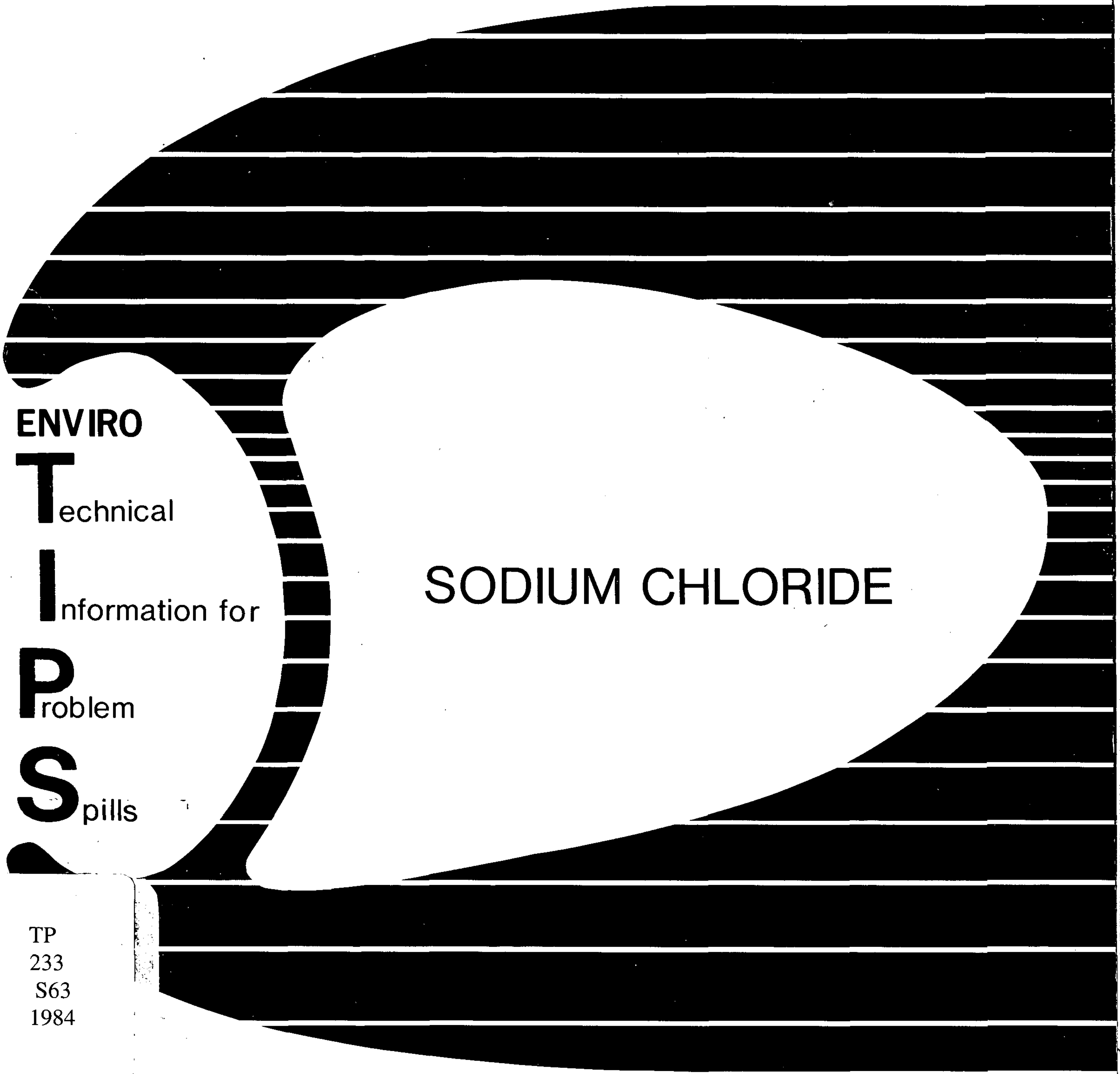
Environment Canada
Environmental Protection Service

Environnement Canada
Service de la protection de l'environnement



ENVIRO

Technical
Information for
Problem
Spills

SODIUM CHLORIDE

March 1984

Canada

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in planning for and designing countermeasures for spills of these substances. The manual has been reviewed by the Environmental Protection Service and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Readers are advised to consult other sources of information before making critical decisions. Mention of trade names or commercial products does not constitute endorsement for use.

