van Hoorn, J.W. ed. 1988. Agrohydrology - Recent Developments. Proceedings of the Symposium 'Agrohydrology' at the IAC 1987, Wageningen. Elsevier. Amsterdam.

Abbreviations of Organizations

ADB	Asian Development Bank
ASA	American Society of Agronomy
ASCE	American Society of Civil Engineers
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
DSE	Deutsche Stiftung für Internationale Entwicklung
DVWK	Deutscher Verband für Wasserwirtschaft und Kulturtechnik
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agricultural Organization of the United Nations
(FAO CP)	FAO Conservation Paper
(FAO-EEP)	FAO Environment and Energy Paper
(FAO IDP)	FAO Irrigation and Drainage Paper
(FAO ICTP)	FAO Investment Centre Technical Paper
(FAO PY)	FAO Production Yearbook
(FAO SB)	FAO Soils Bulletin
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
ICID	Internation Commission on Irrigation and Drainage
ICOLD	International Commission on Large Dams
IIED	International Institute for Environment and Development
ILACO	International Land Devlopment Consultants Arnhem
ILRI	International Institute for Land Reclamation and Improvement
INCID	Indian Commission on Irrigation and Drainage
IRRI	International Rice Research Institute
ISM	International Soil Museum Wageningen
ISTRO	International Soil Tillage Research Organization
IUCN	The World Conservaton Union
OAS	Organization of American States
ODI	Overseas Development Institute
ODU	Overseas Development Unit of Hydraulics Ressearch

OECD	Organization for Economic Co-Operation and Development
PEEM	Panel of Experts on Environmental Management (WHO)
RSU	Rat der Sachverständigen für Umweltfragen (FRG)
SSSA	Soil Science Society of America
UNEP	United Nations Environmental Programme
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Devlopment
USDA	United States Department of Agriculture
USCID	US Committee on Irrigation and Drainage
WB	The World Bank
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute

Common units and measures

a	year (annum)
dS	deci-Siemens (equivalent to mmhos)
EC	electrical conductivity (salinity measure)
ECe	EC from a saturated soil extract
EO	open water evaporation
ESP	exchangeable sodium percentage
ET	evapotranspiration
g	gram
ha	hectare
hr	hour
l	litre
M	million
MCM	million cubic meter
m	meter
N	north
TDS	total dissolved solids
W	Watt; kW kilowatt, MW megawatt, GW gigawatt
y	year

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Table 1-1

Key Environmental Issues in Irrigation Schemes

1. Use of agro-chemicals and ecotoxicological impairments
   (1) pesticides: choice; transport; storage; handling; use-maintenance-repair of application equipment; safe & effective use; complience with local laws and regulations; disposal
   (2) fertilizers including soil amendments/conditioners: choice, storage, handling, safe & effcient use, disposal
   (3) post-harvest control measures

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2 Direct intervention into protected areas (IUCN-categories I to X)
   strict nature reserves, national parks, natural monument, managed nature reserves, biosphere reserves, natural world heritage sites; protected landscape, resource reserve, multiple use management areas

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3. Direct or indirect interventions into wetlands and other ecologically sensitive areas (ESAs)
   (1) wetlands which have important functions, products or attributes: estuarines, mangroves, floodplains, freshwater marshes, lakes, peatlands, swamp forests
   (2) areas susceptible to wind or water erosion
   (3) habitats that support important natural vegetation on soils of low inherent fertility and
   (4) yields of little value if transformed
   (5) habitats that provide important biogenetic and medicinal potentials
   (6) critical habitats of threatened plant & fauna species for breeding, feeding or staging

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4. Interventions in sensitive water resources
   (i) international rivers or groundwater reservoirs
   (ii) important national water reserves
   (iii) water supplies of regional importance

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5. Implications to public health
   (1) extra risks in faecal-oral (water-washed or water-borne), water-washed, water-based or water-related vector-borne diseases: increase in community vulnerability, environmental receptivity and vigilance of health services
   (2) extra risks from excreata use
   (3) extra risks from water pollution (pathogenic microorgansim, nitrogens, toxicants)
   (4) risks from toxic aerosols (pesticide applications)
   (5) risks from chemical health control measures: molluscicides, residual house sprayings

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6. Impairments of socio-cultural values
   (1) critical habitats which provide livelyhood for specific and minority population groups
   (2) areas of unique historical, archeological, or other cultural heritage, or important to cultural or religious beliefs
   (3) unique areas of diversified rural patterns: settlements, diversified croplands
   (4) areas which provide important habitat for natural industry: cottage industry, handicraft materials, indigenous food

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7. Resettlement and migrants
   relocations or evacuations; scheduled or unscheduled migrants, temporary residents

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8. Degradaded watersheds
   typically impairments on irrigation schemes: floods, unreliable water supply, sedimentation, etc.

Important Potential Impacts Caused by Irrigated Agriculture

Water regime impacts

* river flow changes, flooding pattern changes, groundwater fall/ -rise, saltwater intrusion

Stream morphology and water body changes

* stream degradation (bank erosion, river bed changes)
* creation or alteration of impoundments, drainage lakes
* estuary degradation (coastal erosion, delta formation)

Pollution

* particle pollution of surface waters (erosion, sediment transportation, siltation)
* organic pollution of surface waters (nutrients, organic compounds, pathogens)
* eutrophication of surface waters (nutrients, organic compounds)
* organic pollution of groundwaters (nutrients, organic compounds, pathogens)
* toxic concentrations of substances in surface waters (metals, salts, pesticides)
* toxic concentrations of substances in groundwaters (salts, metals, pesticides)
* toxic concentration of substances in soils (salts, acids, pathogens, metals, pesticides)
* gas emissions (air pollution, radiatively active gases)
* aerosol emissions (pathogens, toxic concentrations of pesticides)

Soil degradation

* soil loss or accumulation (wind & water erosion)
* waterlogging
* salinization (also: acidification, alkalinization)
* soil compaction and structural degradation
* loss in fertility (biotic activity, agricultural productivity)
* biological imbalances increase (pests, weeds)

Eco-biological imbalances

* impairment or loss of valuable wetlands
* plant community changes (terrestrial flora)
* plant diversity loss (terrestrial flora)
* threatened or/and endemic species loss or impairments
* wildlife habitat loss, wildlife migration restrictions

Land use and ecomomic development conflicts

* conflicts with competing agricultural uses
* conflicts with other land uses
* use of non-renewable resources (fuel, materials, etc.)
* conflicts with other water users (industrial, domestic, agricultural)
* conflicts with navigation (through water regime & stream morphology changes)
* conflicts with fishery
* conflicts with natural resources industry
* conflicts with forestry/woodland uses
* conflicts with planning (policies, programmes, projects)

Public health risks

* communicable disease risks (communal vulnerability, environmental receptivity, vigilance of health services)
* non-communicable disease risks (occupational, water and air pollution, phytotoxic crop contamination, accidents)
* risks associated with general well-being (water supply, nutrition, habitation, sanitation)

Natural beauty impairments (landscape diversity, aesthetics)

Cultural heritage site loss or impairments (buildings, monuments etc.)

Socio-economic impacts (higher order impacts)

* regional disparity
* population change
* community facilities
* group development (and participation)
* ethnic minority group development
* employment/labour
* women's situation
* income

Resettlement effects (migrants, evacuees)

Important Potential Environmental Impacts on Irrigation

* river regime changes (hinterland degradation, upstream uses)
* groundwater regime changes (regional urban uses, hinterland degradation)
* surface water pollution (upstream urban pollutions, hinterland degradation)
* groundwater pollution (urban pollutions, agricultural pollutions)
* soil erosion (regional degradation)
* soil contamination (wastewater reuse)
* air pollution (urban pollution, traffic pollution)
* land use competition (livestock grazing, urban uses)
* health hazards (vector diseases, aninal diseases etc.).

Table 10.3 River Runoff and Its Use

(cubic kilometers per year)

Table 2-1

Elements	Europe	Asia	Africa	North America	South America	Australia Oceania	U.S.S.R.	World Total
	World Regions							
Total River Runoff	2,321	10,485	3,808	6,945	10,377	2,011	4,350	40,67
Groundwater Discharge to Rivers	845	2,879	1,464	2,222	3,736	483	1,020	12,69
Surface Runoff	1,476	7,606	2,720	4,723	6,641	1,528	3,330	27,98
1980s								
Water Withdrawal	364	1,591	176	767	161	26	443	3,53
Consumptive Use	134	1,145	146	339	110	19	239	2,12
Waste and Returning Waters	230	446	42	428	51	7	204	1,41
Use of Resources (percentage of total river runoff)	16	15	4	11	2	1	10	9
Year 2000 Projection								
Water Withdrawal	404	2,160	289	946	293	35	533	4,66
Consumptive Use	158	1,433	201	434	165	22.5	286	2,70
Waste and Returning Waters	246	727	88	512	128	12.5	247	1,96
Use of Resources (percentage of total river runoff)	17	21	7	14	3	2	12	11

Tab. 4-4: Wassernutzung nach Sektoren und Entwicklung der Entnahme (%)

Table 2-2

Region	Agriculture / Landwirtschaft: utilisation / Nutzung (%)		Agriculture / Landwirtschaft: increase / Anstieg (%)	Domestic uses / Haushalte und öffentliche Nutzung: Nutzung (%)		Domestic uses / Haushalte und öffentliche Nutzung: Anstieg (%)	Industry / Industrie: utilisation / Nutzung (%)		Industry / Industrie: increase / Anstieg (%)
	80er Jahre	2000	80er Jahre bis 2000	80er Jahre	2000	80er Jahre bis 2000	80er Jahre	2000	80er Jahre bis 2000
Europa	31	26 – 33	14	14	12 – 15	17	55	52 – 62	4 – 55
Asien	86	74	15	6	10	127	8	16 – 17	171 – 186
Afrika	68	71 – 73	33	7	13 – 14	200	5	14 – 16	362 – 438
Nordamerika	48	46	18	10	11	36	43	43 – 44	22 – 26
Südamerika	56	38 – 39	29	19	17	67	24	43 – 48	233 – 267
Australien und Ozeanien	74	69 – 70	25	19	19	34	7	11 – 12	114 – 150
UdSSR	65	62 – 63	15	6	7	52	29	29 – 31	20 – 28
GESAMT	68	59 – 62	17	8	10 – 11	74	24	27 – 30	52 – 72

Quelle: World Resources Institute, World Resources 1990–91, New York, Oxford 1990

Table 10.4 Water Withdrawals for Irrigation

Table 2-3a

Region	1980s: Areas of irrigation (million hectares)	1980s: Water withdrawal (cubic kilometers)	1980s: Consumptive use (cubic kilometers)	1980s: Recycled water (cubic kilometers)	Year 2000 Projection: Areas of irrigation (million hectares)	Year 2000 Projection: Water withdrawal (cubic kilometers)	Year 2000 Projection: Consumptive use (cubic kilometers)	Year 2000 Projection: Recycled water (cubic kilometers)
Europe	17	110	95	15	19	125	105	20
Asia	140	1,300	980	320	165	1,500	1,150	350
Africa	11	120	85	35	15	160	110	50
North America	29	330	215	115	35	390	260	130
South America	8.5	70	55	15	11	90	70	20
Australia and Oceania	2.0	16	13	3	2.5	20	15	5
U.S.S.R.	20	260	180	80	23.5	300	210	90
World Total	227.5	2,206	1,623	583	271	2,585	1,920	665

Source: A.V. Belyaev, U.S.S.R. Academy of Sciences, Institute of Geography, Moscow in consultation with other international sources.
Note: Oceania is defined as Australia, Fiji, New Zealand, Papua New Guinea, and Solomon Islands.

Sources: World Resources Institute

Table 1. Sources of Water Supply in 16 Asian Countries

Type	Arable Area (million ha)	Actual cultivated area (million ha)	Cropping intensity (%)
Surface irrigation	100.0	144.5	145
Groundwater irrigation	35.0	46.3	132
Rainfed and others	223.0	227.0	102
Total	358.0	417.8	117

Note: Summarization of 16 Asian countries i.e. Bangladesh, Bhutan, China, Korea (DPR), Korea (Republic of), India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam and Japan.

Table 2-3b

Table 2. Groundwater Utilization in Asian Countries

Country	Groundwater potential (Billion cubic metre/year)	Groundwater Utilization (Billion cubic metre/year) Irri	Others	Total	Land irrigated by groundwater (Net) (million ha)
Bangladesh	–	6.0	1.7	7.7	0.8
China	700	39.6	–	–	9.0
India	423	43.5	6.5	50.0	19.0
Indonesia	456	0.01	3.7	3.7	0.02
Pakistan	–	40.0	–	40.0	5.6
Philippines	33	0.5	2.1	2.6	0.2
Thailand	–	0.2	2.7	2.9	0.01

Source: Water Resources Journal (ESCAP) Dec. 1986 and other information gathered by FAO/RAPA.

Table 2-3c

Table 2. Area Irrigated by Different Sources in India During 1950-51 to 1984-84 (Area: '000 ha)

Source	1950-51	1960-61	1970-71	1980-81	1984-85
Canals	8295 (39.8)	10370 (42.1)	12838 (41.3)	15292 (39.5)	15861 (37.9)
Tanks	3613 (17.3)	4561 (18.5)	4112 (13.2)	3198 (08.2)	3330 (07.9)
Tube wells	N.A.	135 (0.6)	4461 (14.3)	9527 (24.6)	11265 (27.2)
Other wells	5978 (28.7)	7155 (29.0)	7426 (23.9)	8207 (21.1)	8723 (20.9)
Other sources	2967 (14.2)	2440 (09.8)	2266 (07.3)	2585 (06.6)	2600 (06.2)
Total (Net Irrigated Area)	20853 (100.0)	24661 (100.0)	31103 (100.0)	38806 (100.0)	41779 (100.0)

(Figures in parenthesis indicate percentage of total irrigated area)

Source: Indian Agriculture in Brief 21st Edition, Directorate of Economics and Statistics, Dept. of Agric. & Coop., Ministry of Agriculture, Government of India, New Delhi.

Source: APO 1991

Table 22.1 Freshwater Resources and Withdrawal

	Annual Internal Renewable Water Resources		Annual River Flows		Annual Withdrawal				Sectoral Withdrawal (percent)		
	Total (cubic km)	1990 Per Capita (000 cubic meters)	From Other Countries (cubic km)	To Other Countries (cubic km)	Year of Data	Total (cubic km)	Percentage of Water Resources (a)	Per Capita (cubic meters)	Domestic	Industry	Agriculture
WORLD	**40,673.00 b**	**7.69**			**1987 b**	**3296**	**8**	**660**	**8**	**23**	**69**
AFRICA	**4,184.00 b**	**6.46**			**1987 b**	**144**	**3**	**244**	**7**	**5**	**88**
Algeria	18.90	0.75	0.20	0.70	1980	3.00	16	161	22	4	74
Angola	158.00 b	15.77	X	X	1987 b	0.48	0	43	14	10	76
Benin	26.00	5.48	X	X	1987 b	0.11	0	26	28	14	58
Botswana	1.00	0.78	17.00	X	1980	0.09	1	98	5	10	85
Burkina Faso	28.00 b	3.11	X	X	1987 b	0.15	1	20	28	5	67
Burundi	3.60 b	0.66	X	X	1987 b	0.10	3	20	36	0	64
Cameroon	208.00	18.50	X	X	1987 b	0.40	0	30	46	19	35
Cape Verde	0.20	0.53	0.00	0.00	1972	0.04	20	148	9	2	89
Central African Rep	141.00 b	48.40	X	X	1987 b	0.07	0	27	21	5	74
Chad	38.40 b	6.76	X	X	1987 b	0.18	0	35	16	2	82
Comoros	1.02 b	1.97	0.00	0.00	1987 b	0.01	1	15	48	5	47
Congo	181.00 b	90.77	621.00	X	1987 b	0.04	0	20	62	27	11
Cote d'Ivoire	74.00	5.87	X	X	1987 b	0.71	1	68	22	11	67
Djibouti	0.30	0.74	0.00	X	1973 b	0.01	2	28	28	21	51
Egypt	1.80	0.03	56.50	0.00	1985	56.40	97	1,202	7 c	5 c	88 c
Equatorial Guinea	30.00 b	68.18	X	X	1987 b	0.01	0	11	81	13	6
Ethiopia	110.00	2.35	X	X	1987 b	2.21	2	48	11	3	86
Gabon	164.00 b	140.05	X	X	1987 b	0.06	0	51	72	22	6
Gambia, The	3.00	3.50	19.00	X	1982	0.02	0	33	7	2	91
Ghana	53.00	3.53	X	X	1970	0.30	1	35	35	13	52
Guinea	226.00 b	32.87	X	X	1987 b	0.74	0	115	10	3	87
Guinea-Bissau	31.00 b	31.41	X	X	1987 b	0.01	0	18	31	6	63
Kenya	14.80	0.59	X	X	1987 b	1.09	7	46	27	11	62
Lesotho	4.00 b	2.25	X	X	1987 b	0.05	1	34	22	22	56
Liberia	232.00 b	90.84	X	X	1987 b	0.13	0	54	27	13	60
Libya	0.70	0.15	0.00	0.00	1985	2.62	374	262	15	10	75
Madagascar	40.00	3.34	0.00	0.00	1984	16.30	41	1,675	1	0	99
Malawi	9.00 b	1.07	X	X	1987 b	0.16	2	22	34	17	49
Mali	62.00 b	6.62	X	X	1987 b	1.36	2	159	2	1	97
Mauritania	0.40	0.20	7.00	X	1978	0.73	10	473	12	4	84
Mauritius	2.20	1.99	0.00	0.00	1974	0.36	16	415	16	7	77
Morocco	30.00	1.19	0.00	0.30	1985	11.00	37	501	6 c	3 c	91 c
Mozambique, People's Rep	58.00 b	3.70	X	X	1987 b	0.76	1	53	24	10	66
Niger	14.00 b	1.97	30.00	X	1987 b	0.29	1	44	21	5	74
Nigeria	261.00 b	2.31	47.00	X	1987 b	3.63	1	44	31	15	54
Rwanda	6.30 b	0.87	X	X	1987 b	0.15	2	23	24	8	68
Senegal	23.20 b	3.15	12.00	X	1987 b	1.36	4	201	5	3	92
Sierra Leone	160.00 b	38.54	X	X	1987 b	0.37	0	99	7	4	89
Somalia	11.50	1.52	0.00	X	1987 b	0.81	7	167	3	0	97
South Africa	50.00	1.42	X	X	1970	9.20	18	404	16	17	67
Sudan	30.00	1.19	100.00	56.50	1977	16.60	14	1,089	1	0	99
Swaziland	6.96 b	8.82	X	X	1987 b	0.29	4	414	5	2	93
Tanzania	76.00 b	2.78	X	X	1970	0.48	1	36	21	5	74
Togo	11.50	3.33	X	X	1987 b	0.09	1	40	62	13	25
Tunisia	3.75	0.46	0.60	0.00	1985	2.30	53	325	13	7	80
Uganda	66.00 b	3.58	X	X	1970	0.20	0	20	32	8	60
Zaire	1,019.00 b	28.31	X	X	1987 b	0.70	0	22	58	25	17
Zambia	96.00 b	11.35	X	X	1970	0.36	0	86	63	11	26
Zimbabwe	23.00 b	2.37	X	X	1987 b	1.22	5	129	14	7	79
NORTH & CENTRAL AMERICA	**6,945.00 b**	**16.26**			**1987 b**	**697**	**10**	**1,692**	**9**	**42**	**49**
Barbados	0.05	0.20	0.00	0.00	1962	0.03	51	117	52	41	7
Canada	2,901.00	109.37	X	X	1980	36.15	1	1,501	18	70	12
Costa Rica	95.00	31.51	X	X	1970	1.35	1	779	4	7	89
Cuba	34.50	3.34	0.00	0.00	1975	8.10	23	868	9	2	89
Dominican Rep	20.00	2.79	X	X	1987 b	2.97	15	453	5	6	89
El Salvador	18.95	3.61	X	X	1975	1.00	5	241	7	4	89
Guatemala	116.00	12.61	X	X	1970	0.73	1	139	9	17	74
Haiti	11.00	1.69	X	X	1987 b	0.04	0	46	24	8	68
Honduras	102.00	19.85	X	X	1970	1.34	1	508	4	5	91
Jamaica	8.30	3.29	0.00	0.00	1975	0.32	4	157	7	7	86
Mexico	357.40	4.03	X	X	1975	54.20	15	901	6	8	86
Nicaragua	175.00	45.21	X	X	1975	0.89	1	370	25	21	54
Panama	144.00	59.55	X	X	1975	1.30	1	744	12	11	77
Trinidad and Tobago	5.10 b	3.98	0.00	0.00	1975	0.15	3	149	27	38	35
United States	2,478.00	9.94	X	X	1985	467.00	19	2,162	12 c	46 c	42 c
SOUTH AMERICA	**10,377.00 b**	**34.96**			**1987 b**	**133**	**1**	**476**	**18**	**23**	**59**
Argentina	694.00	21.47	300.00	X	1976	27.60	3	1,059	9	18	73
Bolivia	300.00 b	41.02	X	X	1987 b	1.24	0	184	10	5	85
Brazil	5,190.00	34.52	1760.00	X	1987 b	35.04	1	212	43	17	40
Chile	468.00 b	35.53	X	X	1975	16.80	4	1,625	6	5	89
Colombia	1,070.00	33.63	X	X	1987 b	5.34	0	179	41	16	43
Ecuador	314.00	29.12	X	X	1987 b	5.56	2	561	7	3	90
Guyana	241.00 b	231.73	X	X	1971	5.40	2	7,616	1	0	99
Paraguay	94.00 b	21.98	220.00	X	1987 b	0.43	0	111	15	7	78
Peru	40.00	1.79	X	X	1987 b	6.10	15	294	19	9	72
Suriname	200.00 b	496.28	X	X	1987 b	0.46	0	1,181	6	5	89
Uruguay	59.00 b	18.86	65.00	X	1965	0.65	1	241	6	3	91
Venezuela	856.00	43.37	461.00	X	1970	4.10	0	387	43	11	46

	Annual Internal Renewable Water Resources		Annual River Flows		Annual Withdrawal				Sectoral Withdrawal (percent)		
	Total (cubic km)	1990 Per Capita (000 cubic meters)	From Other Countries (cubic km)	To Other Countries (cubic km)	Year of Data	Total (cubic km)	Percentage of Water Resources [a]	Per Capita (cubic meters)	Domestic	Industry	Agriculture
ASIA	**10,485.00**	**3.37**			**1987 b**	**1,531.00**	**15**	**526**	**6**	**8**	**86**
Afghanistan	50.00	3.02	X	X	1987 b	26.11	52	1,436	1	0	99
Bahrain	0.00	0.00	X	X	1975	0.20	X	735	60	36	4
Bangladesh	1,357.00	11.74	1000.00	X	1987 b	22.50	1	211	3	1	96
Bhutan	95.00 b	62.66	X	X	1987 b	0.02	0	15	36	10	54
China	2,800.00	2.47	0.00	X	1980	460.00	16	462	6	7	87
Cyprus	0.90	1.28	0.00	0.00	1985	0.54	60	807	7 c	2 c	91 c
India	1,850.00	2.17	235.00	X	1975	380.00	18	612	3	4	93
Indonesia	2,530.00	14.02	X	X	1987 b	16.59	1	96	13	11	76
Iran, Islamic Rep	117.50	2.08	X	X	1975	45.40	39	1,362	4	9	87
Iraq	34.00	1.80	66.00	X	1970	42.80	43	4,575	3	5	92
Israel	1.70	0.37	0.45	0.00	1986	1.90	88	447	16 c	5 c	79 c
Japan	547.00	4.43	0.00	0.00	1980	107.80	20	923	17	33	50
Jordan	0.70	0.16	0.40	X	1975	0.45	41	173	29	6	65
Kampuchea, Dem	88.10	10.68	410.00	X	1987 b	0.52	0	69	5	1	94
Korea, Dem People's Rep	67.00 b	2.92	X	X	1987 b	14.16	21	1,649	11	16	73
Korea, Rep	63.00	1.45	X	X	1976	10.70	17	298	11	14	75
Kuwait	0.00	0.00	0.00	X	1974	0.01	X	10	64	32	4
Lao People's Dem Rep	270.00	66.32	X	X	1987 b	0.99	0	228	8	10	82
Lebanon	4.80	1.62	0.00	0.86	1975	0.75	16	271	11	4	85
Malaysia	456.00	26.30	X	X	1975	9.42	2	765	23	30	47
Mongolia	24.60	11.05	X	X	1987 b	0.55	2	272	11	27	62
Myanmar	1,082.00	25.96	X	X	1987 b	3.96	0	103	7	3	90
Nepal	170.00	8.88	X	X	1987 b	2.68	2	155	4	1	95
Oman	2.00	1.36	0.00	X	1975	0.43	22	561	3	3	94
Pakistan	298.00	2.43	170.00	X	1975	153.40	33	2,053	1	1	98
Philippines	323.00	5.18	0.00	0.00	1975	29.50	9	693	18	21	61
Qatar	0.02	0.06	0.00	X	1975	0.04	174	234	36	26	38
Saudi Arabia	2.20	0.16	0.00	X	1975	2.33	106	321	45	8	47
Singapore	0.60	0.22	0.00	0.00	1975	0.19	32	84	45	51	4
Sri Lanka	43.20	2.51	0.00	0.00	1970	6.30	15	503	2	2	96
Syrian Arab Rep	7.60	0.61	27.90	30.00	1976	3.34	9	449	7	10	83
Thailand	110.00	1.97	69.00	X	1987 b	31.90	18	599	4	6	90
Turkey	196.00	3.52	7.00	69.00	1985	15.60	8	317	24 c	19 c	57 c
United Arab Emirates	0.30	0.19	0.00	X	1980	0.42	140	429	11	9	80
Viet Nam	376.00 b	5.60	X	X	1987 b	5.07	1	81	13	9	78
Yemen Arab Rep	1.00	0.12	0.00	X	1987 b	1.47	147	X	4	2	94
Yemen, People's Dem Rep	1.50	0.60	0.00	X	1975	1.93	129	1,167	5	2	93
EUROPE	**2,321.00 b**	**4.66**			**1987 b**	**359**	**15**	**726**	**13**	**64**	**33**
Albania	10.00	3.08	11.30	X	1970	0.20	1	94	6	18	76
Austria	56.30	7.51	34.00	X	1980	3.13	3	417	19	73	8
Belgium	8.40	0.85	4.10	X	1980	9.03	72	917	11	85	4
Bulgaria	18.00	2.00	187.00	X	1980	14.18	7	1,600	7	38	55
Czechoslovakia	28.00	1.79	62.60	X	1980	5.80	6	379	23	68	9
Denmark	11.00	2.15	2.00	X	1977	1.40	11	277	30	27	43
Finland	110.00	22.11	3.00	X	1980	3.70	3	774	12	85	3
France	170.00	3.03	15.00	20.50	1984	33.30	18	606	16	69	15
German Dem Rep	17.00	1.02	17.00	X	1980	9.13	27	545	14	68	18
Germany, Fed Rep	79.00	1.30	82.00	X	1981	41.40	26	671	10	70	20
Greece	45.15	4.49	13.50	3.00	1980	7.00	12	726	8	29	63
Hungary	6.00	0.57	109.00	X	1980	5.38	5	502	9	55	36
Iceland	170.00	671.94	0.00	0.00	1987 b	0.09	0	349	31	63	6
Ireland	50.00	13.44	0.00	X	1972	0.40	1	135	16	74	10
Italy	179.40	3.13	7.60	0.00	1981	46.35	25	811	14	27	59
Luxembourg	1.00	2.72	4.00	X	1976	0.06	1	166	42	45	13
Malta	0.03	0.07	0.00	0.00	1978	0.02	92	68	76	8	16
Netherlands	10.00	0.68	80.00	X	1980	14.20	16	1,004	5	61	34
Norway	405.00	96.15	8.00	X	1980	2.00	0	489	20	72	8
Poland	49.40	1.29	6.80	X	1980	16.80	30	472	16	60	24
Portugal	34.00	3.31	31.60	X	1980	10.50	16	1,062	15	37	48
Romania	37.00	1.59	171.00	X	1980	25.40	12	1,144	8	33	59
Spain	110.30	2.80	1.00	17.00	1985	26.30	24	682	12	26	62
Sweden	176.00	21.11	4.00	X	1980	3.98	2	479	36	55	9
Switzerland	42.50	6.52	7.50	X	1985	3.20	6	502	23	73	4
United Kingdom	120.00	2.11	0.00	X	1980	28.35	24	507	20	77	3
Yugoslavia	150.00	6.29	115.00	200.00	1980	8.77	3	393	16	72	12
U.S.S.R.	**4,384.00**	**15.22**	**300.00**	**X**	**1980**	**353.00**	**8**	**1,330**	**6**	**29**	**65**
OCEANIA	**2,011.00 b**	**75.96**			**1987 b**	**23**	**1**	**907**	**18**	**16**	**76**
Australia	343.00	20.48	0.00	0.00	1975	17.80	5	1,306	65	2	33
Fiji	28.55 b	38.12	0.00	0.00	1987 b	0.03	0	37	20	20	60
New Zealand	397.00	117.49	0.00	0.00	1980	1.20	0	379	46	10	44
Papua New Guinea	801.00 b	199.70	X	X	1987 b	0.10	0	25	29	22	49
Solomon Islands	44.70 b	149.00	0.00	0.00	1987 b	0.00	0	18	40	20	40

Sources: Bureau of Geological and Mining Research, National Geological Survey, France; U.S. Geological Survey; and Institute of Geography, National Academy of Sciences, U.S.S.R.

Notes:
a. Water resources include both internal renewable resources and river flows from other countries.
b. Estimated by the Institute of Geography, U.S.S.R.
c. Sectoral percentages date from the year of other withdrawal data.
0 = zero or less than half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 2-4 a

Table 1. Definitions of arid regions.

Type of Climate	P / Etp	Vegetation	Interannual Variability of P	P (in mm)	Utilization
Hyper-arid	0.03	No permanent vegetation or a very few very scattered shrubs; ephemeral when rain or dew, with short cycle. Oasis permanent water.	up to 100%	Nil or very low, extremely irregular with sometimes no rain during long periods of several years.	Oasis culture. True nomadism by transport caravans
Arid	0.03-0.20	Constructed along with water channels, spiny or succulent plants. Steppes, pseudo-steppes, para-steppes.	50-100%	From 80-150 to 200-350. Low atmospherio humidity. High rainfall variability.	Pastoralism No farming except with irrigation
Semi-arid	0.20-0.50	Steppes, pseudo-steppes, para-steppe, low savannas low savannas with bush, thorny low savannas exceptionally savannas where high rainfall in summer.	25-50%	From 300-400 to 700-800 with summer rains. From 200-250 to 450-500 with winter rains.	Rain-fed cultivation with more or less regular production. Combined with sedentary livestock production.
Sub-humid	0.50-0.75	Savannas and wooded savannas. Riparian forests along rivers. Maquis and Chaparrals under Mediterranean climate: Steppes on tchernozems	Less than 25%	Abundant with usually more than six humid months (more than 30 mm)	Rain-fed cultivation and industrial crops with a regular production.

Table 2-4b

Table 2. Distribution of arid lands

Continents	Total Area (km^2)	Semi-Arid (km^2) (A)	%	Arid (km^2) (B)	%	Hyperarid (km^2) (C)	%	Total (km^2) (A+B+C)	%
America	39,917,000	3,943,160	10	2,910,000	7.5	780,700	2	7,633,860	19.5
Africa	29,797,000	5,546,490	18.5	7,325,560	24.5	4,527,240	15	17,309,280	58
Asia	42,365,000	6,354,750	15	8,049,350	19	1,270,950	3	15,675,050	37
Australia	7,703,850	2,234,120	29	3,928,960	51	0	0	6,163,080	80
Europe	10,032,100	752,500	7.5	200,500	2	0	0	953,000	9.5
Total	129,814,950	18,741,020	14.5	22,414,370	17	6,578,890	5	47,734,270	36.5
Other lands (Greenland) (New Zealand)	23,418,050	0	0	0	0	0	0	0	0
Total Land Area	153,233,000	18,831,020	12.2	22,414,370	14.6	6,578,890	4.2	47,734,270	31

Sources: FAO 1985 (CG)

Table 2-5 a

Verschmutzungs-art	Mexiko, Zentral und Südamerika				Indischer Subkontinent	Südost-asien	Pazifische Inseln	China	Japan, Australien und Neuseeland
	Vereinigte Staaten	Karibik	Amazonas Orinoko	Andere Gebiete					
Pathogene Keime	0–1	1–2	0	1–3	1–3	1–2	2–3	1–3	0–1
Organische Stoffe	0	1–2	0	1–3	1–3	0–2	0–1	1–3	0–1
Versalzung	0	1–2	0	0	0–1	0–1	0–3	0–2	0–2
Nitrate	0–1	1	0	0–1	0–1	0–1	1–2	0–2	0–1
Fluoride	0	0	0	0	0–1	0	0	0–2	0
Eutrophierung	1–2	1–2	0	1–3	0–1	0–3	0	0–2	0–1
Schwermetalle	0–1	0–1	0–1 [a]	1–3	0–1	0–2	0–1	0–2	0–2
Pestizide	0–1	n/a	0	1–3	0–1	0–1	0–1	0–1	0–1
Ind. organische Stoffe	0–1	0–1	0	1–3	n/a	n/a	n/a	n/a	n/a
Sedimente	0–1	0–1	0–1 [a]	1–3	0–2	0–2	0–1	0–3	0–1
Versauerung	0–2 [b]	0	0	0–1	0	0–1	0	0–1	0–1
Abwärme	0	0	0	0	n/a	n/a	n/a	n/a	n/a
Radioaktivität	0	0	0	0	n/a	n/a	n/a	n/a	n/a

[a] Quecksilber und Verschmutzung durch Sedimente aus der Goldexploration an einigen Flüssen

[b] Ost-Kanada und nordöstliche USA

App. 4–7 (a): Wasserqualität in Afrika

Verschmutzungs-art	Maghreb	Sahel	Golf von Guinea	Kongo-Becken	Nil- [a] Becken	Östl. und südl. Seen	Große Seen	Arabische Halbinsel [a]	Östl. Mittelmeergebiet
Pathogene Keime	1–2	1–3	1–3	1–2	1–2	1–3	1	0	1
Organische Stoffe	1–2	1–2	1–2	0–1	1–2	1–2	0	0	1
Versalzung	0–2	0–2	0–1	0	0–1	1–2	0	3	1
Nitrate	0–2	1–2	1–2	0–1	0–1	1	0	0	1
Fluoride	0–3	0–2	0	0	0	1–3	0	0	0
Eutrophierung	0–2	0–1	1	0	0–2	0	1 [c]	0	1–2
Schwermetalle	0–1	0–1	0–1	0–2 [b]	0–1	0–1	0	0	0
Pestizide	0–1	1	1–2	1	0–1	0–1	1 [c]	0	1–2 [c]
Ind. organische Stoffe	0–1	0	0–1	0–1	0–1	0	0	1 [b]	1 [c]
Sedimente	1–3	0–2	0	0	0–2	0–2	0	0	1
Versauerung	0	0–1 [d]	0	0	0	0	0	0	0
Abwärme	0	0	0	0	0	0	0	1 [b]	0
Radioaktivität	0	0–1 [e]	0	0	0	0	0	0	0

0 keine Verschmutzung oder irrelevant

1 geringe Verschmutzung, Wasser kann verwendet werden, wenn geeignete Maßnahmen ergriffen werden

2 stärkere Verschmutzung

3 schwere Beeinträchtigung für Wassernutzung

[a] Uranminen im Niger

[b] Oberes Zaire Basin

[c] Lokale Probleme

[d] Übersäuerung des Bodens

[e] Die schlechteste Qualität wird generell im Nildelta vorgefunden

[a] kein Oberflächenwasser, überwiegend Grundwasser und Meerwasserentsalzung

[b] möglicherweise in Küstengebieten

[c] möglicherweise in Flüssen

Quelle: Water Quality, Progress in Implementing the Mar del Planta Action Plan, New York, 1990

Source: GITEC 1992

Table 2-5 b

Table 20: Comparison of Typical Magnitudes of Concentrations from Nonpoint Sources and Sewage (Novotny and Chester, 1981)

	Suspended Solids[a]	BOD_5	COD	Total N	Total P	Lead	Total Coliform
Precipitation	11–13	12–13	9–16	1.2–1.3	0.02–0.04		
Background levels	5–1000	0.5–3		0.05–0.5	0.01–0.2	0.1	
Agricultural cropland		7	80	9	0.02–1.7		
Animal feedlots	30	1000–11,000	31,000–41,000	920–2100	290–380		
Urban storm water	100–10,000 (630)[b]	10–250 (30)	20–600	3–10	0.6	0.35	10^3–10^8
Combined sewers	100–2000 (410)	20–600 (115)	20–1000	9–10	1.9	0.37	10^5–10^8
Municipal sewage, untreated	100–330 (200)	100–300 (200)	250–750	40	10		10^7–10^9
Municipal sewage, treated	10–30	15–30	25–80	30	5		10^2–10^4

[a]all units are in mg/l except for total coliform expressed in no./100 ml.
[b]( ) flow weighted averages

Source: Canter 1986

Table 2-5 c

TABLE 3.9 Summary of Nonpoint Source Characteristics[a]

Source	Concentration (mg/liter) COD	BOD	NO_3–N	Total N	Total P	Area yield rate (kg/ha/year) COD	BOD	NO_3–N	Total N	Total P	Surface area of interest
Precipitation	9–16	12–13	0.14–1.1	1.2–1.3	0.02–0.04	124	–	1.5–4.1	5.6–10	0.05–0.06	Total land area
Forested land	–	–	0.1–1.3	0.3–1.8	0.01–0.11	–	–	0.7–8.8	3–13	0.03–0.9	Forest area
Range land	–	–	–	–	–	–	–	0.7	–	0.08	Range land
Agricultural crop land	80	7	0.4	9	0.02–1.7	–	–	–	0.1–13	0.06–2.9	Active-crop land
Land receiving manure	–	–	–	–	–	–	–	–	4–13	0.8–2.9	Crop or unused land used for manure disposal
Irrigation tile drainage, western United States											
Surface flow	–	–	0.4–1.5	0.6–2.2	0.2–0.4	–	–	–	3–27	1.0–4.4	Irrigated western soils
Subsurface drainage	–	–	1.8–19	2.1–19	0.1–0.3	–	–	83	42–186	3–10	Irrigated western soils
Crop land tile drainage	–	–	–	10–25	0.02–0.7	–	–	–	0.3–13	0.01–0.3	Active crop land requiring drainage
Urban land drainage	85–110	12–160	–	3	0.2–1.1	220–310	30–50	–	7–9	1.1–5.6	Urban land areas
Seepage from stacked manure	25,900–31,500	10,300–13,800	–	1,800–2,350	190–280	–	–	–	–	–	Manure holding area
Feedlot runoff	3,100–41,000	1,000–11,000	10–23	920–2,100	290–360	7,200	1,560	–	100–1,600	10–620	Confined, unenclosed animal holding areas

[a]Data do not reflect the extreme ranges caused by improper waste management or extreme storm conditions; the data represent the range of average values reported.

Source: Loehr 1976

Table 2-5 d

Herkunft der Gewässerbelastungen

	leicht abbaubar		schwer abbaubar			
	Schmutzfracht BSB_5	Nährstoffe N,P	Rest-CSB	krit. Schadstoffe	Salze	Metalle
Herkunft						
Haushalte	+++	+++	++	0	++	I
Industrie	+++	++	+++	+++	+++	+++
Landwirtschaft	++	++	+	+	+	0

+++ : Über 25% der Gesamtmenge
++ : 5 - 25% " "
+ : 1 - 5% " "
I : 0,2 - 1% " "

Source: Boesel 1990

Table 2-6

TABLE 8.1 N a P content in different sources (after McCarty).

Source	Nitrogen (mil. kg/year)	Phosphorus (mil. kg/year)
Domestic wastes	500 to 720	90 to 225
Industrial wastes	> 450	x
Runoff from agricultural land	680 to 6800	54 to 545
Runoff from non-agricultural land	180 to 860	68 to 340
Wastes from livestock production	> 450	x
Runoff from urban areas	50 to 500	5 to 77
Atmospheric precipitation	13 to 265	1.5 to 4

x - no data

Source: Holy 1980

Table 9-1. Factors affecting pesticide entrainment and transport in runoff. After Leonard (1988).

Factors	Comment	Selected references
	1. Climatic	
A. Rainfall/runoff timing with respect to pesticide appliction	Highest concentration of pesticide in runoff occurs in first significant runoff event after application. Pesticide concentration and availability at the soil and foliar surfaces dissipate with time thereafter.	White et al., 1967; Bovey et al., 1975; Bradley et al., 1972; Wauchope & Leonard, 1980a, b; Baker & Johnson, 1979; Edwards et al., 1980; Smith et al., 1983; Triplett et al., 1978
B. Rainfall intensity	Surface runoff occurs when rainfall rate exceeds infiltration rate. Increasing intensity increases runoff rate and energy available for pesticide extraction and transport. May also affect depth of surface interaction. Increasing intensity reduces time to runoff within storm.	Skaggs & Khaleel, 1982; Sharpley et al., 1981; Sharpley, 1985a
C. Rainfall duration/ amount	Affects total runoff volumes; pesticide washoff from foliage related to total rainfall amount; leaching below soil surface also affected.	White et al., 1967; Bovey et al., 1975; Baker et al., 1981; Willia et al., 1980
D. Time to runoff after inception of rainfall	Runoff concentrations increased as time to runoff decreased. Pesticide concentrations and availability are greater in first part of the event before significant reduction occurs as a result of leaching and incorporation by raindrop impact.	Baker & Laflen, 1979; Gaynor & Volk, 1981; Baker et al., 1982; Barnett et al., 1967
E. Water temperature	Little data available, but increasing temperature normally increases pesticide solubility and decreases physical adsorption.	Barnett et al., 1967; Bailey et al., 1974
	2. Soil	
A. Soil texture and organic matter contents	Affecte infiltration rates; runoff is uaually higher on finer-textured soile. Time to runoff is greater on sandy soils reducing initial runoff concentrationa of soluble pesticides. Organic matter content affects pesticide adsorption and mobility. Soil texture also affects soil erodibility, particle transport potential, and chemical enrichment factora.	Rawls & Brakenaiek, 1982; Rao & Davidson, 1980; Wischmeier & Smith, 1978; Foster et al., 1980
B. Surface crusting and compaction	Crusting and compaction decreases infiltration rates, reduces time to runoff, and increases initial concentrations of soluble pesticides	Baker & Laflen, 1979
C. Water content	Initial soil water content at beginning of a rainstorm may increase runoff potential, reduce time to runoff, and reduce leaching of soluble chemicals below soil surface before runoff inception.	Kniael & Baird, 1969; Davidson et al., 1975; Barnett et al., 1967
D. Slope	Increasing slope may increase runoff rate, soil detachment and transport, and increase effective surface depth for chemical extraction.	Wauchope, 1978; Sharpley et al., 1981; Foster et al., 1980
E. Degree of aggregation and stabiilty	Soil particle aggregation and stability affects infiltration rates, crusting potential, effective depth for chemical entrainment, sediment transport potential, and adsorbed chemical enrichment in sediment.	Sharpley et al., 1981; Foster et al., 1980; Ahuja et al., 1981
	3. Pesticide	
A. Solubility	Soluble pesticides may be more readily removed from crop residue and foliage during the initial rainfall or be leached into the soil. However, when time to runoff ie short, runoff concentration may be enhanced by increasing solubility.	Barnett et al., 1967; Trichill et al., 1968; Baker et al., 1978; Baker & Johnson, 1979; Willis et al., 1980; Baker et al., 1982
B. Sorption properties	Pesticides strongly adsorbed in soil will be retained near application site, i.e., possibly at soil surface and be more susceptible to runoff. Amounts of runoff when dependent on amount of soil erosion and sediment transport.	McDowell et al., 1981; Willis et al., 1983
C. Polarity/ionic nature	Adsorption of nonpolar compounds determined by soil organic matter; ionized compounds, and weak acids/bases affected more by mineral surface and soil pH. Lyophillic compounds retained on foliage by leaf surface and waxes, whereas polar compounds more easily removed from foliage by rainfall.	Rao & Davidson, 1980; Willis et al., 1980; Wauchope & Leonard, 1980a, b
D. Persistance	Pesticides that remain at the soil surface for longer periods of time because of their resistance to volatilization, chemical, photochemical, and biological degradation have higher probability of runoff.	Wauchope, 1978; Mills & Leonard, 1984; Leonard & Knisel, 1986
E. Formulation	Wettable powders are particularly susceptible to entrainment and transport. Liquid forms may be more readily transported than granular. Esters less soluble than salts produced higher runoff concentrations under conditions where initial leaching into soil surface is important.	Wauchope, 1978; Rohde et al., 1979; Wauchope & Leonard, 1980a, b; Wauchope, 1987b
F. Application rate	Runoff concentrationa are proportional to amounts of pesticide present in runoff zone. At usual rates of application for pest control, pathways and processes (e.g., sorption and degradation rates) are not affected by initial amounts present, therefore, runoff potential is in proportion to amounts applied.	Barnett et al., 1967; Hall, 1974; Leonard et al., 1976
G. Placement	Pesticide incorporation or any placement below the soil surface reduces concentrations exposed to runoff process.	Leonard et al., 1979; Wauchope, 1978; Rohde et al., 1979; Wauchope & Leonard, 1980a, b
	4. Management	
A. Erosion control practicea	Reduces transport of adsorbed/insoluble compounds. Also reduces transport of soluble compounds if runoff volumes are also reduced during critical times after pesticide application.	Caro, 1976; McDowell & Grissinger, 1976; Pionke, 1977; McDowell et al., 1981; Willis et al., 1983
B. Residue management	Crop residues can reduce pesticide runoff by increasing time to runoff, decreasing runoff volumes, and decreasing erosion and sediment transport. However, pesticide runoff may be increased under conditions where pesticides are washed from the crop residue directly into runoff water (high initial soil water, clay soil, intense rainfall immediately after pesticide application).	Triplett et al., 1978; Baker et al., 1978; Baker & Johnson, 1979; Edwards et al., 1980; Baker et al., 1982; Hall et al., 1984
C. Vegetative buffer strips	Buffer strips around treated fields may reduce transport of some pesticides by secondary infiltration, sediment deposition and sorption on plant surfaces and debris.	Asmussen et al., 1977; Rohde et al., 1980
D. Irrigation	Chemical application by sprinkler irrigation may move soluble pesticides into soil surface and reduce runoff potential. Aerial application of pesticides during periods of flood irrigation greatly increases pesticide runoff in surface drainage.	Dowler et al., 1982; Spencer et al., 1985

Source: Leonard in: Cheng ed. 1990

Table 9-2. Runoff losses of pesticides from small plots and single cover watersheds (1978–1985).

Compound	Rate, kg/ha	Location	Crop/Cover	Conc. in runoff, µg/kg†	Total seasonal losses, % of application	Comments	Reference
			Runoff from natural rainfall or snowmelt				
Atrazine	Various	Ohio	No-till and conventionally tilled corn	480	0–5.7	No-till reduced herbicide runoff primarily by reducing runoff volume. Time of runoff event relative to application most important factor	Triplett et al., 1978
Simazine	Various	Ohio	No-till and conventionally tilled corn	1200	0–5.4		
Simazine	Various	Various	Irrigation canals	250	--	Applied to canals with and without flowing water	Anderson et al., 1978
2,4-D	3.7	Florida	Citrus	75	--	Concentrations in tile outflow generally in range of 20–25 µg/L	Wheeler et al., 1978
Atrazine	1.45–4.03	Georgia	Corn	1 900 (water)	0.2–1.9	Results from comprehensive studies to provide data for model development and testing	Leonard et al., 1979
Paraquat	1.53–15.3	Georgia	Corn	980 000 (sed.)	3.4–10.9		
Trifluralin	1.12	Georgia	Soybean	21 (water)	0.1–0.3		
Propazine	1.66	Georgia	Grain sorghum	400 (watar)	6.7		
Cyanazine	1.35–1.61	Georgia	Corn	180 (water)	0.07–1.0		
Diphenamid	2.31–3.52	Georgia	Soybean	2 070 (water)	0.1–7.2		
Alachlor	2.24	Iowa	Corn		0.96 (avg.)	Losses depend on time between application and runoff; decreased runoff and erosion decreased pesticide losses, but not in proportion because conc. in water and sediment were higher for conservation systems	Baker & Johnson, 1979
Atrazine	2.24	Iowa	Corn		2.1 (avg.)		
Cyanazine	2.24	Iowa	Corn		2.1 (avg.)		
Fonofos	1.12	Iowa	Corn		0.36 (avg.)		
Ethoprop (liquid)		Georgia	Soybean	283	0.1	Major differences in runoff and dissipation of ethoprop observed between liquid and granular formulations	Rohde et al., 1979
Ethoprop (granular)		Georgia	Soybean	45	0.01		
Atrazine		Maryland	Corn	16.9 (avg.)	1	Field soil sampling indicated both vertical and lateral movement of atrazine, but not of alachlor	Wu, 1980
Alachlor		Maryland	Corn	0.6 (avg.)	0.16		
Picloram	2.8	Arizona	Pinyon-Juniper	320	1.1	Highest runoff conc. in initial runoff event after application	Johnsen, 980
Glyphosate	1.10–8.96	Ohio	No-till corn	5200 one event others ≤100	1.85 (extreme yr, <1 other yr and watersheds	Abnormally high conc. because of high application rate and runoff occurring 1 d after application	Edwards et al., 1980
Trifluralin	1.12	Georgia	Soybean	38	0.17	Trifluralin detected in surface runoff for 16 wk after application; none in tile outflow except trace 16 wk after application	Rohde et al., 1980
Permethrin	0.112 (10 applications)	Louisiana	Cotton	<1	<1	Runoff losses low even under extreme runoff conditions	Carrol et al., 1981
Toxaphene		Mississippi	Cotton	--	1–0.5	Linear relationships observed between sediment yields and toxaphene yields in runoff. 93% of toxaphene in runoff attached to sediment; 7% in solution	McDowell et al., 1981
2,4-D		Oregon	Rangeland	--	0.014	Nearly all herbicide runoff observed resulted from direct deposits in stream channels and streambanks	Norris et al., 1982
Picloram		Oregon	Rangeland	--	0.35		
2,4-D		Saskatchewan, Canada	Wheat stubble, fallow	31 (avg.)	4.1 (6-yr avg.)	Snowmelt runoff	Nicholaichuk & Grover, 1983
			Fallow	3 (avg.)	0.3		
Toxaphene		Mississippi	Cotton			Pesticide conc. in sediment were directly proportional to sediment clay and organic matter conc. Storm and yield of pesticides were linear functions of storm sediment yields in years where no new applications made. In those years, correlations required separation into similar tillage-application regimes	Willis et al., 1983
DDT		Mississippi	Cotton				
DDE		Mississippi	Cotton				
Trifluralin		Mississippi	Cotton				
Azinophos-Methyl		Louisiana	Sugarcane	250	0.55	1981 losses shown were twice that in 1980, mainly because of rainfall timing relative to application. Fenvalerate might cause problems for aquatic habitats immediately surrounding application sites	Smith et al., 1983
Fenvalerate		Louisiana	Sugarcane		0.56		
Cyanazine	1.1–1.7	Pennsylvania	No-till and conventionally tilled corn		0.73–5.7 conventional <0.01–0.75 no-till	Herbicide runoff reduction accomplished primarily by reduction in volume of runoff	Hall et al., 1984
Picloram		Texas	Bermudagrass	250	6.3	Conditions during study strongly conducive to herbicide transport from treated source area. Studies additionally traced transport through larger watershed system	Mayeaux et al., 1984

Sources: Leonard in Cheng ed. 1990

Compound	Rate, kg/ha	Location	Crop/Cover	Conc. in runoff, µg/kg†	Total seasonal losses, % of application	Comments	Reference
				Runoff from simulated rainfall			
Cyanazine	2.24	Iowa	Corn with various treatments	1 330 (water) 5 140–420 (sed.)	11.0 avg. all treatments	Herbicide losses under conservation tillage greater than under conventional tillage; effects of reduced runoff volumes offset by higher conc. Total losses of Fonophos related to sediment transport	Baker et al., 1978
Alachlor	2.24	Iowa	Same as above	610–60 (water) 3 590–510 (sed.)	7.9 avg. all treatments		
Fonofos	1.2	Iowa	Same as above	19–41 (water)	1.8 avg. all treatments		
Propachlor	2.5	Iowa	Fallow with wheel-track and pesticide incorporation variables	3 800 (water) 7 000 (sed.)	0.8–12.7	Runoff losses from surface applications compared to incorporated applications; runoff losses enhanced by wheel tracks because of increased runoff volumes and shorter times to start of runoff	Baker & Laflen, 1979
Atrazine	2.5	Iowa		6 800 (water) 28 000 (sed.)			
Alachlor	2.5	Iowa		5 000 (water) 22 000 (sed.)	1.7–22.1		
Fluometuron	4.4	Various	–	0.87 0.30 (avg.)	<1 avg.	Major emphasis placed on first event	Wiese et al., 1980
Atrazine			Limed and unlimed soil		3.7	Greater sediment transport of terbutryne. Liming significantly reduced runoff volumes.	Gaynor & Volk, 1981
Terbutryne			Same as above		0.3		
Propachlor	2.09	Iowa	Fallow and plots with corn residue	59–173 (water; avg.) 370–840 (sed.; avg.)	0.76–6.1	Values given are for range of averages across treatments. Herbicide conc. not affected by placement above or below residue, but were negatively correlated with time to runoff which was increased by presence of residue	Baker et al., 1982
Atrazine	2.09	Iowa		83–141 (water; avg.) 600–1110 (sed.; avg.)	0.97–5.7		
Alachlor	2.09	Iowa		78–220 (water; avg.) 880–2240 (sed.; avg.)	1.0–8.6		

Table 9-2. Continued.