11-12-96

SODIUM CHLORIDE

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Ottawa, Ontario

March 1984

Cat. No. En 48-10/4-1984E
ISBN 0-662-13155-X
BEAUREGARD PRESS LIMITED

FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited. The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 SUMMARY

SODIUM CHLORIDE ($NaCl$)

White crystalline solid or powder with no odour

SYNONYMS

Table Salt, Sea Salt, Halite, Rock Salt, Common Salt, Iodized Salt, Sodium Monochloride, Brine

IDENTIFICATION NUMBERS

UN No. No hazard No. required; CAS No. 7647-14-5

GRADES & PURITIES

Common, industrial: > 97 percent; table, fine: > 99.5 percent

IMMEDIATE CONCERNS

Human Health: Low health risk

PHYSICAL PROPERTY DATA

State (15°C, 1 atm): crystals or powder
Boiling Point: 1,413°C
Melting Point: 801°C
Flammability: noncombustible
Specific Gravity (water=1): 2.165 (25°/4°C)

Solubility (in water): 35.7 g/100 mL @ 0°C
Behaviour (in water): sinks and dissolves
Behaviour (in air): absorbs moisture from air

ENVIRONMENTAL CONCERNS

The presence of excessive amounts of sodium and chloride ions in soils results in reduced soil fertility. Vegetation and trees are adversely affected by spills. Sodium chloride does not have a potential for food chain concentration

COUNTERMEASURES

Emergency Control Procedures in/on

Soil: For solids, pick up spills with shovels and place into containers. For solutions, contain with barriers and recover spills with pumps

2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

Appearance	Cubic, white crystals, granules or powder; colourless and transparent or translucent when in large crystals (Merck 1976)
Usual shipping state(s)	Solid sodium chloride usually containing some calcium and magnesium chlorides (Merck 1976)
Physical state at 15°C, 1 atm	Solid
Melting point	801°C (CRC 1980)
Boiling point	1,413°C (CRC 1980)
Decomposition temperature	820°C (Kaufmann 1960)

Densities

Specific gravity	2.165 (25°/4°C) (CRC 1980)

Fire Properties

Flammability	Noncombustible (Kaufmann 1960)
Decomposition temperature	820°C (Kaufmann 1960)
Decomposition products	Sodium and chlorine. Will decompose slightly to give sodium hydroxide and hydrogen chloride in the presence of water vapour (Kaufmann 1960)

Other Properties

Molecular weight of pure substance	58.44 (CRC 1960)
Constituent components (percent) (of typical commercial grades)	>97 to >99.5 percent NaCl
Resistivity	4.6 x 10^4 ohm•m (Kaufmann 1960)
Refractive index	1.5442 (CRC 1980)

Viscosity	15 mPa•s (liquid at 816°C) (Kaufmann 1960) 2.0 mPa•s (26 percent aqueous solution at 20°C) (Kaufmann 1960)
Liquid interfacial tension with air	103.8 mN/m (liquid at 803°C) (Kaufmann 1960)
Hygroscopicity	Absorbs moisture from air (Merck 1976)
Latent heat of fusion	30.2 kJ/ mole (at melting point) (CRC 1980)
Heat of vaporization	171 kJ/mole (at boiling point) (Kaufmann 1960)
Heat of formation	-411.3 kJ/mole (25°C) (Sussex 1977)
Ionization potential	8.92 eV (Rosenstock 1977)
Heat of solution	3.9 kJ/mole (25°C) (CRC 1980)
Heat capacity constant pressure (Cp)	50.8 J/mole•°C (Kaufmann 1960)
Coefficient of thermal expansion	3.99 x 10^{-5}/°C (25°C); therefore, in heating from 20° to 100°C, NaCl would linearly expand 0.32 percent (Kaufmann 1960)
Thermal conductivity	0.0697 J/s•cm•°C (0°C) (Lange's Handbook 1979)
pH of aqueous solution	6.7 to 7.3 (Merck 1976)
Eutectic compositions	23.3 percent aqueous solution (f.p. - 21.13°C) (Lange's Handbook 1979)

Solubility (g/100 mL)