Compound	Rate, kg/ha	Location	Crop/Cover	Conc. in runoff, µg/kg†	Total seasonal losses, % of application	Comments	Reference
				Runoff from irrigated fields			
Cycloate	2.9	California	Sugarbeets	6.2	0.03	Irrigation runoff	Spencer et al., 1985
DCPA	3.4–7.6	California	Cotton	189	1.22–1.40	Irrigation runoff	
Dinitramine	1.3	California	Cotton	34	1.32	Irrigation runoff	
EPTC	2.8–13.8	California	Sugarbeet and alfalfa	1630	6.4–7.2	EPTC applied in irrigation water at 2 mg/L	
Prometryn	1.3–3.1	California	Cotton	1408	0.95–5.0	Irrigation runoff	
Trifluralin	0.96–1.1	California	Cotton	19	0.14–0.29	Irrigation runoff	
Azinphosmethyl	0.52	California	Cotton	<0.5	–	Irrigation runoff	
Chlorpyrifos	0.98–2.88	California	Cotton	480	0.02–0.24	Significant proportion of losses because of aerial application during irrigation	
Diazinon	0.48–2.69	California	Sugarbeet, mellon	22	0.04–0.07	Irrigation runoff	
Malathion	1.17–4.46	California	Cotton, sugarbeet, alfalfa, lettuce	21	0.0003–0.09	Irrigation runoff	
Methidathion	1.02–1.12	California	Cotton	473	0.16–2.0	Significant proportion of losses because of aerial application during irrigation	
Mevinphos	0.14	California	Alfalfa	26	0.27	Irrigation runoff	
Ethyl Parathion	0.28–4.20	California	Lettuce, sugarbeet, alfalfa	77	0.02–0.51	Irrigation runoff	
Methyl Parathion	0.14–2.1	California	Lettuce, sugarbeet	27	0.003–0.32	Irrigation runoff	
Sulprophos	4.55–6.00	California	Cotton	0.32	0.001–0.007	Irrigation runoff	
Methomyl	0.4–5.82	California	Cotton, lettuce, sugarbeet, alfalfa	223	0.13–1.73	Irrigetion runoff	
Endosulfan	1.66–5.96	California	Lettuce, melon	104	0.19–0.62	Irrigaiton runoff	
Ethylan	3.2	California	Lettuce	8.0	0.008	Irrigetion runoff	
Fenvalerate	0.27–1.23	California	Cotton	133	0.05–0.21	Significant proportion of losses beceuse of aerial application during irrigation	
Permethrin	0.10–0.71	California	Cotton	71	0–0.16	Significant proportion of losses because of aerial application during application	

†Maximum reported concentrations unless specified otherwise.

Source: Leonard in: Cheng ed. 1990

Table 9-3. Pesticides in streams and water bodies resulting from agricultural applications. Selected examples (1978–1985).

Watershed stream systems	Location	Pesticide residues found	Conc. ranges (μg/kg)	Loads	Comments	Reference
Grassed watershed (53 ha); with partial treatment by herbicide. Stream system draining 1772 ha of perennial pasture watershed	Riesel, TX	Picloram	250 maximum from treated 8-ha area	Most of herbicide leaving treated area was transported through the 53-ha watershed-system, but at reduced concentrations	Experiments conducted to study patterns of dilution, transport, and dissipation of herbicides in complex watersheds	Mayeux et al., 1984
			13 720 injected directly into stream	Only a small fraction of injection detected to pass 5400-m point. Apparent loss because of concentration decreasing to below limit of detection		
Rivers and agricultural drainage	Japan	CNP	0.01–16.67		Highest levels found above 4 wk after rice planting and when flood watere released from paddies.	Suzuki et al., 1978
2025 ha of agricultural watershed; corn and soybean major crop	Lincoln, NE	Atrazine Alachlor Propachlor	14–24 0–1.4 0.58–3.0		Results based on limited sampling during drought yeara	Schepera et al., 1980
Black Creek Watershed	Allen Co., IN	2,4,5-T	0.2–7.7		Atrazine, alachlor, carbofuran, and malathion not detected	Dudley & Karr, 1980
Honey Creek Watershed and rivers of Northwest Ohio	Northwestern Ohio	Atrazine Simazine Metribuzin Alachlor Metolachlor Butylate Phorate Terbufos Fonofos Carbofuran	87† 7.4† 2.3† 105† 140† 0.49† 0.24† 0.54† 1.0† 45†	7.5% of applied atrazine exported from Honey Creek Watershed in 1981	Study reports higher concentration values than expected from other published sources; however, rainfall during study was two to three times above long-term average. Author concludes that concentrationa observed not acutely toxic to fish and invertebrates, but may produce inhibitory growth effects on plants and algae	Baker et al., 1981
Parana River, 600 km upstream from mouth	Argentina	Lindane Parathion Alpha-BHC	0.009‡ 0.022‡ 0.009‡		Sediment transported pesticides were positively correlated with discharge as was sediment concentrationa	Lenardon et al., 1984
Well water, surface water (lakes, ponds, and rivers), and municipal water	205 sites in South Carolina	DBCP	0–0.4		In area of high use, 37% of surface water samples exceeded background (0.05 μg/L) levels, but none above 0.4	Carter & Riley, 1981
Forested watersheds	Central Tennessee	None	–	–	1.68 kg/ha a.i. hexazinone applied as pelleta. No detectable residue in streamflow for 28-wk after application	Neary, 1983
Forested watershed; 104 ha containing four 1-ha watersheds	Upper Piedmont, GA	Hexazinone	442 ± 53 first event maximum for treated area. 0–40 hexazinone + metabolite in streamflow for 104-ha watershed	0.53% of application (avg. from watersheds)	Authors conclude that residue not high enough for aquatic damage	Neary et al., 1983
Wye River Estuary	Eastern Chesapeake Bay region	Atrazine	0–300 edge of field; 15 maximum in estuary; <3 avg. in estuary at peak loading	>3% moved in estuary	Herbicide level rarely approached levels that would reduce aquatic photoaynthetic rate	Glotfelty et al., 1984
		Simazine	Simazine concentration in estuary significantly lower than for atrazine			
Various drainage basins surrounding Chesapeake Bay	Chesapeake Bay area	Linuron	<10 (sed.) <0.2 water		No apparent accumulation of linuron in estuary	Zahnow & Riggleman, 1980
Rhode River Watershed	Chesapeake Bay, MD	Atrazine	0–40		Little corralation between use and hericide loading rates in water; herbicides in runoff from nontreated areas suggested aerial or aubsurface transport in addition to surface runoff	Wu et al., 1983
		Alachlor	0–6			
11 agricultural watersheds ranging in size from 20–79 km^2	Canadian Great Lakes Basin, Co. Ontario	18 parent compounds plus isomers and metaholites found in drainage watera. Organochlorinea not in current use also detected. Only atrazine, endosulfan, and simazine appeared year round	Atrazine 1.1, 1.6§ Endosulfan 0.0037, 0.002§ Simazine 0.02, 0.06§	2.02 g ha^{-1} yr	Report summarizes extensive studies on pesticides in streamflow; concentrations of four pesticides (organochlorines consistently greater than established water quality criteria. No herbicide concentrations exceeded criteria	Frank et al., 1982

† Maximum values observed. ‡ Mean valuea. § Ovarall mean for 11 watersheds 1976 and 1977, respectively.

Source: Leonard in: Cheng ed. 1990

Table 26: Classification of Pesticides by Availability Index A[a] (Wauchope and Leonard, 1980)

Class	Assigned Value of A, ppb ha kg^{-1}	Properties of Pesticide or Application Situation	Pesticide Data Used in A Calculation Common Name
I	10,000	Wettable powders applied to soil surface	Cyanazine, prometryne, fluometuron, simazine, atrazine, terbuthylazine, diphenamid, propazine, propachlor, metribuzine, linuron
		Soluble salts which strongly bind to clay particles	MSMA, paraquat
		Soluble salts applied to foliage	Arsenic acid[b], 2,4,5-T,2,4-D, picloram, dicamba
		Nonionic pesticides applied in diesel oil	2,4,5-T ester[c]
II	3,000	Soluble salts applied to soil	2,4-D, picloram, 2,4,5-T, dicamba, fenac
		Granular and pelleted pesticides, regardless of solubility--even if incorporated	Picloram, endrin, fonofas, dieldrin, carbaryl, carbofuran, diazinon
III	1,000	EC (insoluble), persistent pesticides applied to foliage	Endosulfan, endrin, DDT, toxaphene, diuron, methoxychlor
		Incorporated but persistent	Dieldrin
IV	300	Insoluble pesticides applied to soil surface	Alachlor, 2,4-D ester, methoxychlor
		All incorporated but not persistent pesticides except granular/pelleted soluble salts	Atrazine, dichlobenil, trifluralin
		EC (insoluble) and nonpersistent pesticides applied to foliage	Parathion

[a]the ratio between application rate (kg/ha) and runoff concentration (ppb) if runoff occurs immediately after application.

[b]Arsenic acid was not used as a "pesticide", but as a defoliant, in this experiment.

[c]Limited data available

Source: Canter 1986

Table 3-1 a

Regional Distribution of Salinity/ Alkalinity and Irrigated Soils (in 1,000 ha)

region	salt-affected soils	irrigated soils
North America	15755 ha	32000 ha
Central America	1965 ha	included in N-America
South America	129163 ha	10000 ha
Africa	80538 ha	12000 ha
Southern Asia	84838 ha	included in N-Asia
North./Cent.-Asia	211886 ha	220000 ha
SE-Asia	19983 ha	see N-Asia.
Australia	357330 ha	2200 ha
Europa	50804 ha	30000 ha
total	952062 ha	306200 ha

salt affected soils include: Solonchaks and soils with saline phases, Solonetz, and soils with alkaline phases; figures from Szabolcs 1979

irrigated soils in 1985: figures from Framji ICID 198

Table 3-1 b

TABLE 2. Distribution of salinity and alkalinity in countries most extensively affected (expressed in 1,000 ha)

Area	Solonchaks	Saline phase	Solonetz	Alkaline phase	Total
North America					
Canada	—	264	6,974	—	7,238
United States of America	—	5,927	2,590	—	8,517
Mexico and Central America					
Cuba	—	316	—	—	316
Mexico	242	1,407	—	—	1,649
South America					
Argentina	1,905	30,568	11,818	41,321	85,612
Bolivia	—	5,233	716	—	5,949
Brazil	4,141	—	362	—	4,503
Chile	1,860	3,140	—	3,642	8,642
Colombia	907	—	—	—	907
Ecuador	387	—	—	—	387
Paraguay	—	20,008	1,894	—	21,902
Peru	21	—	—	—	21
Venezuela	1,240	—	—	—	1,240
Africa					
Afars and Issas	59	1,682	—	—	1,741
Algeria	1,132	1,889	—	129	3,150
Angola	126	314	86	—	526
Botswana	1,131	3,878	—	670	5,679
Chad	2,417	—	3,728	2,122	8,267
Egypt	3,283	4,077	—	—	7,360
Ethiopia	319	10,289	—	425	11,033
Gambia	—	150	—	—	150
Ghana	200	—	—	118	318
Guinea	—	525	—	—	525
Guinea-Bissau	—	194	—	—	194
Kenya	3,501	909	—	448	4,858
Liberia	—	362	44	—	406
Libyan Arab Jamahiriya	905	1,552	—	—	2,457
Madagascar	37	—	—	1,287	1,324
Mali	—	2,770	—	—	2,770
Mauritania	150	490	—	—	640
Morocco	42	1,106	—	—	1,148
Namibia	562	—	1,751	—	2,313
Niger	—	—	11	1,378	1,489
Nigeria	455	210	—	5,837	6,502
Rhodesia	—	—	—	26	26
Senegal	141	624	—	—	765
Sierra Leone	—	307	—	—	307
Somalia	1,043	526	3,754	279	5,602
Sudan	—	2,138	—	2,736	4,874
Tunisia	990	—	—	—	990
United Republic of Cameroon	—	—	—	671	671
United Republic of Tanzania	—	2,954	—	583	3,537
Zaire	—	53	—	—	53
Zambia	—	—	—	863	863
South Asia					
Afghanistan	2,924	177	—	—	3,101
Bangladesh	—	2,479	—	538	3,017
Burma	634	—	—	—	634
India	2,979	20,243	—	574	23,796
Iran	24,817	1,582	—	686	27,085
Iraq	6,679	47	—	—	6,726
Israel	28	—	—	—	28
Jordan	74	106	—	—	180
Kuwait	209	—	—	—	209
Muscat and Oman	290	—	—	—	290
Pakistan	1,103	9,353	—	—	10,456
Qatar	225	—	—	—	225
Sarawak	—	1,538	—	—	1,538
Saudi Arabia	6,002	—	—	—	6,002
Sri Lanka	180	20	—	—	200
Syrian Arab Republic	—	532	—	—	532
United Arab Emirates	1,089	—	—	—	1,089
North and Central Asia					
China	7,307	28,914	—	437	36,658
Mongolia	3,728	342	—	—	4,070
Solomon Islands	—	238	—	—	238
U.S.S.R.	11,430	39,662	30,062	89,566	170,720
South-East Asia					
Democratic Kampuchea	—	1,291	—	—	1,291
Indonesia	—	13,213	—	—	13,213
Malaysia	—	3,040	—	—	3,040
Socialist Republic of Viet Nam	—	983	—	—	983
Thailand	—	1,456	—	—	1,456
Australasia					
Australia	16,567	702	38,111	301,860	357,240
Fiji	—	90	—	—	90

Table 17: Irrigated land damaged by salinisation in the top five irrigators and the world estimate for mid 1980s.

Table 3-1 c

Country	Area damaged (Mha)	Share of irrigated land damaged (per cent)
India	20.0	36
China	7.0	15
United States	5.2	27
Pakistan	3.2	20
Soviet Union	2.5	12
Sub-total	37.9	24
World	60.2	24

Source: Postel (1990).

Table 11: Global extent of human-induced salinisation.

Table 3-2 a

Continent	Light (Mha)	Moderate (Mha)	Strong (Mha)	Extreme (Mha)	Total (Mha)
Africa	4.7	7.7	2.4	-	14.8
Asia	26.8	8.5	17.0	0.4	52.7
South America	1.8	0.3	-	-	2.1
North and Central America	0.3	1.5	0.5	-	2.3
Europe	1.0	2.3	0.5	-	3.8
Australasia	-	0.5	-	0.4	0.9
Total	34.6	20.8	20.4	0.8	76.6

Source: Oldeman, et al. (1991b).

Table 10: Human-induced soil degradation for the World.

Table 3-2b

Type	Light (Mha)	Moderate (Mha)	Strong (Mha)	Extreme (Mha)	Total (Mha)	Total (Per cent)
Loss of Topsoil	301.2	454.5	161.2	3.8	920.3	
Terrain Deformation	42.0	72.2	56.0	2.8	173.3	
WATER	343.2	526.7	217.2	6.6	1093.7	55.7
Loss of Topsoil	230.5	213.5	9.4	0.9	454.2	
Terrain Deformation	38.1	30.0	14.4	-	82.5	
Overblowing	-	10.1	0.5	1.0	11.6	
WIND	268.6	253.6	24.3	1.9	548.3	27.9
Loss of nutrients	52.4	63.1	19.8	-	135.3	
Salinization	34.8	20.4	20.3	0.8	76.3	
Pollution	4.1	17.1	0.5	-	21.8	
Acidification	1.7	2.7	1.3	-	5.7	
CHEMICAL	93.0	103.3	41.9	0.8	239.1	12.2
Compaction	34.8	22.1	11.3	-	68.2	
Waterlogging	6.0	3.7	0.8	-	10.5	
Subsidence organic soils	3.4	1.0	0.2	-	4.6	
PHYSICAL	44.2	26.8	12.3	-	83.3	4.2
Total (Mha)	749.0	910.5	295.7	9.3	1964.4	
(Per cent)	38.1	46.1	15.1	0.5		100

Source: Oldeman et al. (1991b).

Source: from Ghassami et al. 1993 (draft)

Table 18: Global estimate of secondary salinisation in the world's irrigated lands.

Table 3-3 a

Country	Cropped area[a] (Mha)	Irrigated area[a] (Mha)	Share of irrigated to cropped area (per cent)	Salt affected land in irrigated area[b] (Mha)	Share of salt affected to irrigated land (per cent)
China	96.97	44.83	46.2	6.70	15.0
India	168.99	42.10	24.9	7.00	16.6
CIS	232.57	20.48	8.8	3.70	18.1
United States	189.91	18.10	9.5	5.63	31.1
Pakistan	20.76	16.08	77.5	4.22	26.2
Iran	14.83	5.74	38.7	1.72	30.0
Thailand	20.05	4.00	19.9	0.40	10.0
Egypt	2.69	2.69	100.0	0.88	33.0
Australia	47.11	1.83	3.9	0.16	8.7
Argentina	35.75	1.72	4.8	0.58	33.7
South Africa	13.17	1.13	8.6	0.10	8.9
Sub-total	842.80	158.70	18.8	31.09	20.0
World	1473.70	227.11	15.4	45.4	20.0

Source: (a) Data for 1987 from FAO (1989); (b) Data for 1980s from different sources referred to in part two of this publication.

Source: Ghassami et al. 1993 (draft)

Table 3-3 b

Pakistan: Indus Basin, (1954), river salinity is low; increasing groundwater salinity in downstream stretches. totally 18 Mio ha, 10% saline, 24% partly saline

Upper Indus: 11 Mio ha, saline 6%, partly saline 14%

Lower Indus: 7 Mio ha, saline 18%, partly saline 39%

annual increase in damage: 20,000 ha (1950s); 40,000 ha (1960s)

in total out of 29 Mio arable land 23% are salt affected. (FAO 1971)

Totally, some 40% of irrigated soils are affected by waterlogging, of which some 14-17% are seriously affected (watertable within 1.5m). About 40% of the total areas have saline groundwater. (Anver in: ICID (STS-B2) 1991).

Iran. 16.8 Mio ha are arable land; 7 Mio ha are saline (naturally or human-made)

Iraq 3.6 Mio ha arable; 1.9 Mio cultuivated (1962), 50% are strongly saline (declined yields at all degrees), in irrigated areas 20-60% are affected by salinity, less often in northern parts (higher rainfall).; major cause: waterlogging, use of saline water; high sodicity and alkalinity in places; drainage systems are only recently introduced, hence, and accumulation of salts and built-up of soil salinity and shallow water table over millennia (Dieleman 1977).

Saudi Arabia: Large scale problems in new development schemes, due to lack of drainage systems; traditional systems only affected by sewage from big schemes

Libya. Large scale problems in some new developed schemes: use of saline irrigation water, lack of drainage systems, selection of unsuitable soils (primary salinity); development of suitable land with minor problems; often excellent water quality, artificial or natural drainage of new systems created ocassionally problems of waterlogging and salinization in adjacent traditional irrigation.

Haiti. Large scale development may create problems if inherent soil properties are not considered and under poor water management; analysis revealed that -after 22 years development - slightly saline soils are desalinized and problems aggrevated in soils already saline prior to irrigation (Petermann 1986)

Jordan. About 12% of Jordan Valley soils are affected (recently developed areas) (FAO 1970).

Syria. 8 Mio ha arable land; some 6.6. Mio ha are cultuivated, some 0.5 Mio irrigated; 50% of irrigated areas (0.22 Mio ha) in Euphrates/Khabour Valleys are affected by salinity: 10% pf area abandoned, 15% high and 25% moderate yield losses in 1970s. (FAO 1970).

Egypt. About 0.8 Mio ha, ie 30% of arable land is affected by salinity, waterlogging and insufficient natural darainage (FAO 1970). In New Valley irrigated soils: 25% are non-saline, 50% moderately saline; 25% strongly saline (either top- or subsoils); under continuous irrigation with good management soils become desalinized under irrigation initial salt contents are moderately high, ocassionally extremely high; extreme secondary salinization on low lying areas without drainage; proper selection of irrigated areas, average water management practices and adequate draiange can avoid degradation.

Country	Area	Population	Average annual rainfall	Average annual runoff			Annual water use		Cultivated land		Irrigation-induced salt affected land
				Volume	Depth	Percent of rainfall	Total volume	Volume used for irrigation	Total	Irrigated	
	(10^6 km^2)	(10^6)	(mm)	(10^9 m^3)	(mm)	(%)	(10^9m^3)	(10^9m^3)	(10^6 ha)	(10^6 ha)	(10^6 ha)
Argentina	2.8	32	515	914	330	64	26	19	35.8	1.5	0.58
Australia	7.7	17	465	397	52	11	15	10	47.1	1.8	0.16
China	9.6	1134	630	2600	272	43	444	~~300-400~~ 383	100.0	48.0	6.70
CIS	22.4	291	531	4740	215	40	344	195	232.6	20.5	3.70
Egypt	1.0	52	0	0	0	0	38	34	2.7	2.7	0.88
India	3.3	850	1250	1897	577	46	552	460	169.0	42.1	7.00
Iran	1.6	56	243	71.5	43	18	75	73	14.8	5.7	1.72
Pakistan	0.8	112	348	175	220	63	na	123	20.4	17.6	4.22
South Africa	1.2	36	502	53.5	44	9	12	9	13.2	1.1	0.1
Thailand	0.5	56	1550	171	333	21	na	na	20.0	4.0	0.40
USA	9.4	250	762	1930	206	27	551	120	224.5	19.7	5.63
World	149.0	5292	800	46 768	314	39	4132	2680	1473.70	227.11	45.40

na: Not available

Main affected areas	Major causes	Major management options	Remarks
San Juan, Mendoza, Salta and Rio Negro Provinces.	Extensive irrigation without drainage facilities.	Improving drainage facilities and irrigation systems.	
Murray Basin and southwest of Western Australia.	Land clearing, extensive irrigation, construction of hydraulic structures.	In Murray Basin: interception schemes and disposal of saline drainage and groundwater to evaporation basins. In Western Australia: reforestation.	(a) In the irrigated areas 0.65 x 10^6 ha have water tables shallower than 2m. (b) 0.80 x 10^6 ha are affected by dryland salinity. (c) salinisation of water resources in the Murray Basin, Western Australia and South Australia, is a major problem.
Huang-Huai-Hai Plain (containing 3.06 Mha salt affected land out of a total 20 Mha irrigated).	Excessive irrigation without adequate drainage facilities.	Conjuctive use of surface and groundwater resources.	
Central Asia, Ukraine, Caucasus region and Volga Basin.	Excessive irrigation without adequate drainage facilities.	Increasing irrigation efficiency by lining irrigation canals, using efficient irrigation methods, automation of irrigation systems, using subsurface drainage methods (tile drainage and vertical drainage) and changes in agricultural practices.	
Nile Valley and Delta.	Extensive perennial irrigation.	Development of surface and sub-surface pipe drainage facilities.	Egypt has practically no surface runoff. The 55.5 x 10^9 m^3 of the Nile water is Egypt's share from the Nile Basin.
Punjab, Haryana, Uttar Padesh, Bihar, Rajastan, Madhyapradesh.	Excessive irrigation without drainage facilities.	Conjunctive use of surface and groundwater, improved irrigation and drainage.	
Many irrigation projects including Zarrineh-Rud, Moghan, North Ahwaz, Khalafabad, Shadgan, Doroudzan and Isfahan.	Low rainfall, high potential evaporation, inadequate irrigation and drainage facilities, irrigation with low quality water.	Improving irrigation and drainage facilities, conjunctive use of surface and groundwater, improved agricultural practices.	
Indus River Basin.	Extensive use of surface water for irrigation and inadequate drainage facilities.	Conjunctive use of surface and groundwater, improving drainage facilities, disposal of saline drainage waters to the sea.	
Breede, Fish and Sundays River Basins.	Irrigation on soils with sub-surface salt contents.	Improved irrigation and drainage systems.	Salinisation of surface water resources supplying the main population centres, and the industrial, mining and agricultural sectors is a much more important issue compared to land salinisation. Salt affected rivers include Breede, Berg, Fish and Vaal. Salinisation is mainly due to increased human activity such as the discharge of industrial, mining and municipal effluents to the river system, as well as return flow from irrigation schemes and the phenomenon of dryland salinity.
Khorat and Sakon Nakhon Basin in Khorat Plateau, Lam Pao and Nong Wai.	Land clearing, reservoir construction, salt making and irrigation.	Reforestation, banning salt making, controlling groundwater depth, land levelling and surface mulching.	(a) Dryland salinity affects 2.85 x 10^6 ha mainly in Khorat Plateau. (b) Irrigated land salinity is mainly limited to Lam Pao and Nong Wai irrigated areas.
Colorado River Basin, San Joaquin Valley, Imperial Valley, Coachella Valley, Lower Rio Grande	Excessive irrigation without adequate drainage facilities	On-farm physical improvement and irrigation management, water pricing and irrigation management, blending drainage water with good quality surface water, disposal of drainage water to evaporation basin.	Salinity of the Colorado River and disposal of irrigation return flow in San Joaquin Valley are among the major issues.
Arid and semi-arid regions of the world, including countries such as: Argentina, Australia, China, Egypt, India, Iran, Iraq, Pakistan, Thailand, The United States and the Soviet Union.	Excessive irrigation without adequate drainage facilities, land clearing and construction of hydraulic structures.	Improving surface and sub-surface drainage facilities, conjunctive use of surface and groundwater resources, and improving farm management.	45.4 x 10^6 ha of land affected by human induced salinisation represents only the salt affected land in the world irrigated areas.

Source: Ghassami et al. 1993 (draft)

Table 3-3 c

Table 3-3

Table 8.8. Soil loss under different vegetal covers

Cover	Slope (per cent)	Soil loss ($kg\,m^{-2}\,y^{-1}$)	
Primary tropical rain forest	—	0.009	(1)
Secondary tropical rain forest	—	0.013	(1)
	7	0.003	(2)
Temperate mixed woodland	19	0.005	(3)
Dense savanna grass	4	0.005–0.02	(2)
Lucerne	9	0.025	(4)
Blue grass	9	0.007	(4)
Maize (shifting cultivation plot)	—	0.03	(1)
Maize (1st year in maize/oats/ clover rotation)	9	4.4	(4)
Maize (with grass bunds)	—	0.7	(5)
Maize (no conservation)	—	1.2	(5)
Maize (rows up and down slope)	9	9.4	(4)
Maize (on subsoil)	9	12.8	(4)
Coffee (clean weeded)	—	2.2	(5)
	—	1.8–5.5	(5)
Banana	7	1.5	(2)
Banana (trash mulch)	—	0.05	(5)
Manioc	7	9.0	(2)
Sorghum	2	0.3–1.2	(2)
	—	2.6–5.2	(5)
Cotton	2	0.05–1.9	(2)
Ground nuts	2	0.3–1.2	(2)
Crotalaria	7	4.0–5.0	(2)
Upland rice (1st year)	—	0.017	(1)
Upland rice (12th year)	—	0.289	(1)
Bare soil in humid tropics	7	10.0–17.0	(2)
Bare soil in savanna	4	1.8–3.0	(2)
Bare soil in temperate climate	19	1.0	(3)

After (1) Kellman, 1969; (2) Roose, 1971; (3) Morgan, 1977; (4) FAO, 1965; (5) Temple, 1972b.

Source: Kirkby/Morgan ed. 1980

Table 3-4

Table 8.1. Recommended values for maximum permissible soil loss ($kg\,m^{-2}\,y^{-1}$)

Meso-scale (e.g. field level)	
Deep fertile loamy soils; values used in the Mid-West of USA	0.6–1.1[a]
Thin, highly erodible soils	0.2–0.5[b,c]
Very deep loamy soils derived from volcanic deposits, e.g. in Kenya	1.3–1.5[b]
Soil depths: 0–25 cm	0.2[d]
25–50 cm	0.2–0.5[d]
50–100 cm	0.5–0.7[d]
100–150 cm	0.7–0.9[d]
over 150 cm	1.1
Probable realistic value for very erodible areas, e.g. mountains in the tropics	2.5
Macro-scale (e.g. drainage basins)	0.2
Micro-scale (e.g. construction sites)	2.5

After [a] Wischmeier and Smith (1965); [b] Hudson (1971); [c] Smith and Stamey (1965); [d] Arnoldus (1977).

Source: Kirkby/Morgan ed. 1980

Table 3-5

Table 1.1 Rates of erosion in selected countries ($kg\,m^{-2}\,y^{-1}$)

	Natural	Cultivated	Bare soil
China	< 0.20	15.00–20.00	28.00–36.00
USA	0.003–0.30	0.50–17.00	0.40– 9.00
Ivory Coast	0.003–0.02	0.01– 9.00	1.00–75.00
Nigeria	0.05 –0.10	0.01– 3.50	0.30–15.00
India	0.05 –0.10	0.03– 2.00	1.00– 2.00
Belgium	0.01 –0.05	0.30– 3.00	0.70– 8.20
UK	0.01 –0.05	0.01– 0.30	1.00– 4.50

Sources: Bollinne, 1978; Browning, Norton, McCall and Bell, 1948; Fournier, 1972; Jiang, Qi and Tan, 1981: Lal, 1976; Morgan, 1981a; Rao, 1981; Roose, 1971.

Source: Morgan 1986

Table 3-6

Table 1.5: TOTAL ESTIMATED ANNUAL COSTS OF SOIL EROSION ON JAVA (US$ million)

	West Java	Central Java	Yogyakarta	East Java	Java
On-Site	141.5	29.1	5.7	138.6	315.0
Off-Site					
Irrigation System Siltation	1.7-5.7	0.8-2.7	0.1-0.5	1.2-4.0	7.9-12.9
Harbor Dredging (1984/85)	0.4-0.9	0.1-0.3	-	0.9-2.2	1.4-3.4
Reservoir Sedimentation	9.0-41.3	3.5-16.3	-	3.8-17.3	16.3-74.9
Total	152.6-189.4	33.5-48.4	5.8-6.2	144.5-162.1	340.6-406.2

Source: World Bank (1989a).

Doolette/Magrath 1990

Table 3-7

Table 12-1. Relation of physicochemical properties to environmental behavior.

Physical chemical data	Related to
Solubility in water	Leaching, degree of adsorption, mobility in environment, and uptake by plants
Partition coefficient	Bioaccumulation potential, and adsorption by organic matter
Hydrolysis	Persistence in environment or biota
Ionization	Route and mechanism of adsorption or uptake, persistence, and interaction with other molecular species
Vapor pressure	Atmospheric mobility, and rate of vaporization
Reactivity	Metabolism, microbiological, and photochemical and autochemical degradation

Source: Madhun/Freed in: Cheng ed. 1990

Table 3-8

Table 2-1. Pesticide sources and environmental exposure pathways.

Pesticide source	Transport process	Exposure pathway	Receptor (Population at risk)
Canopy	Volatilization	Inhalation/skin contact	Human, animals
Crop residue	Volatilization	Inhalation/skin contact	Human, animals
Soil surface	Volatilization	Inhalation/skin contact	Human, animals
Root zone and below	Volatilization	Inhalation/skin contact	Human, animals
Grain/foliage	Manufacturing/feeding†	Food/ingestion	Human, animals
Crop residue	Overland flow†	Surface water (potable water)/ingestiou	Human, fish
Runoff	Overland flow†	Surface water (potable water and food chain)	Human, fish
Eroded soil particles and formulation—bound	Overland flow†	Ingestion surface water (food chain)/ingestion, contact	Fish
Leachate-dissolved-bound on colloidal particles	Leaching/percolation†	Groundwater (potable water)/ingestion	Human, animals

† Environmental flux of concern to either on-site or off-site receptors. After Bailey et al. (1985).

Source: Himel et al. in Cheng ed. 1990

Table 14-1. Status of knowledge concerning pesticide fate processes.

I. Transformation processes
  A. Sorption
    1. Hydrophobic pesticides
      Causative factors known
      Sorbate—hydrophobic, low water solubility
      Sorbent—organic matter content
      Predictor—K_{oc} or K_{ow} × fraction of organic matter; well-tested relationship
      Isotherm behavior—variable—reversible or irreversible, linear or nonlinear
      Desorption—kinetically controlled
    2. Hydrophilic pesticides
      Causative factors not well known
      Sorbate—acidic in character, pKa
      Basic in character, pKb
      Ionic
      Sorbent—not well known
      Lewis acid-base character or complexation capability
      Predictor—prototype, not tested
      Desorption—not well understood
  B. Microbial transformations
    1. Hydrophobic and hydrophilic pesticides in an oxidizing environment
      Causative factors known—temperature, pH, nutrient, and moisture content
      Mechanisms known for major families
      Transformation products known (their environmental behavior not well characterized)
      Organism specificity—essentially known
      Kinetics—well known
    2. Hydrophobic and hydrophilic pesticides in an anaerobic environment
      Causative factors—Eh, pH, O_2 nutrient content—not well known
      Redox chemistry not well understood
      Kinetics—not well defined
      Organism specificity—not well known
  C. Chemical transformations
    1. Hydrophobic and hydrophilic pesticides in an oxidizing environment
      Structure-reactivity relationships fairly well known
      Causative factors—pH, temperature, ionic strength—well known
      Surface catalytic properties of heterogeneous media surfaces—early definitive stage
      Mechanisms—hydrolysis, (acid, base, and neutral) substitution, elimination, and ring cleavage—well known
      Kinetics—generally well known
      Products—generally well known
    2. Hydrophilic and hydrophobic pesticides in an anaerobic environment
      Causative factors not well known
      Mechanisms—early definitive stage
      Kinetics—not well known
      Products—not well known
  D. Photolysis
    1. Water
      Causative factors—fairly well known
      Role of Fe, Mn, and DOC content currently being defined
      Mechanisms—known for major families
      Predictor—prototype available
    2. Soil surface
      Causative factors, pathways, mechanisms, known, research in its infancy
    3. Foliar or crop residue surface
      Similar stage as photolysis on soil surface
      Effect of leaf morphology and biochemical character on process not defined
  E. Bioaccumulation/biomagnification
      Causative factors not entirely known
      Data on hydrophobic pesticide bioaccumulation/magnification known
      Predictor—first-generation pharmacokinetic prototype available for fish
II. Transport processes
  A. Volatilization
    1. Soil surface
      Causative factors—vapor density, soil matrix properties, and meteorological conditions—well known
      Predictors—screening level simulation models available
    2. Foliar surface
      Causative factors not well known
      Predictor—not available
  B. Drift
      Causative factors—partially known
      Predictor—simulation models
  C. Erosion/pesticide overland flow
      Causative factors—generally well known for solution and sediment-bound pesticides
      Predictor—simulation models available
  D. Washoff
      Causative factors—partially known
      Predictor—prototype model available
  E. Infiltration
      Causative factors—known
      Predictor—equations available
  F. Percolation and leaching in subsoil
      Causative factors—generally known except for spatial variability of soil properties
      Predictor—coupled advective/dispersion model with linear or nonlinear/reversible or irreversible sorptive algorithms are available. Generally, not well tested. Transfer function model available but not well tested.
  G. Groundwater/pesticide transport in aquifer
      Causative factors not well-defined
      Predictor—1, 2, and 3D models available, not widely tested
  H. Aeolian pickup and transport
      Causative factors generally known
      Applicable pesticides—sorbed pesticide
      Predictor—models available, but in question and being re-evaluated

Source: Bailey in Cheng ed. 1990

Table 3-10

Table 2. Effects of Salts on Adsorption of Herbicides by Soils and Soil Components[a]

Adsorbent	Herbicide	Salt effect: Ionic strength <1	Salt effect: Ionic strength >1	Experimental conditions	
Montmorillonite Na	Fenuron	–[b]	+	NaCl	
Montmorillonite Na	Fenuron	0 or –	+	NaCl	
Montmorillonite Mg	Monuron			$MgCl_2$	Identical concentrations
Montmorillonite Ca				$CaCl_2$	
Soils	Terbutryne	–	+	NaCl	Identical ionic strength
	Atrazine			KCl $CaCl_2$	
Goethite	2,4-D	–	+	NaCl	
Soils	1,3,5-triazines	+		KCl	Identical ionic strength
	Substituted ureas			NH_4Cl $CaCl_2$	
Soils	Picloram	+		KCl	Identical concentrations
				$CaCl_2$	
Soils	Prometryn	+		NaCl	Identical
	Fluometuron	–		$CaCl_2$	concentrations

[a] After Calvet (1980).
[b] 0 = no effect; – = the adsorption decreases as the ionic strength increases; + = the adsorption increases with the ionic strength.

Behavior of Herbicides in Irrigated Soils

Table 3-12

Table 7. Half-Life (Days) of Some Paddy Herbicides in Flooded Soils[a]

Herbicide	In laboratory experiments[b]	In paddy fields[c]
2,4-D	30–40	33, 48
2,4-D ethyl	<1 hr	
MCPA	3, 4, 7, 7, 15, 20	7, –
MCPA ethyl	7–14	
Phenothiol	<1	.5
Dalapon	3–5, 14–21	10–15, 20–31
PCP	5, 10–17, 12–70 (mean 30), 60	3–10, 6–7, 10–17
Benthiocarb	7–100 (mean 40)	3–8, 7, 8, 11, 62
Molinate	7, 15, 18, 30	<1, <5, <5, <5, <9, 11
Swep	2–9, 10–11, 7–14	<10
Propanil	<1–1, 1, 5	<1–1
Naproanilide	5, 6	2, <4, 4
Napropamide	49, 56	<20, 20
Butachlor	9–30	6, 8
Credazine	90–150	22, 45
Trifluralin	9, 10, 22, 45	10, 45
Nitrofen	3–35 (mean 11)	~14
Chlornitrofen	7–35 (mean 15), 17, 35	7, 9, 12, 13, ~14
Chlomethoxynil	7–35 (mean 15), 30	7–8
Bifenox	4, 4	4, 4
Oxadiazon	75, 93–98	
Bentazone	5, 33, 45	15, 15
Simetryn	<37, 63	
Prometryne	100, 120	
Paraquat	>180	>180
Diquat	>150	

[a] Data collected from various sources; after Crosby, 1983.
[b] Each chemical was mixed with soil and incubated at 25 to 30°C in dark.
[c] Persistence in soils in paddy rice fields in Japan. Most herbicides were applied in May or June.

Table 3-11

Table 1. Effect of the Temperature on the Adsorption of Herbicides by Organic Materials, Minerals, and Soils[a]

Adsorbent	Herbicide	Effect of temperature
Montmorillonite (pH 8.5)	Simazine	–[b]
Illite	2,4-D	–
Montmorillonite	2,4-D	0
Montmorillonite Na	Paraquat	0
Vermiculite Na	Paraquat	+
Peat	Monuron	0
	Simazine	0
	Atrazine	0
	2,4-D	0
Humic acid	Atrazine	+
Humic acid Lignin	Atrazine	+
Humic acid	Atrazine	+
Charcoal	Prometon	0
	2,4-D	–
Soils	1,3,5,-triazines	–
Soils	Alachlor	–
Soils	Picloram	–
Soils	12 dinitroanilines	–

[a] After Calvet (1980).
[b] 0 = no effect; – = adsorption decreases as temperature increases; + = adsorption increases with temperature.

Table 3-13

Table 8. Fate of Molinate When Applied in Paddy Soils[a]

Process	Estimated loss (%)
Soil adsorption and metabolism	<10
Plant uptake and metabolism	< 5
Aqueous microbial metabolism	< 1
Hydrolysis	< 1
Photolysis	5–10
Volatilization to atmosphere	75–85

[a] After Crosby (1983).

Sources: Yaron et al. 1985

Table 3-14

Tab. 2.7.3/4: Mittlere Gehalte (mg/kg) einiger Mikro-Nährelemente und potentiell toxischer Elemente in Gesteinen (n. WEDEPOHL 1984, Lockersedimente n. BLUME, BRÜMMER 1984)

	As	Be	Bi	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Se	Sn	Tl	V	Zn
Kontinentale Kruste	3.4	2.9	.08	.10	19	88	35	.02	800	1.5	45	15	.08	2.5	.49	109	69
Ultrabas. Gesteine	1			.05	150	1 600	10	.03	1 600	0.3	2 000	1		0.5	.06	40	50
Basalte, Gabbro	1.5	0.6	.04	.10	48	168	90	.02	1 390	1	134	3.5	.09	1.5	.08	251	100
Gneise, Glimmersch.	4.3	3.8	.10	.10	13	76	23	.02	600	(1.5)	26	16	.08	2.5	.65	60	65
Granit, Gesteine	1.5	5.5	.19	.09	4	12	13	.03	325	1.8	7	32	.04	3.5	1.1	94	50
Grauwacken	8	3	.07	.09	20	50	45	.11	750	0.7	40	14	0.1	(3)	.20	67	105
Tonsteine	10	3	.13	.13	19	90	45	.45	850	1.3	68	22	0.5	2.5	.68	130	95
Kalke	2.5	(0.5)	.02	.16	2	11	4	.03	700	0.4	15	5	.19	(.2)	.05	20	23
Sandsteine	1			.05	0.3	35	5	.03	50	0.2	2	7			.08		15
Löß	6.5			(.2)	9	67	15	.02	300	1.2	28	34		1.8		64	53
Geschiebemergel	8			0.3	7	35	15	.04	400	1	18	20		3.4		29	40
Meerschlick	11			0.3	8		15	.01	460		22	43					96
Sande	1.3			0.1		1.5	< 3	< .01	46	1	5	10		3		3.3	11
( ) wenige Daten																	

Table 3-15

Tab. 2.7.3/6: Natürliche und anthropogene Quellen der atmosphärischen Belastung, Angaben in 10^8 g/a (nach LANTZY und MCKENZIE 1979, aus MERIAN 1984)

	natürlich			anthropogen			
Element	Kontinent. Staub Fracht	Vulkan Staub Fracht	Vulkan Gas Fracht	Indust. Partikel Emission	Fracht d. foss. Brennstoffe	gesamte anthrop. Emission	Atmosph. Interferenz-faktor[1])
Al	356 500	132 700	8.4	40 000	32 000	72 000	15
Ti	23 000	12 000	–	3 600	1 600	5 200	15
Sm	32	9	–	7	5	12	29
Fe	190 000	87 750	3.7	75 000	32 000	107 000	39
Mn	4 250	1 800	2.1	3 000	160	3 160	32
Co	40	30	0.04	24	20	44	63
Cr	500	84	0.005	650	290	940	161
V	500	150	0.05	1 000	1 100	2 100	323
Ni	200	83	0.0009	600	380	980	346
Sn	50	2.4	0.005	400	30	430	821
Cu	100	93	0.012	2 200	450	2 630	1 363
Cd	2.5	0.4	0.01	40	15	55	1 897
Zn	250	108	0.14	7 000	1 400	8 400	2 346
As	25	3	0.1	620	160	780	2 786
Se	3	1	0.13	50	90	140	3 390
Sb	9.5	0.3	0.013	200	180	380	3 878
Mo	10	1.4	0.02	100	410	510	4 474
Ag	0.5	0.1	0.0001	40	10	50	8 333
Hg	0.3	0.1	0.001	50	60	110	27 500
Pb	50	8.7	0.012	16 000	4 300	20 300	34 583

[1]) Interferenzfaktor = $\frac{\text{totale anthropogene Emission}}{\text{totale natürliche Emission}}$

Sources: Blume ed. 1992

Tab. 2.7.3/17: Physiologische Notwendigkeit und potentielle Toxizität für Pflanzen und Tiere (n. ADRIANO 1986).

Table 3-16

	Ernährungs-physiologisch essentiell bzw. nützlich		Potentiell toxisch für		Bemerkung
Element	Pflanze	Tiere	Pflanze	Tiere	
Ag	–	–		+	
As	–	+	+	+	Wirkt bei Pflanzen in geringeren Konz. toxisch als bei Tieren
B	+	–	+		
Ba	–	?			
Be	–	–	+	+	Bindungsformen wichtig
Bi	–	–	+	+	
Cd	–	–	+	+	Bereits in geringen Konz. toxisch, Anreicherung über Nahrungsketten
Co	+	+	+	+	relativ ungiftig, starke Anreicherung über Nahrungsketten
Cr	–	+	+		Bindungsformen entscheidend für Toxizität Cr^{VI} sehr giftig
Cu	+	+	+		Org.-komplexe Bindung in Böden
Hg	–	–		+	Anreicherung über Nahrungsketten
Mn	+	+			Löslichkeit im Boden stark Redoxabhängig
Mo	+	+		+	In Pflanzen stark angereichert, bereits in geringem Überschuß für Tiere toxisch
Ni	–	+	+	+	Sehr mobil in Pflanzen, relativ ungiftig
Pb	–	–	+	+	Weit verbreitet über die Atmosphäre
Sb	–	–		+	Relativ unlöslich
Se	+	+	+	+	Bereits in geringem Überschuß für Tiere toxisch, synergistische, antagonistische Wirkungen mit anderen Spurenelementen
Sn	–	+		+	Relativ ungiftig, geringe Pflanzenaufnahme
Tl	–	–		–	Sehr mobil in Pflanzen
V	+	+		+	Bereits in geringem Überschuß toxisch
W	–	–			Geringe Gehalte in Boden und Pflanzen, unlöslich
Zn	+	+			Weite Spanne zwischen Pflanzenbedarf u. Toxizität. Für Tiere besteht oft Mangel

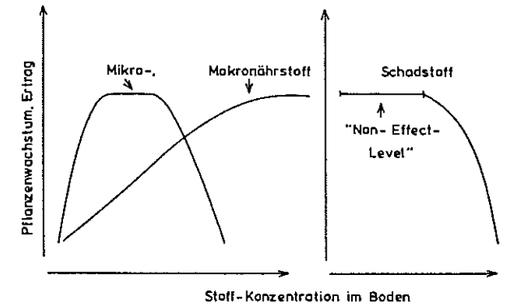


Abb. 2.7.3/10: Einfluß der Konzentration von Mikro- und Makronährstoffen sowie Schadstoffen auf Pflanzenwachstum und Ertrag (schematische Darstellung, n. BRÜMMER 1989)

Source: Blume ed. 1992

Tab. 2.7.3/18: Transferkoeffizient Boden-Pflanze, normale Gehalte in Böden, normale und kritische Konzentrationen von Schwermetallen im Pflanzenmaterial (Bezug auf T.S.) (aus SAUERBECK 1985, n. KLOKE et al. 1984; ergänzt).

Table 3-17 a

Element	normal Grenzw.[1]) in Böden mg/kg	mg/kg	Transfer-Koeffizient Boden-Pflanze	normal in Pflanzen	krit. für Pflanzenwuchs	krit. als Tierfutter
Cd	0.01 – 0.7	3	1 – 10	< 0.1 – 1	5 – 10	0.5 – 1
Co	1 – 10	(50)	0.01 – 0.1	0.01 – 0.5	10 – 20	10 – 50
Cr	2 – 50	100	0.01 – 0.1	< 0.1 – 1	1 – 2	50 – 3 000
Cu	1 – 40	100	0.1 – 1	3 – 15	15 – 20	30 – 100
Hg	0.01 – 0.5	2	0.01 – 0.1	< 0.1 – 0.5	0.5 – 1	> 1
Ni	2 – 50	50	0.1 – 1	0.1 – 5	20 – 30	50 – 60
Pb	0.1 – 20	100	0.01 – 0.1	1 – 5	10 – 20	10 – 30
Tl	0.01 – 0.5	(1)	1 – 10	< 0.5 – 5	20 – 30	1 – 5
Zn	3 – 50	300	1 – 10	15 – 150	150 – 200	300 – 1 000
As	0.1 – 20	(20)	0.01 – 0.1	< 0.1 – 5	10 – 20	> 50
B	3 – 100	(25)	1 – 10	5 – 30	> 75	150
Be	0.2 – 40		0.01 – 0.1	0.01 – 0.5	> 1	?
F	20 – 400	(200)	0.01 – 0.1	1 – 5	> 50	40 – 200
Mo	0.2 – 5		0.1 – 10	0.1 – 3	> 100	10 – 58
Se	0.01 – 5	(5)	0.1 – 10	0.1 – 2	10 – 20	4 – 5
Sn	1 – 20		0.01 – 0.1	?	> 60	?
V	0.01 – 200		0.1 – 1	0.1 – 1	10	10 – 50

[1]) Grenzwerte der Klärschlammverordnung; ( ) in Diskussion

Table 3-17 b

Tab. 2.7.3/21: Schwermetallgehalte von belastungsgefährdeten Böden Nordrhein-Westfalens im Einflußbereich verschiedener Belastungsursachen (Angaben in mg/kg Boden, Erklärung teilweise im Text, n. KÖNIG und KRÄMER 1985).

Element	Grundbelastung	Normalgehalte[1])	Klärschlamm	Straßen	Emission (Rhein-Ruhrgebiet)	Überschwemmung	Erzabbau	Grenzwerte[2])
Cd	0.8	0 – 1	0.8	0.9	1.4	2.7	3.7	3
Zn	110	0 – 50	120	160	250	480	610	300
Pb	50	0 – 20	40	65	70	150	810	100
Cu	20	0 – 20	35	18	40	75	30	100
Cr	30	0 – 50	70	30	35	60	30	100
Hg	0.30	0 – 1	0.25	0.35	0.35	1.10	0.43	2
Ni	50	0 – 50	23	17	21	39	25	50

[1]) Normalgehalte nach KLOKE (1980) [2]) Grenzwerte der Klärschlammverordnung

Tab. 2.7.3/19: Relative Akkumulation von Schwermetallen in eßbaren Pflanzenteilen verschiedener Obst- und Gemüsearten (n. BERGMANN 1988)

Table 3-18

Akkumulation			
hoch	mittel	niedrig	sehr niedrig
Salat (*Lactuca sativa*) Spinat (*Spinacia oler.*) Mangold (Beta vulgaris var.*cicla*) Endivie (*Cichorium endivia*) Kresse (*Lepidium latifol.*) Möhren (*Daucus carota*)	Grünkohl (*Brassica oler.* var. *acephala*) Kohl (*Brassica oler.*) Rote Rüben (*Beta vulg. conditiva*) Steckrüben (*Brassica rapa*) Rettich (*Raphanus sativus*) Kartoffel (*Solanum tuberosum*)	Kopfkohl (*Brassica oler.*) Zuckermais (*Zea mays*) Broccoli (*Brassica oler. italica*) Blumenkohl (*Brassica oler.* var. *botrytis*) Rosenkohl (*Brassica oler. gemmifera*) Sellerie (*Apium graveolens*) Beerenfrüchte	Bohnen (*Phaseolus*) Erbsen (*Pisum sativum*) Melonen (*Cucumis melo*) Tomaten (*Lycopersicum esculentum*) Paprika (*Capsicum annuum*) Eierfrüchte (*Solanum melongena*) Kernobst, Steinobst

Sources: Blume ed. 1992

Table 3-19

Tab. 2.8.4/2: Wasserqualitätsvergleiche (in mg/l) nach AUTORENKOLLEKTIV, 1972; VEH u. EDOM, 1981; BAUMANN et al., 1976; GTZ, 1984

Stoffe	Trinkwasser	Abwasser häuslich	Kanaleinleitung	Landw. Ansprüche
1	2	3	4	5
$KMnO_4$-Verbr.	0 – 12	500 – 1 450	–	12 – 4 000
BSB_5	0 – 4	200 – 400	500	25 – 50
Leitf. $\mu S \times cm^{-1}$	100 – 400	1 800 – 4 200	–	750 – 3 000
Salzkonz.	50 – 250	1 200 – 2 700	–	500 – 1 900
Reaktion, pH	6.5 – 8.5	7.8 – 8.6	6.5 – 10.0	5 – 8
Gesamt-Rückst.	100 – 1 000	500 – 1 400	–	5 000
Glühverlust -	5 – 65	200 – 1 000	–	*
Org.geb. Kohlenst.	5 – 40	50 – 420	–	*
Kjeldahl-N	0 – 15	4 – 50	–	*
Mineral.-N	5 – 10	5 – 55	–	*
Gesamt-P	0.01 – 1.5	10 – 50	–	*
Phosphat-P	0.001 – 0.1	1 – 15	–	*
Nitrat-N	0 – 20	0.2 – 20	–	1 – 10
Nitrit-N	0 – 0.06	0.05 – 0.1	6	1
Ammonium-N	0 – 0.4	5 – 50	80	25 – 120
Chlorid	0 – 250	100 – 1 000	500	140 – 350
Sulfat	0 – 150	50 – 150	300 – 600	300
Hydrogencarbonat	1 – 100	1 200	–	2 – 10
Natrium	10 – 50	50 – 450	–	20 – 50
Kalium	2 – 10	10 – 80	–	*
Calzium	15 – 70	30 – 80	–	*
Magnesium	0 – 60	10 – 20	–	*
Eisen	0 – 0.20	0.1 – 0.7	5	2 – 20
Sauerstoff	6 – 12	0 – 5	–	Sättigung
Ges. Härte, mmol l^{-1}	0.4 – 5.5	2 – 10	–	*
Carb.-Härte mmol l^{-1}	0.4 – 2.2	3.9 – 7.6	–	*
Kohlendioxid	1	–	–	–
Cyanide	0.05	0.01 – 0.05	0.1 – 20.0	0.05 – 1.0
Chrom III	0.05	0.025 – 0.05	3	0.01 – 1.0
Chrom VI	–	–	0.5	–
Zink	0 – 15	5 – 15	5	1 – 10
Kupfer	0 – 1.5	0.1 – 1.0	2	0.2 – 5.0
Cadmium	0 – 0.006	0.005 – 0.01	0.5	0.1 – 1.0
Arsen	0 – 0.2	0.01 – 0.05	1	0.1 – 2.0
Sulfit-Schwefel	0 – 0.05	0.05 – 0.1	2 – 5	–
Aktives Chlor	0 – 0.3	–	5	0.3 – 1.0
Gesamt-Phenol	0 – 0.001	0.002 – 0.5	50 – 100	5 – 250
Teer	0	0	10	–
Fette, Öle	0	20 – 40	250	5 – 10
Waschakt. Sub.	0	0.5 – 10	10	50 – 200
Lösungsmittel	0	–	1	–
Aluminium	0 – 0.05	–	=	5 – 20
Blei	0 – 0.3	0.05 – 0.2	2	0.5 – 10
Fluoride	0 – 1.5	2 – 20	60	1 – 15
Quecksilber	0 – 0.004	0 – 0.05	0.05	0.001 – 0.02
Selen	0 – 0.008	0 – 0.005	1	0.001 – 0.02
Nickel	0 – 0.05	0 – 0.02	4	0.2 – 2.0
Antimon	0 – 0.01	–	–	–
Barium	0 – 0.1	–	–	1 – 4
Silber	0 – 0.01	–	–	–
Mangan	0 – 0.1	0 – 0.05	–	0.5 – 10
Bor	–	1	–	1 – 2
Beryllium	–	–	–	0.1 – 0.5
Kobalt	–	–	–	0.2 – 5.0
Lithium	–	–	–	2.5 – 5.0
Molybdän	–	0 – 0.005	–	0.01 – 0.05
Vanadium	–	–	–	0.1 – 1.0
Zinn	–	–	5	–
Urochrome	0 – 0.2	20 – 60	50	–

Legende: Spalte 2: Streubreite aktueller Trinkwasserqualität Europas
Spalte 3: Abwasserqualität der Bundesrepublik Deutschland
Spalte 4: Angaben zur Einleitung i.d. öffentliche Kanalnetz
Spalte 5: Angaben f.d. landw. Abwasserverwertung
– = keine Angaben i.d. Literatur = = keine Begrenzung f.d. Stoff
* = Pflanzennährstoff, Bodenverbesserung, hohe Konz. erwünscht

Source: Blume ed. 1990

Table 3-20 a

Wastewater agricultural nutrients

Nutrients	kg/1,000m³
N	50
P	10
K	30

Source: Shuval et al. 1986

Table 3-20 b

Table 2.4 Typical properties of primary effluents (Thomas and Law 1977)

Constituent	Concentration	
	Range	Median
	mg/l	
Solids		
Total dissolved	200–1500	500
Total suspended	50–150	100
BOD	65–200	135
COD	150–750	335
Nitrogen		
Total	10–60	40
Free ammonia	7–40	30
Nitrate	—	<0.1
Phosphorus, total	5–17	8

Source: Feigin et al 1991

Table 2.2 Concentration of trace elements in raw and treated municipal effluents and the permissible level in irrigation water[a] and upper limit for drinking water for livestock[b]

Element	Raw wastewater		Primary effluent		Secondary effluent		Water quality criteria for irrigation[c]		Upper limit for drinking water (livestock)
	Range	Median	Range	Median	Range	Median	Long-term	Short-term[d]	
					mg/l				
Aluminium (Al)	—	—	—	—	—	—	5.0	—	5.0
Arsenic (As)	< 0.0003–1.9	0.085	< 0.005–0.03	< 0.005	< 0.005–0.023	< 0.005	0.1	10.0	0.2
Beryllium (Be)	—	—	—	—	—	—	0.1	—	0.1
Boron (B)	< 0.123–20.0	—	< 0.01–2.5	1.0	< 0.1–2.5	0.7	0.75	2.0	5.0
Cadmium (Cd)	< 0.0012–2.1	0.024	< 0.02–6.4	< 0.02	< 0.005–0.15	< 0.005	0.01	0.05	0.05
Chromium (Cr)	< 0.0008–83.3	0.400	< 0.05–6.8	< 0.05	< 0.005–1.2	0.02	0.1	20.0	1.0
Cobalt (Co)	—	—	—	—	—	—	0.05	—	1.0
Copper (Cu)	< 0.0001–36.5	0.420	< 0.02–5.9	0.10	< 0.006–1.3	0.04	0.20	5.0	0.5
Fluorine (F)	—	—	—	—	—	—	1.0	—	2.0
Iron (Fe)	—	—	—	—	—	—	5.0	—	Not needed
Lead (Pb)	0.001–11.6	0.120	< 0.02–6.0	< 0.2	0.003–0.35	0.008	5.0	20.0	0.1
Lithium (Li)	—	—	—	—	—	—	2.5	—	—
Manganese (Mn)	—	—	—	—	—	—	0.2	—	0.05
Mercury (Hg)	< 0.0001–3.0	0.110	0.0001–0.125	0.0009	< 0.0002–0.001	0.0005	—	—	0.01
Molybdenum (Mo)	< 0.0011–0.9	—	< 0.001–0.02	0.007	0.001–0.0018	0.007	0.01	0.05	—
Nickel (Ni)	0.002–111.4	0.230	< 0.1–1.5	< 0.1	0.003–0.6	0.004	0.2	2.0	—
Selenium (Se)	< 0.002–10.0	0.041	< 0.005–0.02	< 0.005	< 0.005–0.02	< 0.005	0.02	0.05	0.05
Vanadium (V)	—	—	—	—	—	—	0.1	—	0.1
Zinc (Zn)	< 0.001–28.7	0.52	< 0.02–2.0	0.12	0.004–1.2	0.04	2.0	10.0	24.0

[a] Chang and Page (1983); Page and Chang (1985).
[b] Ayers and Westcot (1985).
[c] The maximum concentration is based on a water application rate of 1200 mm/yr. In cases of higher rates, the maximum concentration should be adjusted accordingly.
[d] For use on fine-textured soils.

Table 3.16 Range in concentrations of selected trace elements in dry digested sewage sludges[a] (Chaney 1989)

Element[b]	Reported range		Typical median sludge	Typical soil	Maximum domestic sludge
	Minimum	Maximum			
As	1.1	230	10	—	—
Cd	1	3410	10	0.1	25
Cd/Zn, %	0.1	110	0.8	—	1.5
Co	11.3	2490	30	—	200
Cu	84	17000	800	15	1000
Cr	10	99000	500	25	1000
F	80	33500	260	200	1000
Fe, %	0.1	15.4	1.7	2.0	4.0
Hg	0.6	56	6	—	10
Mn	32	9870	260	500	—
Mo	0.1	3700	20	—	35
Ni	2	5300	80	25	200
Pb[c]	13	26000	250	15	500
Sn	2.6	329	14	—	—
Se	1.7	17.2	5	—	—
Zn	101	49000	1700	50	2500

[a] Composting using wood chips as a bulking agent generally produces composted sludge 50% as high in trace elements as a digested sludge from the same treatment plant.
[b] mg/kg unless otherwise noted.
[c] Sludge Pb concentration has dropped significantly during the 1980's in the USA due to reduction of leaded gasoline.

Sources: Feigin et al. 1991

Table 3-22 a

Tab. 2.7.3/18: Transferkoeffizient Boden-Pflanze, normale Gehalte in Böden, normale und kritische Konzentrationen von Schwermetallen im Pflanzenmaterial (Bezug auf T.S.) (aus SAUERBECK 1985, n. KLOKE et al. 1984; ergänzt).

Element	normal Grenzw.[1]) in Böden mg/kg	mg/kg	Transfer-Koeffizient Boden-Pflanze	normal in Pflanzen	krit. für Pflanzenwuchs	krit. als Tierfutter
Cd	0.01 – 0.7	3	1 – 10	< 0.1 – 1	5 – 10	0.5 – 1
Co	1 – 10	(50)	0.01 – 0.1	0.01 – 0.5	10 – 20	10 – 50
Cr	2 – 50	100	0.01 – 0.1	< 0.1 – 1	1 – 2	50 – 3 000
Cu	1 – 40	100	0.1 – 1	3 – 15	15 – 20	30 – 100
Hg	0.01 – 0.5	2	0.01 – 0.1	< 0.1 – 0.5	0.5 – 1	> 1
Ni	2 – 50	50	0.1 – 1	0.1 – 5	20 – 30	50 – 60
Pb	0.1 – 20	100	0.01 – 0.1	1 – 5	10 – 20	10 – 30
Tl	0.01 – 0.5	(1)	1 – 10	< 0.5 – 5	20 – 30	1 – 5
Zn	3 – 50	300	1 – 10	15 – 150	150 – 200	300 – 1 000
As	0.1 – 20	(20)	0.01 – 0.1	< 0.1 – 5	10 – 20	> 50
B	3 – 100	(25)	1 – 10	5 – 30	> 75	150
Be	0.2 – 40		0.01 – 0.1	0.01 – 0.5	> 1	?
F	20 – 400	(200)	0.01 – 0.1	1 – 5	> 50	40 – 200
Mo	0.2 – 5		0.1 – 10	0.1 – 3	> 100	10 – 58
Se	0.01 – 5	(5)	0.1 – 10	0.1 – 2	10 – 20	4 – 5
Sn	1 – 20		0.01 – 0.1	?	> 60	?
V	0.01 – 200		0.1 – 1	0.1 – 1	10	10 – 50

[1]) Grenzwerte der Klärschlammverordnung; ( ) in Diskussion

Table 3-22 b

Tab. 2.8.4/5: Entzüge von Spurenelementen durch die Vegetation bei Abwasserbewässerungen (n. ISKANDAR, 1981)

Element	Konz. in Pflanzen mg × kg^{-1}	Ernte-entzug g × ha^{-1} × a^{-1}	Abwasser zufuhr g × ha^{-1} × a^{-1}	Relation Zufuhr zu Entzug v.H.
As	1	3	60	5
B	50	150	12 000	1.25
Cd	0.5	1.5	60	2.5
Cr. ges.	0.5	1.5	300	0.5
Cu	15	45	1 200	3.75
Hg	0.02	0.06	11	0.55
Mo	1	3	60	3
Ni	5	15	240	6.25
Pb	2	6	600	1
Se	0.5	1.5	60	2.5
Zn	50	150	1 800	8.3

Ertragsbasis für Ernteentzug: 3000 kg · ha^{-1} TS;
Abwassergabe: 1 200 mm · a^{-1}

Sources: Blume et al 1992

Table 3-23

Table 3.20 Movement of viruses through soil in relation to wastewater application (After Frankenberger 1985)

Virus type	Nature of fluid	Nature of medium	Flow rate	Distance of travel	Percentage of removal
T1, T2, f2	Distilled water with added salts	9 types of soils from California	0.078–0.313 ml/min	45–50 cm	> 99
Poliovirus 1	Distilled water, 10^{-5} N Ca and Mg salts	Dune sand	1–2 ml/min	20 cm	99.8–99.9
Poliovirus 2	Distilled water	Low humic latosol	4.1–5.7 $m^3 m^{-2} day^{-1}$	4–15 cm	96–99.3
Poliovirus 2	Secondary effluent	Sandy gravel	—	60 m	100
Coxsackie	Spring water	Garden soils	—	90 cm	50
T4	Distilled water	Low humic latosol	4.1–5.7 $m^3 m^{-2} day^{-1}$	4–15 cm	100
T7	Secondary treated	Sandy forest	—	19.5 cm	99.6
Indigenous enteric	Secondary effluent	Loamy sand soil	Intermittent avg: 0.02 cm/min	3–9 m	100

Source: Feigin et al. 1991

Table 3-24

Table 3.3 Movement of bacteria through soils

Nature of fluid	*Type of organism*	*Soil type*	*Maximum distance of travel* (m)
Tertiary treated wastewater	Coliforms	Fine to medium sand	6.1
Secondary effluent on percolation beds	Faecal coliforms	Fine to loamy sand to gravel	9.1
Primary sewage in infiltration beds	Faecal streptococci	Silty sand and gravel	183
Inoculated water and sewage injected subsurface	*Bacillus stearothemophilis*	Crystalline bedrock	28.7
Sewage in buried latrine intersecting groundwater	*Bacillus coli*	Sand and sandy clay	10.7
Canal water in infiltration basins	*Escherichia coli*	Sand dunes	3.1

Source: Frankenberger (1984)

Source: Pescod/Arar 1988

Table 3-25

Table 4.2. Survival times of selected excreted pathogens in soil and on crop surfaces at 20–30 °C

Pathogen	Survival time (days)	
	In soil	On crops
Viruses		
Enteroviruses[a]	< 100 but usually < 20	< 60 but usually < 15
Bacteria		
Faecal coliforms	< 70 but usually < 20	< 30 but usually < 15
Salmonella spp.	< 70 but usually < 20	< 30 but usually < 15
Vibrio cholerae	< 20 but usually < 10	< 5 but usually < 2
Protozoa		
Entamoeba histolytica cysts	< 20 but usually < 10	< 10 but usually < 2
Helminths		
Ascaris lumbricoides eggs	Many months	< 60 but usually < 30
Hookworm larvae	< 90 but usually < 30	< 30 but usually < 10
Taenia saginata eggs	Many months	< 60 but usually < 30
Trichuris trichiura eggs	Many months	< 60 but usually < 30

[a]Includes poliovirus, echovirus, and coxsackievirus.

From Feachem et al. (1983), reproduced by permission of the World Bank.

Source: Mara/Cairncross 1989

Table 3-26

Table 3.18 Survival of pathogens in soils[a] and crops[b]

Organism	Survival time in soils (days)	Survival on crops (days)
Coliforms	38	< 30 (< 15)[c]
Streptococci	35–63	
Fecal streptococci	26–77	
Salmonellae	15–> 280	< 30 (< 15)
Shigella spp.	—	10 (< 5)
Vibrio cholerae	—	5 (< 2)
Salmonella typhi	1–120	
Tubercle bacilli	> 180	
Leptospira	15–43	
Entamoeba histolytica cysts	6–8	< 10 (< 2)
Enteroviruses	8–175	< 60
Ascaris ova	Up to 7 years	
Hookworm larvae	42	< 60 (< 30)
Brucella abortus	30–125	
Q-fever organisms	148	

Source: Feigin et al. 1991

Table 3-27

Survival times of excreted pathogens in feces, night soil, and sludge at 20-30° C

Pathogen	Survival time (days)
Viruses	
Enteroviruses*/	<100 but usually <20
Bacteria	
Fecal coliforms	< 90 but usually <50
Salmonella spp.	< 60 but usually <30
Shigella spp.	< 30 but usually <10
Vibrio cholerae	< 30 but usually < 5
Protozoa	
Entamoeba histolytica cysts	< 30 but usually <15
Helminths	
Ascaris lumbricoides eggs	Many months

*/ Includes polio-, echo-, and coxsackieviruses.

Table 3-28

Survival times of excreted pathogens in freshwater and sewage at 20-30° C

Pathogen	Survival time (days)
Viruses[a]/	
Enteroviruses[b]/	<120 but usually <50
Bacteria	
Fecal coliforms[a]/	< 60 but usually <30
Salmonella spp.[a]/	< 60 but usually <30
Shigella spp.[a]/	< 30 but usually <10
Vibrio cholerae[c]/	< 30 but usually <10
Protozoa	
Entamoeba histolytica cysts	< 30 but usually <15
Helminths	
Ascaris lumbriocoides eggs	Many months

a. In seawater, viral survival is less, and bacterial survival is very much less than in freshwater.
b. Includes polio-, echo-, and coxsackieviruses.
c. V. cholerae survival in aqueous environments is still uncertain.

Table 3-29

Factors affecting survival time of enteric bacteria in soil

Soil factor	Effect on bacterial survival
Antagonism from soil microflora	Increased survival time in sterile soil
Moisture content	Greater survival time in moist soils and during times of high rainfall
Moisture-holding capacity	Survival time is less in sandy soils than in soils with greater water-holding capacity
Organic matter	Increased survival and possible regrowth when sufficient amounts of organic matter are present
pH	Shorter survival time in acid soils (pH 3-5) than in alkaline soils
Sunlight	Shorter survival time at soil surface
Temperature	Longer survival at low temperatures; longer survival in winter than in summer

Source: Adapted from Gerba, Wallis, and Melnick (1975).

Sources: Shuval et al. 1986

Table 3-30

Table 1. Relative stability of pesticides in flooded and nonflooded soils.

Pesticide	Concentration (ppm)	Soil samples	Time (days) for 50% disappearance	
			Flooded	Nonflooded
Insecticides				
BHC (γ–, α–, β–, δ–)	5	4	20	No degradation in 28 days[a]
DDT	20	4	10–45	No degradation in 28 days[b]
Methoxychlor	30	4	5–40	90[b]
Heptachlor	15	4	15–86	90[b]
Chlordane	15	4	No degradation in 90 days	No degradation in 90 days[b]
Dieldrin	15	4	No degradation in 90 days	No degradation in 90 days[b]
Endrin	20	1	8	No degradation in 60 days[b]
	20	3	No degradation in 60 days	No degradation in 60 days[b]
	—	8	<25	>55[c]
Aldrin	20	4	60	35–50[b]
Parathion	50	4	2–9	No degradation in 15 days[d]
Diazinon	10	3	15	35[e]
Isoxathion	30	1	<20	40[f]
Carbofuran	30	1	20	95[g]
Sevin	30	2	13	27[h]
Herbicides				
PCP	100	7	30	50[i]
Nitrofen	10	5	11	50[i]
CNP	10	5	15	50[i]
Chlomethoxynil	10	5	15	50[i]
Benthiocarb	20	5	30–60	10–26[i, j, k]
Swep	5	5	7	2[i]
Propenil	1	1	1	1[i]
Picloram	1	2	60–180	90–180[l]
2, 4, 5-T	10	1	45	30[l]
	10	1	17	84[l]
2, 4-D	20	1	28	9[l]
	20	1	36	36[l]
Amiprophos	—	1	10	80[m]
Trifluralin	1.3	1	3–10	150[n]
Benefin	2.3	1	4	40[o]
Fungicides				
PCNB	100	3	20	No degradation in 60 days[b]
DCNA	100	3	5–30	No degradation in 60 days[p]
Hinosan	50	1	4	10[q]
Kitazin P	10	1	14	10[r]

[a]Yoshida and Castro, 1970. [b]Castro and Yoshida, 1971. [c]Gowda and Sethunathan, 1976. [d]Sethunathan and Yoshida, 1973c. [e]Sethunathan, unpublished data, 1971. [f]Nakagawa et al., 1975. [g]Venkateswarlu et al., 1977. [h]Venkateswarlu and Sethunathan, unpublished data, 1977. [i]Matsunaka and Kuwatsuka, 1975. [j]Chen et al., 1976. [k]Ishikawa et al., 1976. [l]Yoshida, 1975b. [m]Tomizawa, 1975. [n]Probst et al., 1967. [o]Probst and Tepe, 1969. [p]Wang and Broadbent, 1973. [q]Rajaram and Sethunathan, 1976. [r]Tomizawa et al., 1976.

Tab. 10: Nettoprimärproduktion von Teilökosystemen in g C (Annahme: 1 g C = 2 g Trocken-Biomasse). Nach Lieth, Whittaker u. Likens, Likens, Wetzel u. a., in: Riepl

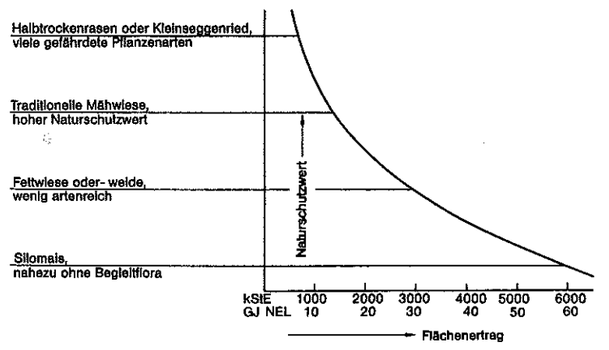
Ökosystem	Produktivität in $g\,C \cdot m^{-2} \cdot Jahr^{-1}$	Flächenausdehnung in %	% der Erdproduktion
Erde total	ca. 150–180	100 %	100%
marine Ökosysteme	Ø ca. 75	71 %	32– 35%
offener Ozean	1– 200	65 %	
Auftriebsgebiete	200– 500	0,1%	
Kontinentalsockel	100– 300	5 %	
Korallenriffe usw.	250–2000	0,1%	
Flußmündungsgebiete	100–1750	0,3%	
terrestrische Ökosysteme	Ø ca. 370–400	27 %	61– 67%
Gletscher, Kältewüsten, Trockenwüsten	0– 5	4,5%	
Tundra	5– 200	1,5%	
Halbwüsten, Buschwüsten	5– 125	3,3%	
borealer Nadelwald	100– 750	2,2%	
sommergrüner gemäßigter Laubmischwald	200–1250	1,3%	
warmtemperierter Mischwald	300–1250	0,9%	
Hartlaubwald, Trockenbüsche, Waldsteppen	125– 750	1,6%	
tropisches Grasland (Steppen u. Savannen)	100–1000	2,8%	
warmgemäßigtes Grasland (Steppen, Wiesen)	100– 750	1,7%	
regengrüne Monsunwälder	300–1750	1,4%	
tropische Regenwälder	500–1750	3,2%	
→ Kulturland	50–3500	2,6%	
limnische Ökosysteme	Ø ca. 125	4,0 %	2,7–3,2%
Flüsse und Seen	1–2500	2,0%	0,3–0,6%
Sümpfe und Marschen	400–1750	2,0%	2,4–2,6%

(R1.11) Durch Landwirtschaft ist die für den Menschen verfügbare Erntemenge pro Fläche stark erhöht worden. Gegenüber der Sammlerkultur hat sie sich etwa vertausendfacht.

	Ernteertrag $kJ/m^2 \cdot a$	erford.Fläche m^2/Mensch
Sammlerkultur	1 - 40	400000
Landwirtsch. ohne Energiezufuhr	100 - 4000	4000
Getreideanbau mit Energiezufuhr	4000 - 40000	400
Algenkulturen mit Energiezufuhr	40000 - 160000	40

Source: Boesel 1990

Figur 4-1c



Source: Hampicke 1991

Table 4-1a

Abb. 22. Zusammenhang zwischen Flächenertrag und Naturschutzwert beim Rauhfutterbau.
Quelle: Hampicke 1988, Abb. 3, p. 14. kStE (Kilo-Stärkeeinheit, in der Rindermast gültig) und GJ NEL (Gigajoule Nettoenergie Laktation in der Milchkuhfütterung) sind Nettoenergiemaße, die auch den Wert des Futters berücksichtigen. Bei gleichem Brennwert enthält 1 kg gutes Heu mehr kStE bzw. GJ NEL als 1 kg schlechtes Heu.

Source: Kinzelbach 1989

Figur 4-1 b

Table 4-2

Table 4: The impact of dams on fish, pasture, and agriculture production on African floodplains

Floodplain	Area in 1960 (ha)	Area remaining in 2020 (ha)	Expected loss of production
Senegal delta	300,000	30,000	90%
Senegal valley	550,000	55,000	90%
Niger delta	3,000,000	2,700,000	10%
Niger valley	300,000	150,000	50%
Sokoto and Rima	100,000	50,000	50%
Hadejia Komadugu	380,000	38,000	90%
Logone	1,100,000	660,000	60%

Source: Dugan 1990 *(Modified after Drijver & Rodenburg, 1988)*

Table 4-3

Übersicht 7. Ursachen und Verursacher des Rückgangs von Pflanzenarten der Roten Liste in der Bundesrepublik Deutschland

Verursacher (Landnutzer und Wirtschaftszweige)	Zahl der betroffenen Pflanzenarten*
Landwirtschaft	513
Forstwirtschaft und Jagd	338
Tourismus und Erholung	161
Rohstoffgewinnung und Kleintagebau	158
Gewerbe, Siedlung, Industrie	155
Wasserwirtschaft	112
Teichwirtschaft	79
Verkehr, Transport	71
Abfall- und Abwasserbeseitigung	71
Militär	53
Wissenschaft, Bildung, Kultus	40
Lebensmittel- und pharmazeutische Industrie	8

Ursachen (Ökofaktoren)	Zahl der betroffenen Pflanzenarten*
Änderung der Nutzung	305
Aufgabe der Nutzung	284
Beseitigung von Sonderstandorten	255
Auffüllung, Bebauung	247
Entwässerung	201
Bodeneutrophierung	176
Abbau und Abgrabung	163
Mechanische Einwirkungen	123
Entkrautung, Rodung, Brand u. a.	115
Sammeln	103
Gewässerausbau und -unterhaltung	68
Aufhören von Bodenverwundungen	59
Einführung von Exoten	43
Luft- und Bodenverunreinigung	38
Gewässereutrophierung	36
Gewässerverunreinigung	35
Schaffung künstlicher Gewässer	27
Herbizidanwendung, Saatgutreinigung	26
Verstädterung von Dörfern	22
Aufgabe bestimmter Feldfrüchte	8

Source: Hampicke 1991

Table 4-5

Table 6: Principal threats to protected wetlands in Asia.

Threat	Incidence (% of sites)
Illegal hunting	48
Drainage or conversion of land for agricultural purposes and human settlement	45
Illegal fishing and/or overfishing	32
Cutting of wood for domestic purposes	29
Pollution from domestic sewage, industrial waste, pesticides and fertilizers	26
Overgrazing by domestic livestock	23
Commercial logging	19
Cutting of aquatic vegetation for fodder, fuel etc.	15
Harvesting of eggs of waterbirds and/or reptiles	15
Eutrophication	12

Source: Data are taken from 69 protected Asian wetlands of international importance considered to be under moderate to severe threat (modified from Scott and Poole, 1989).

Dugan 1990

Table 4-6

Table 5: Examples of Threats to Protected Wetlands

Threat	Example
Groundwater abstraction	The Tablas de Daimiel National Park (Spain) has for several years experienced an acute shortage of water caused in large part by use of groundwater for irrigated agriculture in the surrounding land (Llamas, 1988).
Dams	In Tunisia, the water supply of Lac Ichkeul, a Ramsar and World Heritage site, has been reduced through dam construction in the catchment (Hollis, 1988)
Pollution	In Brazil, gold mining in the basin of the Paraguay river has resulted in severe mercury pollution of the waters of the Pantanal.
	The delicately poised wetland ecosystems of Everglades National Park are threatened by nutrient runoff from peatland converted to agriculture and by altered water flows into the Park.
Siltation	The wetlands of Gonarezhou National Park in Zimbabwe are subject to silting and pollution because of agricultural activities in the basin of the Lundi and Sabi rivers which feed the park (IUCN/UNEP, 1987).
Drainage	In Uruguay, approximately one third of the Bañados del Este, a Ramsar site and Unesco Biosphere Reserve, has been drained for agriculture.

Source: Dugan 1990

Table 4-7

Table 3. Productivity per 100m³ of water for a natural floodplain (inner delta of the Niger) and an irrigated rice scheme (Office du Niger)[1]

	Niger inner delta					Office du Niger	
	Meat	Milk	Fish	Rice	Total	Rice	Total
Total weight (t)	10	118	100	78		100	
Weight/100m³ (g)	44	506	427	235		5 003	
Value/100m³ ($)	0.02	0.20	0.17	0.03	0.42	0.55	0.55
Protein/100m³ (g)	8	17	77	18	119	190	
Energy/100m³ (kcal)	83	318	401	853	1 656	13 749	
Inputs/100m³ ($)						0.12	
Fertilizer	0	0	0	0	0.01		
Management	0	0	Very small		0.08		
Oxen etc.	0	0	Very small		0.03		
Profit margin per 100m³ ($)					0.42		0.43
Loss of interest per 100m³ ($)					0.00		1.08
Net profit per 100m³ ($)					+ 0.42		− 0.65

1. The assumptions underlying this table are detailed in Drijver and Marchand, 1985.
Source: Drijver and Marchand, 1985.

Source: Hoolis et al. 1988

Table 4-8

Table 2. Wetland functions and their human utilization

Role	Elements	Function	Importance to humankind	Unwise use
Store/sink	Rare, threatened or endangered plant and animal species and communities	Genetic diversity Recolonization source	Gene pool Science/education Tourism Recreation Heritage	Excessive or uncontrolled harvest Damage removal or pollution
	Representative plant and/or animal communities	Ecological diversity Habitat maintenance	Gene pool Science/education Tourism Recreation Heritage	Excessive or uncontrolled harvest Damage removal or pollution
	Peat	Nutrient, contaminant and energy store Habitat support Water storage	Fuel, Palaeo-environmental data Horticultural use Heritage Medicinal products	Drainage Harvest faster than accumulation Destruction
	Human habitation sites	Archaeological remains	Heritage/cultural Scientific Recreation	Destruction Lowering the water-table
Pathway	Terrestrial nutrients, water and detritus	Food chain support Habitat support	Food production Water supply Waste disposal	Interruption or abnormal change of flows Pollution
	Tidal exchanges of water detritus and nutrients	Food chain support Habitat support Nursery for aquatic organisms	Fish, shellfish and other food production Waste disposal	Pollution Barriers to flow Dredge and fill
	Animal populations	Support for migratory species including fish	Harvest Recreation Science	Overexploitation Interruption of migration routes Obstruction Habitat degradation
	Lakes and rivers	Waterways	Navigation	Obstruction Reduced flows and levels
Buffer	Water bodies, vegetation, soils and depressions	Flood attenuation	Reduced damage to property and crops	Filling and reduction of storage capacity
	Water bodies, vegetation, soils and depressions	Detention and retention of nutrients	Food production Improved water quality	Removal of vegetation Drainage and flood protection
	Water bodies, vegetation, soils and depressions	Groundwater recharge and discharge	Water supply Habitat maintenance Effluent dilution River fisheries Navigation	Reduction of recharge Overpumping Pollution
	Water bodies and peat	Local and global climate stabilization	Equable climate for agriculture and people	Desiccation
	Water bodies	Large volume Large area	Cooling water	Drainage Filling Thermal pollution
Producer	Production of plants	Food, materials and habitat for migratory species and grazing animals	Harvest of timber, thatch fuel and food Science Recreation	Overgrazing Overexploitation Drainage Excess change to dry land or other agricultural uses
	Animal production	Fish, shellfish, grazing and fur-bearing animals	Harvest and farming	Overexploitation Excess change Habitat degradation
	Organic matter	Methane production Nutrient cycling	Fuel Plant growth	Drainage Desiccation
Sink	Lakes, deltas floodplains	Sediment deposition and detention	Raised soil fertility Clean downstream channels Improved water quality downstream	Channelization Excess reduction of sediment throughout
	Lakes, swamps and marshes	Bio-chemical self-purification Nutrient accumulation	Natural filter for contaminants Treatment of organic wastes, pathogens and effluents	Destruction of the ecosystem Over-loading of the system

Source: Hollis et al., 1987.

Source: Hollis et al. 1988

Table 15.40 Contribution of tropical areas to the global flux (10^{12} g/yr) of CH_4, N_2O, H_2, and CO between different ecosystems and the atmosphere (After Seiler and Conrad, 1985)

Table 5-1

	Total	Tropical areas
CH_4 emission by rice paddies	70–170	67–162
CH_4 emission by wetlands	11–57	9–46
CH_4 emission by ruminants	72–99	20–50
CH_4 emission by termites	2–5	2–5
CH_4 emission by biomass burning	53–97	42–78
CH_4 uptake by soils	32	25
N_2O emission from soils	4.5–17	3–15
N_2O emission from fertilized rice paddies	<0.1	<0.1
H_2 uptake by soils	70–110	30–40
CO uptake by soils	190–580	70–40
CO emission by plants	50–100	40–75
CO production by photochemical oxidation of CH_4 and NMHC	700–2200	560–1800

Source: Lal ed. 1991

Table 5-2

Table 15.39 Global production rates (10^{12} g/yr) of individual sources for atmospheric CH_4 (After Seiler and Conrad, 1985)

	1950	1960	1970	1975
Sources				
Ruminants	49 – 69	56 – 81	65 – 92	72 – 99
Paddy fields	43 – 106	56 – 135	65 – 158	69 – 167
Swamps	11 – 57	11 – 57	11 – 57	11 – 57
Other biogenic sources	8 – 20	8 – 21	9 – 22	9 – 22
Biomass burning	41 – 74	47 – 84	51 – 91	53 – 97
Leakage of natural gas	3 – 4	7 – 10	14 – 20	19 – 29
Coal mining	20	24	28	30
Other nonbiogenic sources	1	1	1	1 – 2
Total production	176 – 351	210 – 413	244 – 469	264 – 503
Sinks				
Reaction with OH	210	230	270	290
Flux into stratosphere	44	48	56	60
Soils	24	26	30	32
Total decomposition	278	304	356	382

Source: Lal ed. 1991

Table 5-3

Table 1. Atmospheric concentrations, increase, residence time, sources and sinks for major greenhouse gases, and their contribution to global warming. (adapted from Bouwman, 1990)

	CO_2	CH_4	N_2O	O_3	CFCs
Residence time (yr)	100	8-12	100-200	0.1-0.3	65-110
Annual increase (%)	0.5	1	0.2-0.3	2.0	3.0
Concentration in 1985	345 ppmv	1.70 ppmv	300 ppbv	na	0.18-0.28 ppbv
Radiative absorption per ppm of increase	1	32	150	2000	> 10 000
Contribution (%) to global warming	50	19	4	8	15
Total source	6.5-7.5 Gt C	400-640 Tg CH_4	11-17 Tg N	–	–
Biotic sources (%)	20-30	70-90	90-100	–	–
Major sources (in Gt or Tg)	fossil fuel (5.7), deforestation (1-2)	paddies (60-140) wetlands (40-160) ruminants (65-100) termites (10-100) landfill sites (30-70) oceans/lakes (15-25) biomass burning (50-100) fossil fuel (50-95)	cultivated soils (3?) natural soils (?) fossil fuel (?)	atmospheric	manmade
Sinks (in Gt or Tg)	atmosph. accum. (3.5) oceans (< 1), biosphere (?), charcoal formation (?)	atmosph. accum. (50) soil oxidation (32) atmosph. chemistry (300-650)	atmosph. accum. (2.8) atmosph. chemistry (10.5) soils (?)	atmosph. accum. atmosph. chemistry	atmosph. accum. atmosph. chemistry

Source: from Scharpenseel ed. 1990

Table 5-4

Tabelle 6/2
Zeitliche Veränderungen verschiedener Merkmale im überfluteten Reisboden (nach TAKAI u. a., 1956)

Merkmal bzw. Größe	Inkubationsdauer (in Tagen)				
	0	2	8	13	21
Ionisiertes Fe (mg/100 g)	0	20	103	114	95
Fe^{++} (% von $Fe^{++} + Fe^{+++}$)	43	59	76	84	78
Aerobe Bakterien (in 1000/g)	34	110	53	62	65
Anaerobe Bakterien (1000/g)	22	23	170	130	45
Sulfatreduz. Bakterien (1000/g)	0,3	1,3	1,8	4,8	2,3
S'' (mg/100 g)	0,2	0,2	2,8	12,5	16,2
NO_3-N (mg/100 g)	0,5	0	0	0	0
NH_4-N (mg/100 g)	0,4	3,4	7,8	8,8	9,6
Gaszusammensetzung (ml/25 g)					
O_2	0,80	0	0	0	0
N_2	2,17	2,00	2,29	4,50	3,37
CH_4	0	0	3,67	12,40	15,07
H_2	0	0,01	0,53	2,96	3,30
CO_2	20,9	43,0	56,4	56,6	50,3

Source: Pagel 1981

Table 5-5

TABLE 25.2 Production of hydrocarbons during first week of waterlogging soils. Production in μ g/kg soil

Soil	*% organic matter*	CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8
Sand	1·4	0·3	0·6	0·1	0·1	1·7
Sandy loam	3·9	3·1	5·5	0·5	1·0	1·6
Gault clay	5·0	12·5	7·6	0·6	1·0	1·6
Loam from basalt	9·8	17·9	13·3	0·5	1·2	1·7

Source: Russel 1973

Table 5-6

TABLE 25.3 The redox potentials associated with the production of different reduced substances in waterlogged soils

Chemical transformation	E_h *(at pH 7) in volts*	
	From	*To*
Disappearance of molecular oxygen	0·6	0·5
Disappearance of nitrates	0·6	0·5
Formation of Mn^{2+}	0·6	0·4
Formation of Fe^{2+}	0·5	0·3
Formation of sulphide	0·0	−0·19
Formation of hydrogen gas	−0·15	−0·22
Formation of methane	−0·15	−0·19

Russel 1973

Table 8-1

Table 8.2 Environmental classification of water-related infections

Category	Infection	Pathogenic agent
1. Faecal–oral (water-borne or water-washed)	Diarrhoeas and dysenteries	
	amoebic dysentery	P
	balantidiasis	P
	Campylobacter enteritis	B
	cholera	B
	E. coli diarrhoea	B
	giardiasis	P
	rotavirus diarrhoea	V
	salmoneilosis	B
	shigellosis (bacillary dysentery)	B
	yersiniosis	B
	Enteric fevers	
	typhoid	B
	paratyphoid	B
	Poliomyelitis	V
	Hepatitis A	V
	Leptospirosis	S
	Ascariasis	H
	Trichuriasis	H
2. Water-washed:		
(a) skin and eye infections	Infectious skin diseases	M
	Infectious eye diseases	M
(b) other	Louse-borne typhus	R
	Louse-borne relapsing fever	S
3. Water-based:		
(a) penetrating skin	Schistosomiasis	H
(b) ingested	Guinea worm	H
	Clonorchiasis	H
	Diphyllobothriasis	H
	Fasciolopsiasis	H
	Paragonimiasis	H
	Others	H
4. Water-related insect vector		
(a) biting near water	Sleeping sickness	P
(b) breeding in water	Filariasis	H
	Malaria	P
	River blindness	H
	Mosquito-borne viruses	
	yellow fever	V
	dengue	V
	others	V

B = bacterium
H = helminth
P = protozoon
M = miscellaneous
R = rickettsia
S = spirochaete
V = virus

Source: Hillman in Rydzewski ed. 1987

Table 8-2

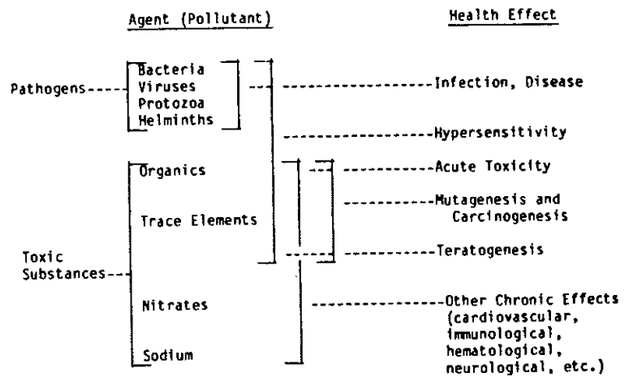


Fig. 3.24 Major health effect of pollutants (Kowal 1983)

Source: Feigin et al. 1991

Table 8-3

Table 4.1 Environmental classification of excreted infections

Category and epidemiological features	Infection	Environmental transmission focus	Major control measure
I. Non-latent; low infective dose	Amoebiasis Balantidiasis Enterobiasis Enteroviral infections Giardiasis Hymenolepiasis Hepatitis A Rotavirus infection	Personal Domestic	Domestic water supply Health education Improved housing Provision of toilets
II. Non-latent; medium or high infective dose; moderately persistent; able to multiply	*Campylobacter* infection Cholera Pathogenic *Escherichia coli* infection Salmonellosis Shigellosis Typhoid Yersiniosis	Personal Domestic Water Crop	Domestic water supply Health education Improved housing Provision of toilets Treatment of excreta before discharge or reuse
III. Latent and persistent; no intermediate host	Ascariasis Hookworm infection Strongyloidiasis Trichuriasis	Yard Field Crop	Provision of toilets Treatment of excreta before land application
IV. Latent and persistent; cow or pig as intermediate host	Taeniasis	Yard Field Fodder	Provisions of toilets Treatment of excreta before land application Cooking, meat inspection
V. Latent and persistent; aquatic intermediate hosts(s)	Clonorchiasis Diphyllobothriasis Fascioliasis Fasciolopsiasis Gastrodiscoidiasis Heterophyiasis Metagonimiasis Opisthorchiasis Paragonimiasis Schistosomiasis	Water	Provision of toilets Treatment of excreta before discharge Control of animal reservoirs Control of intermediate hosts Cooking of water plants and fish Reducing water contact

Source: Feachem et al. (1983).

Source: Mara/Cairncross 1989

TABLE 2-13

Basic epidemiological features of excreted pathogens by environmental category

Pathogen	Excreted load[a]	Latency[b]	Persistence[c]	Multiplication outside human host	Median infective dose (ID_{50})	Significant immunity?	Major nonhuman reservoir?	Intermediate host
CATEGORY I								
Enteroviruses[d]	10^7	0	3 months	No	L	Yes	No	None
Hepatitis A virus	10^6 (?)	0	?	NO	L(?)	Yes	No	None
Rotavirus	10^6 (?)	0	?	No	L(?)	Yes	No(?)	None
Balantidium coli	?	0	?	No	L(?)	No(?)	Yes	None
Entamoeba histolytica	10^5	0	25 days	No	L	No(?)	No	None
Giardia lamblia	10^5	0	25 days	No	L	No(?)	Yes	None
Enterobius vermicularis	Not usually found in feces	0	7 days	No	L	No	No	None
Hymenolepis nana	?	0	1 month	No	L	Yes(?)	No(?)	None
CATEGORY II								
Campylobacter fetus ssp. jejuni	10^7	0	7 days	Yes[e]	H(?)	?	Yes	None
Pathogenic Escherichia coli[f]	10^8	0	3 months	Yes	H	Yes(?)	No(?)	None
Salmonella								
S. typhi	10^8	0	2 months	Yes[e]	H	Yes	No	None
Other salmonellae	10^8	0	3 months	Yes[e]	H	No	Yes	None
Shigella spp.	10^7	0	1 month	Yes[e]	H	No	No	None
Vibrio cholerae	10^7	0	1 month(?)	Yes	H	Yes(?)	No	None
Yersinia enterocolitica	10^5	0	3 months(?)	Yes	H(?)	No	Yes	None
CATEGORY III								
Ascaris lumbricoides	10^4	10 days	1 year	No	L	No	No	None
Hookworms[g]	10^2	7 days	3 months	No	L	No	No	None
Strongyloides stercoralis	10	3 days	3 weeks (free-living stage much longer)	Yes	L	Yes	No	None
Trichuris trichiura	10^3	20 days	9 months	No	L	No	No	None
CATEGORY IV								
Taenia saginata and T. solium[i]	10^4	2 months	9 months	No	L	No	No	Cow (T.saginata) or pig (T.solium)
CATEGORY V								
Clonorchis sinensis[j]	10^2	6 weeks	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Diphyllobothrium latum[j]	10^4	2 months	Life of fish	No	L	No	Yes	Copepod and fish
Fasciola hepatica[h]	?	2 months	4 months	Yes[j]	L	No	Yes	Snail and aquatic plant
Fasciolopsis buski[h]	10^3	2 months	?	Yes[j]	L	No	Yes	Snail and aquatic plant
Gastrodiscoides hominis[h]	?	2 months(?)	?	Yes[j]	L	No	Yes	Snail and aquatic plant
Heterophyes heterophyes[j]	?	6 weeks	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Metagonimus yokogawai[j]	?	6 weeks(?)	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Paragonimus westermani[j]	?	4 months	Life of crab	Yes[j]	L	No	Yes	Snail and crab or crayfish
Schistosoma S.haematobium[h]	4 per milliliter of urine	5 weeks	2 days	Yes[j]	L	Yes	No	Snail
S.japonicum[h]	40	7 weeks	2 days	Yes[j]	L	Yes	Yes	Snail
S.mansoni[h]	40	4 weeks	2 days	Yes[j]	L	?	No	Snail
Leptospira spp.[k]	urine(?)	0	7 days	No	L	Yes(?)	Yes	None

Note: L Low ($\leq 10^2$); M medium ($= 10^4$); H high ($\geq 10^6$).
? Uncertain.

a. Typical average number of organisms per gram of feces (except for Schistosoma haematobium and Leptospira, which occur in urine).
b. Typical minimum time from excretion to infectivity.
c. Estimated maximum life of infective stage at 20°-30° C.
d. Includes polio-, echo-, and coxsackieviruses.
e. Multiplication takes place predominantly on food.
f. Includes enterotoxigenic, enteroinvasive, and enterophathogenic E. coli.
g. Ancylostoma duodenale and Necator americanus.
h. Latency is minimum time from excretion by man to potential reinfection of man. Persistence here refers to maximum survival time of final infective stage. Life cycle involves one intermediate host.
i. Latency and persistence as for Taenia. Life cycle involves two intermediate hosts.
j. Multiplication takes place in intermediate snail host.
k. For the reasons given in Chapter 1, Leptospira spp. do not fit any of the categories defined in Table 2-2.

Source: Suval et al. 1986

TABLE 2-4

Helminthic pathogens excreted in feces

Helminth	Common name	Disease	Transmission	Distribution
Ancylostoma duodenale	Hookworm	Hookworm	Man -> soil -> man	Mainly in warm wet climates
Ascaris lumbricoides	Roundworm	Ascariasis	Man -> soil -> man	Worldwide
Clonorchis sinensis	Chinese liver fluke	Clonorchiasis	Man or animal -> aquatic snail -> fish -> man	Southeast Asia
Diphyllobothrium latum	Fish tapeworm	Diphyllobothriasis	Man or animal -> copepod -> fish -> man	Widely distributed, mainly in temperate regions
Enterobius vermicularis	Pinworm	Enterobiasis	Man -> man	Worldwide
Fasciola hepatica	Sheep liver fluke	Fascioliasis	Sheep -> aquatic snail -> aquatic vegetation -> man	Worldwide in sheep- and cattle-raising areas
Fasciolopsis buski	Giant intestinal fluke	Fasciolopsiasis	Man or pig -> aquatic snail -> aquatic vegetation -> man	Southeast Asia, mainly China
Gastrodiscoides hominis	n.a.	Gastrodiscoidiasis	Pig -> aquatic snail -> aquatic vegetation -> man	India, Bangladesh, Vietnam, Philippines
Heterophyes heterophyes	n.a.	Heterophyiasis	Dog or cat -> brackish water snail -> brackish-water fish -> man	Middle East, southern Europe, Asia
Hymenolepis nana	Dwarf tapeworm	Hymenolepiasis	Man or rodent -> man	Worldwide
Metagonimus yokogawai	n.a.	Metagonimiasis	Dog or cat -> aquatic snail -> freshwater fish -> man	East Asia, Siberia (USSR)
Necator americanus	Hookworm	Hookworm	Man -> soil -> man	Mainly in warm wet climates
Opisthorchis felineus	Cat liver fluke	Opisthorchiasis	Cat or man -> aquatic snail -> fish -> man	USSR, Thailand
O. viverrini *Paragonimus westermani*	n.a. Lung fluke	Paragonimiasis	Pig, man, dog, cat, or other animal -> aquatic snail -> crab or crayfish -> man	Southeast Asia, scattered foci in Africa and South America
Schistosoma haematobium	Schistosome	Schistosomiasis; bilharziasis	Man -> aquatic snail -> man	Africa, Middle East, India
S. japonicum			Animals and man -> snail -> man	Southeast Asia
S. mansoni			Man -> aquatic snail -> man	Africa, Middle East, Central and South America
Strongyloides stercoralis	Threadworm	Strongyloidiasis	Man -> man	Mainly in warm wet climates
Taenia saginata	Beef tapeworm	Taeniasis	Man -> cow -> man	Worldwide
T. solium	Pork tapeworm	Taeniasis	Man -> pig (or man) -> man	Worldwide
Trichuris trichiura	Whipworm	Trichuriasis	Man -> soil -> man	Worldwide

n.a. Not applicable.

Table 8-5 a

Viral pathogens excreted in feces

Virus	Disease	Can symptomless infections occur?	Reservoir
Adenoviruses	Numerous conditions	Yes	Man
Enteroviruses			
Polioviruses	Poliomyelitis, paralysis, and other conditions	Yes	Man
Echoviruses	Numerous conditions	Yes	Man
Coxsackieviruses	Numerous conditions	Yes	Man
Hepatitis A virus	Infectious hepatitis	Yes	Man
Reoviruses	Numerous conditions	Yes	Man and animals
Rotaviruses, Norwalk agent, and other viruses	Diarrhea	Yes	Probably man

Table 8-5 b

Source: Shuval et al. 1986

Bacterial pathogens excreted in feces

Table 8-5 c

Bacterium	Disease	Can symptomless infection occur?	Reservoir
Campylobacter fetus ssp. jejuni	Diarrhea	Yes	Animals & man
Pathogenic Escherichia coli[a/]	Diarrhea	Yes	Man[b/]
Salmonella			
S. typhi	Typhoid fever	Yes	Man
S. paratyphi	Paratyphoid fever	Yes	Man
Other salmonellae	Food poisoning and other salmonelloses	Yes	Animals & man
Shigella spp.	Bacillary dysentery	Yes	Man
Vibrio			
V. cholerae	Cholera	Yes	Man
Other vibrios	Diarrhea	Yes	Man
Yersinia enterocolitica	Diarrhea and septicemia	Yes	Animals & man[c/]

a. Includes enterotoxigenic, enteroinvasive, and enteropathogenic E. coli.
b. Although many animals are infected by pathogenic E. coli, each serotype is more or less specific to a particular animal host.
c. Of the thirty or more serotypes identified so far, a number seem to be associated with particular animal species. There is at present insufficient epidemiological and serological evidence to determine whether distinct serotypes are specific to primates.

TABLE 2-3

Protozoal pathogens excreted in feces

Table 8-5 d

Protozoon	Disease	Can symptomless infection occur?	Reservoir
Balentidium coli	Diarrhea, dysentery, and colonic ulceration	Yes	Man & animals (especially pigs and rats)
Entamoeba histolytica	Colonic ulceration, amoebic dysentery, and liver abscess	Yes	Man
Giardia lamblia	Diarrhea and malabsorption	Yes	Man and animals

Source: Feachem et al. (1983).

Sources: Shuval et al. 1986

Table 2.11 Water-borne pathogens and their effect on health (Cowan and Johnson 1984)

Table 8-6

Group	Genus	Effects on human health
Bacteria	*Salmonella*	Typhoid fever, paratyphoid fever, enteritis, salmonellosis, food poisoning
	Shigella	Dysentery
	Escherichia	Enteritis (pathogenic strains)
	Vibrio	Cholera, enteritis, food poisoning
	Clostridium	Gas gangrene, tetanus, botulism, food poisoning
	Leptospira	Leptospirosis
	Mycobacterium	Tuberculosis, skin granuloma
Viruses	Poliovirus	Fever, poliomyelitis, enteritis
	Coxsackievirus A	Headache, muscular pain
	Coxsackievirus B	Nausea, meningitis
	Echovirus	Diarrhoea, hepatitis
	Adenovirus	Fever, respiratory infection, enteritis, inflammation of the eyes (conjunctivitis), involvement of central nervous system
	Reovirus	Common cold, respiratory tract infections, diarrhoea, hepatitis
	Hepatitis A virus	Infectious hepatitis (fever, nausea, jaundice)
Protozoa	*Entamoeba*	Amoebic dysentery
	Giardia	Giardiasis
Helminths Trematodes	*Schistosoma*	Schistosomiasis (Bilharzia)
Cestodes	*Taenia*	Tapeworm infestation in man, in cattle eating eggs (*T. saginata* or *T. solium*, respectively), eggs develop into the Cysticerus stage
Nematodes	Ascaris	Roundworm infestation
	Anchylostomum	Hook worm infestation
	Heterodera	Potato cyst eelworm

Source: Feigin et al. 1991

Table 8-7

Figure 4.1 Pathogen-host properties influencing the sequence of events between the presence of a pathogen in excreta or wastewater and measurable human disease attributable to excreta or wastewater use

EXCRETED LOAD

- latency
- multiplication
- persistence
- treatment survival

INFECTIVE DOSE APPLIED TO LAND/WATER

- persistence
- intermediate host
- type of use practice
- type of human exposure

INFECTIVE DOSE REACHES HUMAN HOST

- human behaviour
- pattern of human immunity

RISKS OF INFECTION AND DISEASE

- alternative routes of transmission

PUBLIC HEALTH IMPORTANCE OF EXCRETA AND WASTEWATER USE

From Blum & Feachem (1985), reproduced by permission of the International Reference Centre for Waste Disposal.

Source: Mara/Caircross 1989

Table 8-8

TABLE 2-14

Epidemiological characteristics of enteric pathogens vis-à-vis their effectiveness in causing infections through wastewater irrigation

Pathogen	Persistence in environment	Minimum infective dose	Immunity	Concurrent routes of infection	Latency soil development stage
Viruses	Medium	Low	Long	Mainly home contact and food and water	No
Bacteria	Short/medium	Medium/high	Short/medium	Mainly home contact and food and water	No
Protozoa	Short	Low/medium	None/little	Mainly home contact and food and water	No
Helminths	Long	Low	None/little	Mainly soil contact outside home and food	Yes

Source: Shuval et al. 1986

Table 8-9

Table 8.1 Examples of increased prevalence of schistosomiasis resulting from water resource development projects

Country	Project (year completed)	Preproject prevalence (%)	Postproject prevalence (%)	Schistosome species
Egypt[a]	Aswan dam (first) (1906)	6	60 (3 yr later)	*S. haematobium*, *S. mansoni*
Sudan[b]	Gezira scheme (1925)	0	30–60 (15 yr later)	*S. haematobium*, *S. mansoni*
Tanzania[c]	Arusha Chini (1937)	low	53–86 (30 yr later)	*S. mansoni*
Zambia and Rhodesia[d]	Lake Kariba (1958)	0	16 adults, and 69 children (10 yr later)	*S. haematobium*, *S. mansoni*
Ghana[d]	Volta Lake (1966)	low	90 (2 yr later)	*S. haematobium*
Nigeria[d]	Lake Kainji (1969)	low	31 (1 yr later) 45 (2 yr later)	*S. haematobium*
Iran[e]	Dez pilot irrigation project (1965)	15	27 (2 yr later)	*S. haematobium*

Source: Hillman in Rydzewski ed. 1987

Table 8-10

Table 2.1 Type of vector infection, diseases, and disease organism

Type of vector infection	Disease	Disease organism
Mosquito-borne	Malaria	Protozoon
	Filariasis	Nematode
	Yellow fever	Viruses
	Dengue	(arbo viruses =
	Encephalitis	arthropod-borne
	Other arbo-viral infections	viruses)
Snail-borne	Schistosomiasis (bilharzia)	Trematode
	Clonorchiasis	Trematode
	Opisthorchiasis	Trematode
	Paragoniamiasis	Trematode
	Fascioliasis	Trematode
	Fasciolopsiasis	Trematode
Fly-borne	African trypanosomiasis (sleeping sickness)	Protozoon
	Onchocerciasis (river blindness)	Nematode
	Leishmaniasis (kala azar, oriental sore)	Protozoon
	Loiasis (various types)	Nematode
Miscellaneous		
Water flea	Dracontiasis (guinea worm)	Nematode
Bug	American trypanosomiasis (Chagas' disease)	Protozoon
Louse/tick	Plague, louse-borne fevers, and other fevers (tick-borne, mite-borne)	Bacteria, spirochete, rickettsiae

Source: Oomen et al. 1990

Fact sheet for Schistosomiasis

Common name	Bilharzia
Type of causal organism	Blood fluke, genus *Schistosoma*.
Important species	*Schistosoma haematobium, mansoni* and *japonicum*.
Vector	Aquatic snails mainly of the genera *Bulinus, Biomphalaria* and *Oncomelania*, respectively.
Transmission	Human contact with water containing infective stages which are shed from infected snails. Contact often occurs while bathing.
Environment	Fresh water associated with irrigation schemes, reservoirs and water holes.
Effect on human health	Heavily infected individuals feel unwell and weak and may have seriously diseased liver or bladder.
Diagnosis	Eggs are found in stool (*mansoni* and *japonicum*) and urine (*haematobium*).
Treatment	Effective curative drugs are available.
Economic importance	An estimated 200 million people are infected but heavy infection is patchy. However, both the distribution and the number of heavy infections are increasing.
Vector control	Removal of snail habitats or killing snails with chemicals.
Prevention	Provision of safe water sources and proper sanitation, reduced contamination of water with human faeces and urine, changes in human behaviour.

Fact sheet for Malaria

Type of causal organism	Blood protozoon, genus *Plasmodium*
Important species	*Plasmodium falciparum, vivax, ovale* and *malariae*.
Vector	Mosquitoes of the genus *Anopheles*. There are one or two important species in each region.
Transmission	By the bite of mosquitoes which previously fed on infected humans.
Environment	Within 1-2kms of suitable breeding sites which include a wide variety of relatively clean water, depending on species. The mosquito bites at night.
Effect on human health	Fever and weakness are common. *P falciparum* infection can lead to death if untreated. Partial immunity after long exposure.
Diagnosis	Examination of blood films.
Treatment	Effective prophylactic and curative drugs are available but there is increasing drug resistance.
Economic importance	Many hundreds of millions of people are infected or exposed but partial immunity is widespread. Can seriously undermine development projects, especially when non-immune settlers are involved.
Vector control	Source reduction; residual house spraying; environmental management.
Prevention	Prophylaxis; personal protection using bednets and repellents; vector control.

Fact sheet for Onchocerciasis

Common name	River blindness
Type of causal organism	Filarial worm
Important species	*Onchocerca volvulus*
Vector	Blackflies of the genus *Simulium*. Important species include members of the *Simulium damnosum complex*.
Transmission	By the bite of blackflies which previously fed on infected humans. They bite during the day.
Environment	Within about 10kms of rivers and streams where the flies breed in clean, well aerated, fast flowing water.
Effect on human health	Intense itching, skin changes and swelling with blindness in the later stages.
Diagnosis	Examination of skin snips.
Treatment	Oral administration of a newly developed drug called Ivermectin.
Economic importance	Fear of blindness causes people to leave the river valleys. Severe disability due to blindness.
Vector control	Aerial spraying of breeding sites. Design of spillways and canals to reduce breeding.
Prevention	Repellents; vector control.

Fact sheet for Dengue and Dengue Haemorrhagic Fever

Common name	Dengue and Dengue Haemorrhagic Fever (DHF)
Type of causal organism	Virus
Vector	Mosquitoes of the genus *Aedes*. A common species is *Aedes aegypti*.
Transmission	Human contact with day biting mosquitoes.
Environment	Urban areas, houses and gardens.
Effect on human health	Often affects children. DF is relatively mild but DHF is a serious complication requiring hospitalization and frequently results in death.
Diagnosis	Difficult and specialised.
Treatment	Supportive only.
Economic importance	Increasing numbers of epidemics in many tropical and sub-tropical areas. Great public concern.
Vector control	Destruction or emptying artificial containers twice per week. Insecticidal fogging can be used to halt an epidemic.
Prevention	Vector control.

Fact sheet for Japanese Encephalitis

Common name	J.E.
Type of causal organism	Virus
Vector	Mosquitoes in the genus *Culex*.
Transmission	Bite of mosquito. Animal reservoir in pigs and birds such as herons and egrets.
Environment	Ricefields. Night biting mosquitoes.
Effect on human health	Serious mental disturbances leading to brain damage and death. In epidemics children are the main victims.
Diagnosis	Difficult and specialised.
Treatment	Supportive only.
Economic importance	Only a small percentage of infected people develop symptoms. Epidemics could severely disrupt irrigation projects.
Vector control	Ricefield breeding mosquitoes are difficult to control.
Prevention	Avoid pig rearing near irrigation schemes; environmental management.

Fact sheet for African Trypanosomiasis

Common name	Gambian and Rhodesian Sleeping Sickness
Type of causal organism	Protozoon of the genus *Trypanosoma*.
Important species	*Trypanosoma gambiense* and *rhodesiense*
Vector	Tsetse flies, genus *Glossina*.
Transmission	There is an animal reservoir in some regions.
Environment	Savannah woodland and riverain vegetation of Sub-saharan Africa. The fly bites during the day.
Effect on human health	Mental disturbances, brain damage and death.
Diagnosis	Detection of parasite in blood film or other parts of the body.
Treatment	Supervised administration of drugs with toxic side-effects.
Economic importance	A similar disease is a major constraint on cattle production. The human disease is usually sporadic but devastating epidemics continue to occur.
Vector control	Environmental management; insecticide spraying; trapping.
Prevention	Prophylaxis; active case finding where no animal reservoir; reduced fly contact.

Fact sheet for Yellow Fever

Type of causal organism	Virus
Vector	Mosquito of the genus *Aedes*. A common species is *Aedes aegypti*.
Transmission	By the bite of mosquitoes which previously fed on infected humans or monkeys.
Environment	Either forests inhabited by monkeys or urban areas where the mosquito breeding site is artificial containers. The mosquito bites by day.
Effect on human health	Many infections may not produce symptoms but others are very serious.
Diagnosis	Difficult and specialised.
Treatment	Supportive only.
Economic importance	Occasional epidemics with widespread sickness and death.
Vector control	In urban areas artificial containers should be destroyed or emptied twice per week. Insecticidal fogging can be used to halt an epidemic.
Prevention	By vector control and vaccination of the human population.

Fact sheet for Visceral Leishmaniasis

Common name	Kala Azar
Type of causal organism	Protozoon of the genus *Leishmania*.
Important species	*Leishmania donovani*
Vector	Sandflies, genus *Phlebotomus* in the Old World and genus *Lutzomyia* in the new world.
Transmission	Bite of sandfly. Animal reservoir in rodents and canines as well as people.
Environment	In and around houses in India, more rural areas elsewhere.
Effect on human health	Enlargement of liver and spleen. Can cause death if untreated.
Diagnosis	Detection of parasites in organ samples. Detection of antibodies.
Treatment	Supervised administration of drugs with toxic side-effects.
Economic importance	Epidemics have occurred in India but elsewhere cases are sporadic.
Vector control	Residual house spraying with insecticides where transmission is domestic.
Prevention	Destruction of canine reservoirs; vector control; repellents; resiting villages.

Table 8-11 cont.

Fact sheet for Lymphatic Filariasis

Common name	Elephantiasis, Bancroftian filariasis, Brugian filariasis.
Type of causal organism	Filarial worms
Important species	*Wuchereria bancrofti, Brugia malayi.*
Vector	Mosquitoes of the genera *Anopheles, Aedes, Culex* and *Mansonia*. In urban areas the vector is usually *Culex quinquefasciatus* which breeds in water polluted with sewage.
Transmission	By the bite of mosquitoes which previously fed on infected humans or, in one very restricted area, on wild animals.
Environment	Mainly urban. Mainly night biting.
Effect on human health	Repeating fever. Legs and sometimes genitals become very swollen and infected in later stages.
Diagnosis	Detection of the worm larvae in a blood film.
Treatment	Oral administration of a cheap and effective drug known commonly as DEC.
Economic importance	Many millions of people are infected but are not sick while others suffer repeated fever. People with swollen limbs suffer much distress and have difficulty moving about.
Vector control	Source reduction by drainage and larviciding in urban areas; residual house spraying.
Prevention	By vector control or contact prevention.

Fact sheet for Cutaneous Leishmaniasis

Common names	Oriental sore, Espundia, Chiclero's ulcer
Type of causal organism	Protozoon of the genus *Leishmania*.
Important species	*Leishmania tropica, major, braziliensis*
Vector	Sandflies, genus *Phlebotomus* in the Old World and genus *Lutzomyia* in the new world
Transmission	Bite of sandfly. Many reservoir animals, especially colonial rodents.
Environment	Semi-arid regions where irrigation is likely; S. American forests.
Effect on human health	Open sore, self-healing in some regions, more serious in others.
Diagnosis	Microscopic examination of stained material extracted from the ulcer.
Treatment	Self-healing forms require no special treatment. Supervised administration of drugs with toxic side-effects.
Economic importance	Serious outbreaks reported on water development projects in some semi-arid regions.
Vector control	Residual house spraying.
Prevention	Destruction of animal reservoirs; vaccination.

Source: Birley 1992

Table 8-12

Table 2-1
A broad indication of the vector-borne diseases naturally transmitted in each zoogeographical region.

Mexico, Central and South America
Widespread dengue and yellow fever, some bancroftian filariasis, some onchocerciasis, widespread cutaneous and restricted visceral leishmaniasis, widespread schistosomiasis (*mansoni*), widespread Chagas disease, widespread malaria.

North Africa and Asia excluding India and S.E. Asia
Widespread dengue, guinea worm, some bancroftian filariasis, widespread cutaneous and restricted visceral leishmaniasis, restricted schistosomiasis, malaria.

India, S.E. Asia, the Indonesian and Philippine archipelago and Indian Ocean
Widespread dengue, guinea worm, widespread bancroftian and brugian filariasis, some cutaneous and more visceral leishmaniasis, restricted schistosomiasis (*japonicum*), widespread malaria, Japanese encephalitis.

New Guinea, Solomons, Vanuatu and other Islands of the Western Pacific
Restricted dengue, widespread bancroftian filariasis, restricted schistosomiasis (*japonicum*), widespread malaria.

Africa South of the Sahara, Madagascar and S.W. Arabia.
Widespread dengue and yellow fever, bancroftian filariasis, loiasis, widespread onchocerciasis, restricted cutaneous and visceral leishmaniasis, widespread schistosomiasis, sleeping sickness, widespread malaria, guinea worm.

Table 8-13

Table 2-2
A broad indication of the distribution of disease between regions.

Japanese encephalitis is associated with rice growing and pig keeping in Asia, sometimes becoming more severe away from the equator.
Yellow fever is found in West Africa and South America, but not in Asia (although the vector is present).
Malaria is widespread in the tropics and sub-tropics, restricted by altitude.
Sleeping sickness is restricted to Africa, between the Sahara and the Zambezi river basin.
American trypanosomiasis, or Chagas disease, is restricted to Mexico, Central and South America. It is not specifically associated with water.
Bancroftian and brugian filariasis are associated with the humid tropics or coastal areas.
Onchocerciasis is restricted to West Africa, South and Central America and a few foci in East and Central Africa.
Dengue fever is spreading throughout the tropics and sub-tropics.
Dengue haemorrhagic fever is currently reported mainly from India, S.E. Asia, Philippines, the Caribbean and the Indian Ocean.
Schistosomiasis due to *S. mansoni* and *S. haematobium* is associated with the savannahs and semi-arid regions of Africa and the Middle-East and South America.
Schistosomiasis due to *S. japonicum* is restricted to South East Asia, China and the Philippines.
Other forms of schistosomiasis with very restricted distribution include *intercalatum* in Africa and *malayiensis/mekongi* in South East Asia.

Source: Birley 1992

Table 2-7
Distribution of mosquito-borne diseases.

Mosquito	Disease	Distribution
Subfamily: Anopheline Genus: *Anopheles*	Malaria	Throughout tropics and sub-tropics
	Bancroftian filariasis	Asia and Africa
	Brugian filariasis	Asia
	O'nyong nyong virus	Africa
Subfamily: Culicine Genus: *Culex*	Bancroftian filariasis	Throughout tropics
	Encephalitis virus	Asia, Americas, Europe, Africa
Subfamily: Culicine Genus: *Mansonia*	Brugian filariasis	Asia
	Other arboviruses	Africa, Americas
Subfamily: Culicine Genus: *Aedes*	Yellow fever virus	Africa, Americas
	Dengue virus	Asia, Americas, Africa
	Dengue Haemorragic	Asia , Americas
	Other arboviruses	Asia, Americas, Africa
	Bancroftian filariasis	Pacific

Table 8-14

Source: Birly 1992

Table 8-15

Appendix 2
Geographical distribution of schistosomiasis

The list below shows the geographical distribution of schistosomiasis as published in WHO Bulletin 59(1), 1981. The maps overleaf show the geographical distribution of schistosomiasis as published in "The control of schistosomiasis" (a report of a WHO Expert Committee), WHO Technical Report Series No. 728, 1985, pp 17–18. There may well be other endemic areas, not yet reported, on islands and in small countries.

The latest and fullest information about the disease in a particular area may be obtained by writing to one or more of the following organisations:

- a School of Tropical Medicine related to, or working in, the country concerned;
- Pan-American Health Organisation regional office, Washington DC, USA;
- World Health Organisation regional office/HQ, Geneva, Switzerland;
- the British Museum (Natural History), South Kensington, London, UK;
- the Danish Bilharziasis Laboratory, Danmarks Akvarium, Copenhagen, Denmark.

Country or area	Population[a] Date	Population[a] Total (thousands)	Notification of disease	Persons exposed to disease No.	Persons exposed to disease % of population	Endemicity of human schistosomiasis[b] *S. haematobium*	*S. mansoni*	*S. intercalatum*	*S. japonicum*	Schistosomes of veterinary importance
Africa										
Algeria	1977	17 910	–	...	...	+	–	–	–	–
Angola	1975	6 761	+	...	...	+ + +	+ +	–	–	–
Benin	1977	3 286	+	...	...	+ + +	+	–	–	–
Botswana	1977	710	–	200 000	28.2	+ +	+	–	–	*S. mattheei*
Burundi	1975	3 763	–	250 000	6.6	–	+	–	–	–
Central African Republic	1970	2 370	+	1 500 000	63.3	+ +	+ + +	+	–	*S. bovis*
Chad	1977	4 197	–	3 600 000	85.8	+ + +	+ +	+	–	*S. bovis*
Congo[c]	1977	1 440	...	...	...	+ +	+	–	–	...
Egypt	1977	38 741	–	18 000 000	46.4	+ + +	+ + +	–	–	...
Ethiopia	1977	28 981	+	9 000 000	31.0	+ +	+ +	–	–	–
Gabon	1970	500	+	263 000	52.6	+ +	+	+	–	–
Gambia	1977	553	–	400 000	72.3	+ + +	–	–	–	–
Ghana	1976	10 309	–	5 000 000	48.5	+ + +	+ +	–	–	*S. bovis*
Guinea	1967	3 702	–	1 500 000	40.5	+ +	+ +	–	–	–
Guinea-Bissau	1972	482	+	72 500	15.0	+ +	+	–	–	–
Ivory Coast	1975	6 671	+	...	...	+ +	+	–	–	–
Kenya	1977	14 337	+	6 000 000	41.8	+ +	+ +	–	–	*S. bovis* *S. mattheei*
Liberia	1974	1 503	+	700 000	46.6	+ +	+	–	–	–
Libyan Arab Jamahiriya	1975	2 444	+	183 285	7.5	+	+	–	–	–
Madagascar	1970	6 750	+	5 783 503	85.7	+ + +	+ + +	–	–	–
Malawi	1977	5 572	–	...	...	+ + +	+ + +	–	–	–
Mali	1976	6 035	+	3 571 292	59.2	+ + +	+	–	–	–
Mauritania	1976	1 481	–	375 000	25.3	+ +	–	–	–	–
Mauritius	1977	909	+	200 000	22.0	+	–	–	–	...
Morocco[c]	1977	18 245	...	...	...	+ +	–	–	–	–
Mozambique	1976	9 444	–	...	...	+ + +	+ +	–	–	...
Namibia[c]	1974	852	...	...	...	+ +	+ +	–	–	...
Niger[c]	1977	4 859	...	...	...	+ +	–	–	–	...
Nigeria	1977	78 660	+	15 000 000	19.1	+ + +	+ +	–	–	*S. bovis* *S. mattheei*
Rwanda	1977	4 368	–	...	...	–	+	–	–	–
Senegal	1976	5 115	–	2 500 000	48.9	+ + +	+ +	–	–	*S. bovis*
Sierra Leone[c]	1977	3 470	...	...	...	+ +	+	–	–	...
Somalia	1972	2 941	–	1 000 000	34.0	+ +	–	–	–	–
South Africa[c]	1976	26 129	...	...	...	+ +	+ +	–	–	...
Sudan	1977	16 953	–	15 000 000	88.5	+ + +	+ + +	–	–	*S. bovis*
Swaziland	1976	499	+	270 000	54.1	+ + +	+	–	–	*S. mattheei*
Togo	1977	2 348	–	1 953 778	83.2	+ + +	+ +	–	–	–
Tunisia	1977	6 065	–	169 515	2.8	+	–	–	–	...
Uganda	1977	12 353	–	1 000 000	8.1	+ +	+ +	–	–	*S. bovis*
United Republic of Cameroon	1976	7 663	–	3 700 000	48.3	+ +	+ +	+	–	*S. bovis*
United Republic of Tanzania	1977	16 073	–	3 000 000	18.7	+ + +	+ +	–	–	*S. bovis*
Upper Volta	1975	6 144	–	...	...	+ + +	+ +	–	–	–
Zaire	1977	26 376	+	10 000 000	37.9	+	+ + +	+	–	–
Zambia	1976	5 138	–	...	...	+ + +	+ + +	–	–	...
Zimbabwe[c]	1977	6 740	...	...	...					
South America and the Caribbean										
Antigua	1977	72	–	...	...	–	+	–	–	...
Brazil	1977	112 239	–	30 475 000	27.1	–	+ + +	–	–	–
Dominican Republic	1977	4 978	+	279 282	5.6	–	+ +	–	–	–
Guadeloupe	1976	321	–	...	...	–	+	–	–	–
Martinique	1977	319	–	...	...	–	+ +	–	–	–
Montserrat	1974	12	–	...	...	–	+	–	–	–
Puerto Rico	1977	3 303	+	2 079 184	62.9	–	+ +	–	–	–
St Lucia	1975	112	+	...	...	–	+	–	–	...
St Martin	1972	5	...	...	...	–	+	–	–	–
Suriname	1971	385	–	8 608	2.2	–	+	–	–	–
Venezuela	1977	12 737	–	4 000 000	31.4	–	+ +	–	–	–
Asia										
People's Republic of China	1970	700 000	...	...	...	–	–	–	+ +	...
Democratic Kampuchea[c]	1969	6 701	...	...	...	–	–	–	+	...
Democratic Yemen	1977	1 797	–	100 000	5.7	+ +	+	–	–	–
India[c]	1977	625 818	...	...	...	+	–	–	+	...
Indonesia	1975	130 597	–	10 000	0.01	–	–	–	–	*S. bovis*
Iran	1977	34 374	–	150 000	0.4	+	–	–	+	*S. bovis*
Iraq	1977	12 171	–	5 310 000	43.6	+ + +	–	–	+	...
Japan[c]	1977	113 863	...	...	...					
Lao People's Democratic Republic[c]	1977	3 427	...	...	...	–	–	–	+	...
Lebanon[c]	1970	2 126	...	...	...	+	–	–	+	...
Malaysia	1977	12 600	–	1 000 000	7.9	+	–	–	+	–
Philippines	1977	45 028	+	3 961 000	8.8	–	–	–	+	–
Saudi Arabia	1974	7 013	–	1 000 000	14.3	+ +	+ +	–	+	–
Syrian Arab Republic	1977	7 845	–	...	...	+ +	–	–	–	*S. spindale*
Thailand	1977	44 039	+	...	...	–	–	–	+	–
Turkey	1977	42 134	–	...	...	+	–	–	–	–
Yemen Arab Republic	1975	5 238	+	2 000 000	38.2	+ +	+ + +	–	–	–

[a] Latest official estimate (3).
[b] + – low endemicity; + + – medium endemicity; + + + – high endemicity.
[c] These countries did not respond to the questionnaire.
... Data not provided by country.

Source: Oomen et al. 1990

Table 9-1

Table 1. Some estimates of crop losses due to pests of cultivated crops in selected African countries

Country	Crop	% Crop losses caused by			
		Insects	Diseases	Birds	Weeds
Ethiopia	Coffee	-	20-25	-	-
	Sesame	-	100	-	-
	Sorghum	-	-	-	35
Gambia	Millet	-	20-30	-	-
Ghana	Rice	25	5-50	9-25	20-80
	Cassava	10-80	50-100	-	-
	Groundnuts	12-50	5-25	-	-
Kenya	Cashew	-	30	-	-
	Cereals	-	-	12	-
Mozambique	Rice	50	-	-	-
Nigeria	Cocoa	15-25	30-90	-	-
	Coffee	30-80	-	-	-
	Grain legumes	10-95	-	-	-
	Cotton	-	20-50	-	-
	Cereals	15-25	10-20	-	-
Sierra Leone	Swamp rice	10-20	3-80	-	-
	Irrigated rice	30-50	-	-	-
	Groundnuts	-	10	-	-
	Cowpea	30	-	-	-
Sudan	Rice	-	-	-	69
	Millet	20-30	-	-	-
Tanzania	Maize	3-27	5-30	-	-
	Sorghum	4	-	-	-
	Wheat	-	30-100	-	-
	All grain	-	-	50-100	-

Table 9-2

Table 2. Estimates of crop losses of stored products in some African countries, 1970

Country	Crop	% Loss
Burkina Faso	Legumes	50-100
Cameroon	Legumes	10
	Cereals	10-20
Egypt	Rice	5
Ghana	Legumes	9-12
	Cereals	10-15
	Yams	15-40
Nigeria	Legumes	30-40
	Maize	20-30
	Rice	5
	Yams	20-67
Sierra Leone	Rice	5-10
	Legumes	8
Tanzania	Legumes	5
Uganda	Legumes	20-30
	Cereals	15-20

Source: Youdeowei in Yaninek/Herren (IITA) 1989

Table 10-1

AGRICULTURE Checklist 1- KEY BIO-PHYSICAL FACTORS FOR AGRICULTURAL RESETTLEMENT

	Quality of Information: Available,		Current		Reliable	
	yes	no	yes	no	yes	no
1. Physical Factors						
• Bio-climatic regime:						
• Rainfall- total, seasonality and range of						
• variation in annual rainfall						
• Temperature and thermal regime						
• Length of growing period						
• Wind strength						
• Evapotranspiration;						
• Hydrographic setting - the location of the project in relation to the characteristics of the surrounding watershed management unit;						
• Water resources						
Surface water-total availability, seasonal variability and quality						
Ground water-total availability, aquifer recharge rates, quality, potential pollution from agricultural wastes						
Upstream/downstream externalities -forest clearance, flood plain, industry, urban centres						
Drainage and use of drainage water						
• Soils						
Taxonomic classification						
Chemistry and fertility						
Physical structure						
Texture						
Impediments to mechanization - rocks, slopes, internal drainage and susceptibility to erosion						
• Landforms						
Physiography - slopes						
Drainage - network, internal, water table, Groundwater recharge						
Active floodplain - definition, frequency						
2. Biological Factors						
• Ecological Zone						
Areas of major biological significance;						
Biogeographic context						
• Ecosystem stability and resilience.						
Suitability for agriculture						
Pests and diseases of crops and animals						
• Land cover: including vegetation and land use;						
• Protected Areas:						
Existing national parks or equivalent reserves						
Size, legal status, administration						
Proximity to and representativeness of project area						
Candidate areas requiring protection status:						
Critical habitats - biota, watersheds						
Riparian protection.						
3. Natural Hazards and the risk of man-induced hazards:						
• Soil erosion, landslides, earthquakes, volcanism,						
• potential human disease vectors, fire hazards.						

Source: Burbridge (FAO) 1988

AGRICULTURE Checklist 5- INPUTS REQUIRED

	Quality of Information: Available,		Current		Reliable	
	yes	no	yes	no	yes	no
1. Agro-chemicals:						
Will chemical fertilizers, biocides and other materials be required to maintain the proposed production system ?;						
Could these materials pose a hazard to the environment and/or human health if handled inappropriately ?;						
Does the management plan make provision for the safe and effective use of these materials-for example, training farmers how, in what quantities and when to apply them ?;						
Will the use of these materials be monitored?						
Have these materials been tested in the proposed location to test their effectiveness and effect on soil, water, vegetation and animals ?;						
Are the proposed materials available at a cost which the settler will be able to afford, or will less desirable and potentially hazardous materials be substituted due to availability or cost ?						
2. To what extent would resettled farmers depend on off-farm areas for their needs, for instance building materials, grazing for livestock, or water ?;						
	yes	no	yes	no	yes	no
Is there a risk that these demands would lead to conflicts with the existing population and resource uses ?						

AGRICULTURE Checklist 4- CROPPING SYSTEM

	Quality of Information: Available,		Current		Reliable	
	yes	no	yes	no	yes	no
1. Arable agriculture:						
Will new crops be introduced or will the cropping\system be based upon indigenous species?						
Will the cropping system be based upon irrigation or will it be rainfed ?;						
Has the system been field tested in the proposed location?;						
How much effort and skill will be required on the part of the settlers to establish and maintain the proposed cropping system ?						
Will the proposed settlers have the required skills and be able to supply the labour needed to sustain production ?;						
2. Animal Husbandry:						
Would animals be part of the production system ?;						
Which type will be used for which purpose ?;						
Would crop and animal production be integrated ?;						
Will these animals be susceptible to local diseases, and						
is there a risk of introducing new diseases into indigenous stocks ?;						
Is there a programme for inspection of farm animals introduced into new areas ?						
3. Power:						
What sources of power would be required by the production/cropping systems-human, animal, mechanical or would a mixture be used ?;						
Are there adequate supplies of labour, animals machines and the food/fuel and necessary services to maintain the required power at costs settlers are able to afford ?;						
Has provision been made for adequate fuelwood for cooking, heating and other purposes ?;						
4. Tree crops:						
Where tree plantations are part of the production system, would a cover crop, ring weeding or clear weeding be applied ?						

Source: Burbridge (FAO) 1988

Table 10-1 cont

AGRICULTURE Checklist 3- SITE PREPARATION

	Quality of Information: Available,		Current		Reliable	
	yes	no	yes	no	yes	no
1. Land clearance:						
What extent of site modification is required ?;						
Which method of clearance will be used-mechanical or hand ?;						
Is the expertise and experience in land preparation available ?;						
Will commercially valuable trees be harvested and other species salvaged ?;						
2. Have existing rights of access to resources been identified						
3. Have the current land use and vegetation cover been identified ?;						
4. Will compensation be required for loss of land or access to resources ?;						
5. What special management measures are required for sustainable use of the proposed location:						
soil and water conservation;						
potential pest and disease problems;						
adaptation of cropping systems;						
inputs required (agro-chemicals, extension						
services, new crop materials, etc.) ?;						
6. What infrastructure will be required to make the sites viable for resettlement. including						
access-roads, canals, etc.;						
water;						
power;						
irrigation and drainage						
Will the provision of this infrastructure entail major environmental modifications to the site and surrounding areas?						
7. Has the feasibility of establishing sustainable agricultural use on the proposed site been tested ?;						
8. Has the carrying capacity of the proposed sites(s)been evaluated ?;						
9. Does this capacity allow for population growth and demand for land and other resources stimulated by the project?;						
10. Have alternative locations been explored and the comparative advantage of different sites assessed ?						

AGRICULTURE Checklist 2- SITE SELECTION

	Quality of Information: Available,		Current		Reliable	
	yes	no	yes	no	yes	no
1. Have land suitability studies been carried out in accordance with FAO procedures, including:						
classification;						
percentage of total area for each class;						
major limitations (slope, depth of soil ,etc) ?;						
Will the stumps be uprooted, winrowed and burned or left in situ ?						
2. Soil conservation:						
Will soil conservation structures be required; if so,what types ?;						
How will they be constructed and maintained ?;						
Will a cover crop be planted immediately following land clearance?;						
3. Irrigation and Drainage:						
Will irrigation be required ?;						
Have potential irrigation water sources been tested for quality and seasonal availability ?;						
Will the use of these sources reduce water supplies to other users ?;						
Has the potential for soil salinization and/or waterlogging been assessed?;						
Will drainage structures be required ?;						
Is there a suitable discharge for the drainage water ?;						
Have existing and potential water borne disease vectors been analyses ?;						
Does the management plan deal with the long-term operation and maintenance of the irrigation and drainage facilities ?;						
4. Preparation for initial crops:						
How much of the land will be prepared and ready						
for planting by the settlers ?						

Source: Burbridge (FAO) 1988

Table 10-1 cont

Table 10-2

Table 1. Costs and efficiencies of different types of modern irrigation system (Coûts et efficacités pour différents systèmes d'irrigation moderne)

Method and Type	Equipment Initial Cost $ U.S./ha	Life yr	Annual Maintenance % of Cost	Efficiency %
Surface (Precision)				
Basin(level)	370 - 1,085	con	1	70 - 90
Border	370 - 1,085	con	1	70 - 85
Furrow	150 - 750	con	1	65 - 85
Conveyance				
Lined	400 - 1,250	15	3	---
Piped	800 - 2,500	20	1	---
Automation	300	10	5	---
Sprinkle				
Lateral				
Hand-Move	450 - 675	15	2	65 - 80
End-Tow	600 - 950	10	3	65 - 75
Side-Roll	800 - 1,100	15	2	65 - 80
Side-Move	950 - 1,350	15	4	65 - 80
Hose-Fed	450 - 675	5/20	3	60 - 80
Traveling Gun	950 - 1,200	10	6	55 - 70
Center-Pivot				
Standard (400 m)	1,100	15	5	70 - 85
w/Corner	1,200	15	6	65 - 85
Long (500 m)	700	15	5	65 - 85
Linear-Moving				
Ditch-Feed	1,100 - 1,300	15	6	65 - 85
Pipe-Feed	1,600 - 2,050	15	6	65 - 85
Solid-Set				
Portable	2,700 - 3,250	15	2	65 - 75
Permanent	2,300 - 3,500	20	1	65 - 75
Localized				
Orchard				
Drip/Spray	2,200 - 3,500	10/20	3	75 - 90
Bubbler	2,500 - 4,000	15	2	60 - 85
Hose-Pull	1,200 - 1,800	5/20	3	65 - 90
Hose-Basin	1,500 - 1,800	7/20	2	55 - 80
Row-crop				
Reusable	3,000 - 5,000	10/20	3	65 - 90
Disposable	1,850 - 3,000	1/20	20	60 - 80

Derived in a large part from the ASCE 1988 Report, "Selection of Irrigation Methods"

Source: Keller in ICID 1990

Table 11-1

Ökologische Auswirkungen von Flußstauungen

	Wahrscheinlichkeit des Eintreffens	Auswirkung auf Flußabschnitt	Zeitliches Verhalten	Möglichkeit zur Verhinderung	abhängig von	Bedeutung
Klima	sicher	Einzugs-, Speicher-, Unterstromgebiet	permanent	kaum	Fläche des Speichersees. Auswirkungen sekundärer Effekte im Einzugsgebiet	Änderung des Klimas in Richtung feuchterer Verhältnisse, beschränkt auf den regionalen Bereich
Hydrologie	sicher	Speicher-, Unterstromgebiet	permanent	nur begrenzt	Staumanagement, Wasserführung, Flußlänge, Seegröße	Verfüllung des Speichers mit Sedimenten, geändertes Verhalten des Stromes im Bereich unterhalb des Dammes, Flußdeltaveränderungen
Geologie/ Geomorphologie	eventuell	Speicher-, Unterstromgebiet	?	?	Größe und Tiefe des Stausees; tektonisches Verhalten	Erhöhung der Erdbebenaktivität, Veränderung der Sohlenerosion, Flußdeltaveränderungen
Pedeologie (Böden)	sicher	Einzugs-, Speicher-, Unterstromgebiet	permanent	begrenzt	Landnutzing im Einzugsgebiet und Speichergebiet, Bewässerung im Unterstromgebiet	Einfluß auf Sedimentationsrate im Speicher, Erosionsgefahr, Schaffung neuer Kulturlandschaft, Versalzung von Böden
Vegetation und Fauna	sicher	Einzugs-, Speicher-, Unterstromgebiet	permanent	begrenzt	Infrastruktur und Landnutzungsänderung, Waldraubbau	Verlust naturnaher Ökosysteme, Zerschneidung der Landschaft, Verlust genetischen Potentials

Biologische Auswirkungen von Flußstauungen

Gebiet	Wirkung
Einzugsgebiet	Änderung der Wanderungsmöglichkeit für Pflanzen und Tiere (Laichwanderung, Verbreitung von Samen und Früchten etc.); Versumpfung des Stauwurzelbereichs; Überschwemmungen von Uferbereichen nach heftigen Regenfällen (bei flachen Ufern), Rückstau in zuführende Gewässer; Veränderungen im Artengefüge von Pflanzen und Tieren
Speichergebiet	tendenzielle Erhöhung des Trophiegrades; „Wassergüte und Wasserqualität" (1); verrottende Vegetation führt zu Faulschlamm- und Faulgasbildung in Tiefenbereichen; Entwicklung lebensfeindlicher Wasserbereiche; Versumpfung und Versalzung überschwemmter Uferbereiche; Labilität des entstandenen See-Ökosystems in Produktivität, Artenvielfalt und Artengefüge der Pflanzen und Tiere; Massenentwicklung einzelner Arten; vor allem verstärktes Wachstum von Algen und Wasserpflanzen
Unterstrombereich	Änderung der Wasserzusammensetzung, Anreicherung mit Faulgasen etc.; Änderung der Wasserchemie und des Strömungsverhaltens bewirkt Selektionsprozeß für Tier- und Pflanzenarten; Verringerung ehemaliger Überflutungen (Dauer, Nährstoffe, Sedimente, Ausdehnung etc.); Erhöhung des Tideeinflußbereiches und Ausdehnung des Salzwassereinflusses auf Wasser und Land im Deltabereich; Änderung der Wanderungsmöglichkeit für Tiere (vor allem Laichwanderung von Fischarten); Änderung der Lebensbedingungen der aquatischen Tierwelt (Änderung der Wasserchemie und des Strömungsverhaltens, Selektionsprozeß für Tier- und Pflanzenarten)

Auswirkungen von Flußstauungen auf die Fischfauna

Gebiet	Auswirkung
Einzugsgebiet	Ausbleiben von wandernden Arten; Änderung im Artengefüge; Eindringen von fremden Arten aus dem Speichergebiet
Speichergebiet	Ausbleiben von wandernden Arten; Änderung im Artengefüge durch Änderungen der Biotopbedingungen; Geänderte Artenkonkurrenz; Eindringen/Einbringen neuer Arten und dadurch neue Artenkonkurrenz; Eutrophierung verändert Nährstoffangebot und führt zu toxischen Bedingungen (Faulgase); Uferform bestimmt neue Habitatsstrukturen und beeinflußt vor allem das Laichverhalten; Sekundärer Einfluß durch Fischerei
Unterstrombereich	Geändertes Abflußverhalten; Fehlende Sedimente führen zu Habitatsveränderungen; Gefahr der Gasübersättigung (Gasblasenkrankheit); Eintrag von toxischen Gasen und Stoffen aus verändertem Hypolimnion; Änderungen von Überflutungsflächen führt zu verändertem Nahrungsangebot; Änderung chem.-phys. Wasserkomponenten (Trübe, Temperatur, Dichte u.a.) führt zur Selektivität unter den Arten; Änderungen im Delta/Mündungsbereich durch eindringendes Meerwasser führt zu Habitatänderungen

Source: Dilger in Stüben ed. 1987

Table 11-2a

Figure 3.1 Environmental Aspects of Hydroprojects

1.	HEALTH	Some water-related diseases can increase unless precautions are implemented (e.g. vector control, prevention) schistosomiasis, onchocerciasis, encephalitis, malaria, etc. Remediation usually impossible; prevention is the only cost-effective approach.
2.	RESETTLEMENT	of people is expensive and time-consuming when done acceptably. The people can (and should) be better off afterwards. Can hydroprojects become regional development projects, which integrate rural development for people, with watershed management and irrigation? Resettlement of vulnerable ethnic unacculturated minorities should be avoided; if unavoidable, special precautions are necessary.
3.	WILDLIFE	Extinction can be minimized by siting. Loss of wildlife can be mitigated by including a wildland management unit, equivalent to the inundated tract in the watershed. Biotic rescue can assist.
4.	FISH	migrations (if any) will be impaired without passage facilities. Fish promotion in the reservoir can mitigate and produce more than before the project.
5.	BIOMASS REMOVAL	related to whatever water quality is needed downstream, to fisheries, and to navigation. Valuable timbers and fuel should be salvaged; "opportunity cost" of lost timber and foregone use of inundated land should be internalized.
6.	WATER WEEDS	proliferation can increase disease vectors, and transpiration increases water loss and impairs fish and water quality (e.g. Water Hyacinth (Eichhornia), Water Lettuce (Pistia)). Clogging impairs navigation, recreation and irrigation. Some potential to use weeds for compost, biogas, fodder.
7.	WATER QUALITY	within reservoir and downstream; saline intrustions; water retention time (i.e. flow/volume), loss of flushing; decrease nutrients in estuary; pollution monitoring (agricultural leachates, industries).
8.	EROSION	upstream leads to sedimentation which can impair storage; watershed management should be routine. Increased erosivity below dam.
9.	DRAWDOWN STRIP	useful for recession agriculture (with disease and access precautions).
10.	CULTURAL PROPERTY	Archeological, historic, paleontologic, religious and esthetic or natural unique values or sites should be conserved or salvaged.
11.	MULTIPLE USE	can be optimized by tourism, irrigation, fisheries, recreation. Regulation improves seasonal rivers into perennial waterways; advantages for drinking and irrigation.
12.	NAVIGATION	may need special provisions such as locks, cleared shipping lanes, and access ramps if drawdown is large. Lake transport may become economically advantageous.
13.	INDUCED SEISMICITY	Tectonic movements may increase or decrease; monitoring is becoming routine.
14.	INTACT RIVERS	Hydro and other developments are better concentrated on the same rivers in order to preserve representative rivers in their natural states.

Source: R. Goodland (1985).

Source: Dixon et al. 1989

Table 11-2b

Impacts on Water

Alteration of River Flows

1. reduction of floods
2. increase of minimum flows

Modification of Water Quality

1. reduction of turbidity
2. reduction of sediment transport
3. modification of the contents of dissolved gases
4. depletion of oxygen - at early stages
5. oversaturation - (low temperatures)

Possibility of Generation of Induced Seismicity

Eutrophication of Water Bodies

Evaporation versus Evapotranspiration

Reservoir Stability and Riverbed Erosion

Impacts on vegetation

Lose of Individuals within the Reservoir Area

Modification of Plants Habitats

Impacts on Fauna

Ichthyofauna - Consequences of Alterations of their Living Media

1. lentic fish (still waters)
2. lotic fish (running waters)
3. migratory fish
4. semiaquatic mammals
5. water mammals
6. reptiles
7. water fowl

Impacts on Human Activities

Displacement of Populations

Modification of Population Activities

1. extractivist
2. agricultural
3. urban occupations
4. transportation means and facilities

Reduction of Agriculture and Cattle Raising Lands

1. increase of irrigation possibilities
2. potential increase in fish production

Flooding of Archaeological and Cultural Sites and Landmarks

Impacts on Public Health

Waterborne Diseases

Multiplication of Vectors

1. insects
2. mollus

Source: Rangeley in: LeMoigne et al. (WB) 1989

Table 4.1: Selected Environmental Effects and their Economic Impacts

Environmental Effect	Economic Impact	Benefit (B) Cost (C)	Representative Valuation Technique
Environment on Dams			
1. Soil erosion – upstream, sedimentation in reservoir	reduced reservoir capacity; change in capacity; change in water quality; decrease in power	B,C	change in production, preventive expenditures, replacement costs.
Dams on the Environment			
1. Chemical water quality – changes in reservoir and downstream	increased/reduced treatment cost reduced fish catch, loss of production	B,C	preventive expenditures, changes in production.
2. Reduction in silt load, downstream	loss of fertilizer, reduced siltation of canals, better water control	B,C	replacement costs, preventive expenditures avoided.
3. Water temperature changes (drop)	reduction of crop yields (esp. rice)	C	changes in production.
4. Health – water related diseases (humans and animals)	sickness, hospital care care, death; decrease meat and milk production	B,C	loss of earnings, health care costs.
5. Fishery – impacts on fish irrigation, spawning	both loss and increase in fish production	B,C	changes in production, preventive expenditures.
6. Recreation – in the reservoir or river	value of recreation opportunities gained or lost, tourism	B,C	travel cost approach, property value approach.
7. Wildlife and biodiversity	creation or loss of species, habitat and genetic resources	B,C	opportunity cost approach, tourism values lost, replacement costs.
8. Involuntary resettlement	cost of new infrastructure, social costs	B,C	replacement cost approach, "social costs", relocation costs
9. Discharge variations, excessive diurnal variation	disturbs flora and fauna, human use, drownings, recession agriculture	C	relocation costs, changes in production.
10. Flood attenuation	reduces after flood cultivation; reduces flood damage.	B,C	changes in production, flood damages avoided.

Source: Dixon et al. 1989

Major Environmental Factors

Not all dam projects have significant adverse environmental consequences. Whether or not they exist, however, must be determined. One approach to identification of likely environmental factors is to examine the three broad regions associated with any dam project: the dam and its reservoir, the upstream area, and the downstream area. (Figure 1.1 is one representation of this concept.) Some environmental factors are common to all regions, others to only one or two. Similarly, not all of the factors listed necessarily pertain to all dams, nor will all of them necessarily be found in any one dam. For example, some impoundment areas may not include villages, agricultural land, or marketable timber, but the possibility should be considered.

The following listing is a brief summary of major factors. Detailed discussions are found in many sources; in particular, the International Commission on Large Dams (ICOLD) has produced several excellent references (ICOLD, 1981, 1985, 1987) as has the American Society of Civil Engineers (1978). The 1981 ICOLD Bulletin, Dam Projects and Environmental Success, discusses general environmental problems and remedies, health problems, beneficial side effects, and monitoring and control of project. The 1985 Bulletin, Dams and the Environment: Notes on Regional Influences, focuses on the particular environmental concerns in each of three climatic regions: temperate; tropical, sub-tropical and arid; and severe winter environments.

The Dam And Impoundment Area

Specific provisions must be made to eliminate or mitigate environmental damage in the impoundment area during and after construction. Some of these effects are the responsibility of the contractor and others are the responsibility of various government agencies.

Provisions should be incorporated into construction tenders so that the eventual contractor clearly recognizes its responsibility for construction related impacts. The Bank has formalized instructions for contractors that cover many points, including the following:

- location of borrow areas and borrow pits;
- air and water pollution from construction equipment, earth movement, and living quarters;
- screening of laborers for imported water-related diseases;
- solid waste disposal;
- siting of contractor facilities and other infrastructure to minimize destruction of the natural landscape; and,
- noise pollution.

Other environmental effects found in the dam and impoundment area may be the responsibility of the contractor, the project authority, or various government agencies. These environmental impacts can be both negative and positive and include the following:

- Population influx, associated with the need for labor for construction, may cause problems including pollution and a variety of linked social effects including health, security, and impact on local cultures;
- Direct effects on people: reservoir creation may involve inundation of houses, villages, farms and infrastructure such as roads and transmission lines. When people are involved, involuntary resettlement is required. Involuntary resettlement imposes major social and economic costs; it requires particular attention and has been the subject of special in-depth consideration by the World Bank (see Cernea, 1988a, 1988b, and Cernea and Le Moigne, 1989 for details on the Bank's policy and operational guidelines regarding the planning, economic analysis, and implementation of involuntary resettlement);
- Cultural/historical sites: inundation of sites or areas of historic, religious, aesthetic or other particular cultural value, and sites of archeological and paleontological significance requires special attention. (For World Bank experiences with cultural property, see Technical Paper No. 62, Goodland and Webb, 1987);
- Inundation of agricultural land, especially highly productive bottom lands;
- Inundation of forest land, may mean the loss of valuable timber and species diversity. Salvage lumbering can recover some of this potential loss and provide other reservoir benefits; species loss may not be replaceable;
- Inundation of wildlife habitat, particularly habitat of threatened species with consequent impact on biological diversity;
- Inundation of potentially valuable mineral resources;
- Inundated vegetation: biomass left in the reservoir can affect water quality if the water is to be used for potable purposes, reservoir fishing (for example, through interference with nets), operation and longevity of dam and associated machinery (e.g., effect of floating debris, chemical reactions, and wear on turbines);

Source: Dixon et al. 1989

Table 11-4 cont.

- **Water weeds:** Proliferation of water weeds can increase disease vectors, affect water quality and fisheries, increase water loss (through transpiration), affect navigation, recreation and fishing, and clog irrigation structures and turbines;

- **Fisheries:** The dam will block fish migrations in the river, although fish ladders may sometimes be practical. Substantial new reservoir fisheries are often possible if carefully planned and managed. In the Saguling reservoir in Indonesia, for example, the reservoir fishery helped those resettled to restore or even surpass their previous income levels. Similar results have been observed elsewhere including Thailand (Nam Pong) and in Gujarat, India;

- **Water quality** within the reservoir is, in part, dependent on what happens upstream and retention time within the reservoir. Quality may be affected by salt accumulation, eutrophication from weeds and biomass decay, turbidity, pollution from agricultural, industrial and human wastes, and fish processing. By trapping sediment, the reservoir provides better quality water downstream with less suspended matter. See Garzon (1984) for a fuller discussion of water quality in hydroelectric projects;

- **Health:** Establishment of the reservoir and associated water management structures (e.g., canals and ditches) can create conditions fostering establishment and spread of water-related diseases such as schistosomiasis, onchocerciasis, encephalitis, and malaria. Prevention, where possible, is essential, since treatment to eliminate most disease vectors is difficult (or impossible) and expensive once they become established. In other cases, availability of regulated water supplies for municipal and industrial use (M and I) can have major beneficial effects;

- **Effect of drawdown regime,** which may create agricultural possibilities, as well as health, recreational, aesthetic,and access problems;

- **Seismicity** may be induced by large reservoirs;

- **Ground water level** in the surrounding area may be altered;

- **Local climate** may be modified by large reservoirs, especially in terms of humidity and local fog;

- **Temperature** of released water may be higher or lower than ambient river temperature (depending on pattern of release); this will have varying impacts on downstream water users;

Upstream Considerations

A variety of upstream considerations can affect the dam and its reservoir. While not directly "caused" by the dam, these effects may be induced or exacerbated by the dam. For example, dam construction and reservoir filling may provide access to a previously remote and inaccessible area. The induced population in-migration may lead to increased agricultural or mining activities with major implications for soil erosion, sedimentation, and water quality. Some of the more important upstream considerations follow:

Sedimentation is a major problem for many dam projects. Unfortunately, our knowledge of sediment delivery patterns is imperfect and much of the sediment flowing into a reservoir may have started its movement some time ago. These questions are discussed in detail in Mahmood (1987). There is no question that reservoirs will gradually fill with sediment, the question is at what rate and what can be economically done (if anything) to influence that rate. Dead storage capacity is built into most reservoir designs to act as low cost, and effective, sediment traps.

Increased population settlement and economic development in the upper catchment or watershed usually increase soil movement. The timing and ultimate impact of this increased movement on the reservoir varies greatly from case to case.

The major sources of sediment are the following:

- **Existing sediment:** sediment resulting from previous natural or induced erosion remains in the bed of watercourses and elsewhere in the watershed area, and will continue to flow into the reservoir, particularly in periods of heavy rainfall (especially in "young" geological areas, such as the Himalayas);

- **Unusual natural sedimentation:** natural events such as volcanic activity, earthquakes, mudslides, typhoons and "100 year precipitation events" may cause heavy sedimentation regardless of watershed management measures;

- **Road building and other construction,** not necessarily associated with the dam project, can cause soil erosion and associated sedimentation;

- **Erosion** from (usually unplanned) clearance of vegetation, logging, and cultivation by people who have moved into the watershed areas as a direct or indirect result of the construction of the dam project. This is largely a planning and regulation problem.

Changes in land use caused directly or indirectly by the dam and dam construction, primarily from increases in population due to planned or unplanned resettlement from inundated areas or elsewhere. These changes may also go on without the project; the question is the rate of change. In-migration from both downstream and outside the river basin area is often facilitated by the project (improved access due to new roads and water transport). The resource and environmental effects include the following:

- **Cultivation on unsuitable sites,** often unplanned, using unstable or otherwise unsuitable lands (e.g., steep slopes, poor soils) leading to soil erosion and sedimentation;

Source: Dixon et al. 1989

Table 11-4 cont.

- Logging, usually unplanned and often illegal, which results in denudation, unsustainable exploitation of the resource, and erosion;
- Poaching, i.e., illegal, unsustainable exploitation of wildlife;
- Denudation of vegetation for cultivation, fuel collection, and logging;
- Loss of wildland and wildlife habitat, with impact on endangered species and reduction of biological diversity;
- Negative impacts on aesthetic and scenic qualities of the area and the potential for certain recreational uses. The reservoir, however, may create recreational benefits;
- Pollution from settlements and cultivation;

Changed watershed hydrology. The changes in land use patterns, if extensive enough, may affect the timing and magnitude of runoff, especially during major storm events. Changed vegetative patterns may also influence dry season stream flow. Hamilton and King (1983) discuss the relationships between surface cover and hydrology in detail.

Salt inflows from the watershed may accumulate in the reservoir and affect water quality. Similarly, catchment runoff may carry increased quantities of agricultural chemicals and fertilizer with resultant impacts on reservoir water quality.

Downstream Considerations

Numerous impacts are felt downstream. Many are positive and are the reasons why dams are built---increased irrigation, improved water control, hydropower generation and water supply benefits. Whether they are considered direct or indirect project effects, there are other environmental and resource impacts that can be both positive and negative. Among these are the following:

- Impact on river fishery due to changes in flow regime, effect of dam blocking fish migration, changes in water quality (e.g., loss of nutrients trapped by dam, pollution from irrigation return flow, and increased water turbidity);
- Effect on traditional flood plain cultivation through changes in flow and flooding regime, and loss of annual "top dressing" fertilization from limited flooding. Control of severe flooding can also yield benefits through reduced crop and property losses;
- Impact on other water projects: changes in stream flow and water releases from the dam affect dams and irrigation projects elsewhere in the lower basin. The impacts can be both positive and negative. Reduced silt content in water, for example, will lower downstream O & M costs and permit better water management; lower silt levels also decrease potable water treatment costs. On the other hand, weed growth in existing canals may increase with perennial water supplies;
- Impact on municipal and industrial water supply downstream can have both positive and negative effects depending on water quantity and quality;
- Stream bed changes are one possible, but not a common result of the changed water flow and sediment load. This includes the possibility of increased stream bed erosion below the dam due to "hungry" water (with reduced silt loads) being released from the dam;
- Effect on estuarine and marine fisheries and marine biota, including endangered species, through change in flow regime, change in water quality (e.g., pollution from toxic chemical and salts from irrigation return flow to river) and loss of nutrients;
- Salt intrusion into estuarine and lower river basin areas may result from sustained or seasonal reduction in river flow;
- Groundwater level changes: Higher levels due to the high water levels in the reservoir. Downstream, in old flood plain areas, the groundwater level may fall but in irrigated areas, it may rise;
- Health problems from water-related diseases or parasites (similar health problems may also occur in the reservoir itself), primarily from irrigation and associated canals;
- Effects on wildlife and wildlands through loss of or change in habitat may result in an impact on biological diversity.

Assessing Likely Importance

Identification of likely environmental or resource impacts is the first step. Once they have been identified, it is necessary to assess or evaluate which impacts are important and need to be taken into account. Not all impacts are of equal importance and limits on data and resources (money, trained staff, time) mean that decisions must be made on which impacts to consider further.

Certain effects are so obviously important that they will always be included in the expanded analysis: involuntary resettlement is one example. Others may or may not be important. For example, the reservoir may flood a tropical forest and destroy this diverse ecosystem. Are similar areas available nearby? Are there any endangered species that may be driven to extinction? Are there unique cultural or historic sites such as the Abu Simbel monument that was moved to prevent its inundation by Lake Nasser created by the Aswan High Dam?

Given a trained multidisciplinary study team, the most important effects are usually well identified and quantified. Experience from similar projects in the same country or in geographically similar settings can provide valuable guidance and the Bank has considerable in-house expertise on these topics. Assessment is a skill, not a check-list activity.

Source: Dixon et al. 1989

Table I—Checklist of potential impacts from impoundment projects

Construction phase
Sediment pollution and stream siltation
Pesticides, petrochemicals, and other potential pollutants
Quantification of erosion and sediment generation
Relevant criteria for sediment pollution
Protection of water quality during construction—general
- Erosion and sediment control techniques
- Treatment of polluted water from construction site
- Activity scheduling

Components of solid waste from construction operations
Disposal of chemicals and containers
Summary of solid waste impacts
Air pollution sources at construction sites
Noise generators at impoundment construction site
Typical construction noise levels
Rough estimation of noise impacts
Damaging effects of noise

Impoundment area
Probable land use impacts
General methodology for evaluating land use changes and impacts
Loss of stream and bottom land
Relocation impacts
Recreational development—general
- Secondary air pollution impacts (parking, and so on)
- Solid waste generation at recreational areas

Impact of land inundation on impoundment water quality
Organic decomposition and dissolved oxygen deficiency
Solution of iron and manganese
Loss of wildlife habitat
Assimilative capacity changes—general
- Primary determinants
- Critical water quality conditions
- Effects of stratification and density currents

Eutrophication and associated impacts
Consideration of evaporation
Shift from river to lake environment and reduction of species diversity
Sedimentation in impoundment
Modelling of impoundment water quality
Estimating significance of site conditions with respect to impoundment water quality
Potential for erosion in reservoir
Relationship of morphometry to potential eutrophication and weed problems
Nutrient sources and loadings
Quantification of influent water quality
Changes in point and diffuse pollution sources
Probability of water quality problems in stratified reservoirs
Evaluation of reservoir fisheries
Summary of water quality parameters that may be affected by impoundment and relevant criteria
Thermal criteria for fisheries

Downstream and areas of water use
Influence of land acquisition policy on reservoir development
Induced development in region
Land use impacts caused by increased flood protection
Land use impacts of irrigation impoundments
Evaluation of water pollution from irrigation
Policy concerning use of flood plains
Prevention of water quality degradation from irrigation projects
Impacts of water quality changes on downstream biota
Impact of dam as barrier
Flow regime changes—general
- Quantification of hydrographic modification
- Seasonal and diurnal flow variations
- Minimum release requirements
- Low-flow augmentation analysis
- Effects on riparian vegetation
- Flow requirements for salmon and other species

Temperature changes—general
- Important categories of fish species
- Effects of outlet location and impoundment operation
- Possible thermal effects on downstream species composition
- Thermal criteria for fisheries
- Effects on downstream uses

Source: Canter 1983

Table II—Checklist of bio-physical and cultural environment factors for impoundment projects

Category	Sub-category	Factor
Terrestrial	Population	Crops
		Natural vegetation
		Herbivorous mammals
		Carnivorous mammals
		Upland game birds
		Predatory birds
	Habitat/land use	Bottomland forest[1]
		Upland forest[2]
		Open (non-forest) lands[3]
		Drawdown zone
		Land use
	Land quality/ Soil erosion	Soil erosion
		Soil chemistry
		Mineral extraction
	Critical community relationships	Species diversity
Aquatic	Populations	Natural vegetation
		Wetland vegetation
		Zooplankton
		Phytoplankton
		Sport fish
		Commercial fisheries
		Intertidal organisms
		Benthos/Epibenthos
		Waterfowl
	Habitats	Stream[4]
		Freshwater lake[5]
		River Swamp[6]
		Non-river Swamp[7]
	Water quality	pH levels
		Turbidity
		Suspended solids
		Water temperature
		Dissolved oxygen
		Biochemical oxygen demand
		Dissolved solids
		Inorganic nitrogen
		Inorganic phosphate
		Salinity
		Iron and manganese
		Toxic substances
		Pesticides
		Faecal coliforms
		Stream assimilative capacity
	Water quantity	Stream flow variation
		Basin hydrologic loss
	Critical community relationships	Species diversity
Air	Quality	Carbon monoxide
		Hydrocarbons
		Oxides of nitrogen
		Particulates
	Climatology	Diffusion factor
Human Interface	Noise	Noise
	Aesthetics	Width and alignment
		Variety within vegetation type
		Animals—domestic
		Native Fauna
		Appearance of water
		Odor and floating materials
		Odor and visual quality
		Sound
	Historical	Historical internal and external sites
	Archaeological	Archaeological internal and external sites

1. A composite of the species associations; percentage mast-bearing trees; percentage covered by understory; diversity of understory; percentage covered by groundcover; diversity of groundcover; number of trees ≥ 16 in diameter per acre, percentage of trees ≥ 16 in diameter; frequency of inundation; edge (quantity); and edge (quality).
2. A composite of the following: species associations; percentage mast-bearing trees; percentage coverage of understory, diversity of understory; percentage coverage of groundcover, diversity of groundcover; number of trees ≥ 16 in diameter/acre; percentage of trees ≥ 16 in diameter; quantity of edge; and, mean distance to edge.
3. A composite of the following: land use; diversity of land use; quantity of edge; and, mean distance to edge.
4. A composite of the following: sinuosity; dominant centrarchids; mean low water width; turbidity; total dissolved solids; chemical type; diversity of fishes; and, diversity of benthos.
5. A composite of the following: mean depth; turbidity; total dissolved solids; chemical type; shore development; spring flooding above vegetation line; standing crop of fish; standing crop of sport fish; diversity of fish; and, diversity of benthos.
6. A composite of the following: species associations; percentage forest cover; percentage flooded annually; groundcover diversity; percentage of groundcover; and, days subject to river overflow.
7. A composite of the following: species associations; percentage forest cover; percentage flooded annually; groundcover diversity and percentage of groundcover.

Source: Canter 1983