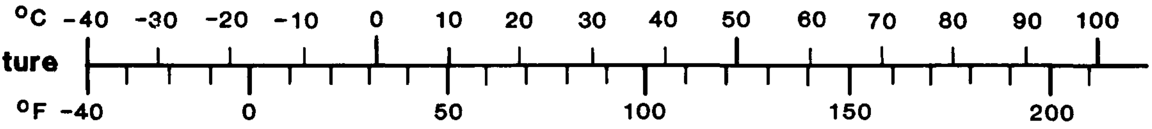
In water	35.7 g/100 mL (0°C) (CRC 1980) 39.12 g/100 mL (100°C) (CRC 1980)
In other common materials	Glycerol: 10 g/100 mL (Merck 1976) Slightly soluble in ethanol and liquid ammonia. Insoluble in hydrochloric acid (CRC 1980)

TABLE 1

SODIUM CHLORIDE

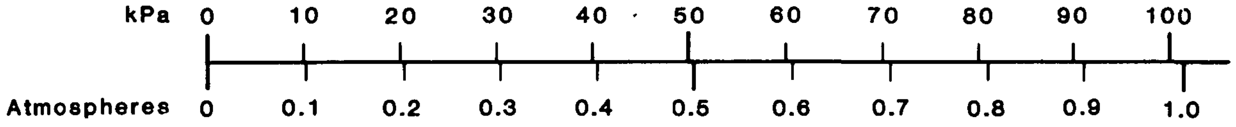
CONVERSION NOMOGRAMS

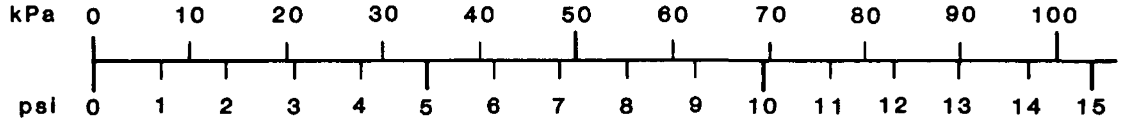
Temperature

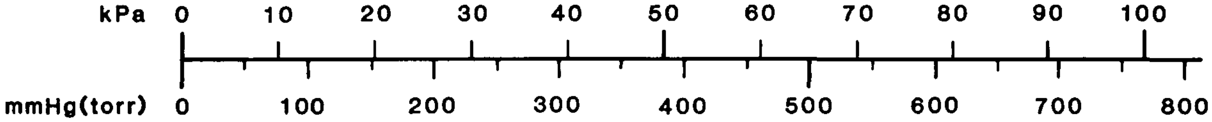


Pressure

1 kPa = 1,000 Pa







Viscosity

Dynamic 1 Pa·s = 1,000 centipoise (cP)

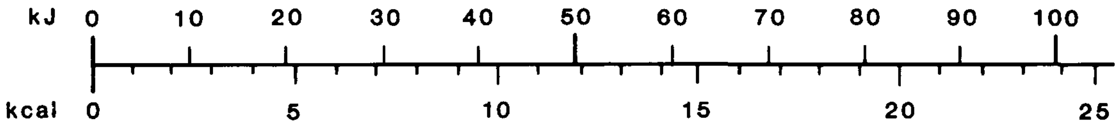
Kinematic 1 m^2/s = 1,000,000 centistokes (cSt)

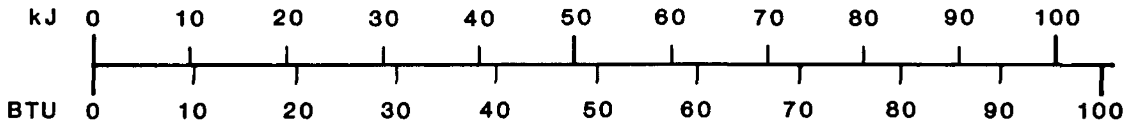
Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat)

1 kJ = 1,000 J





Density

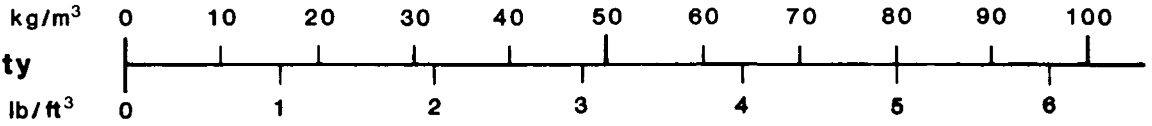


FIGURE 1

SODIUM CHLORIDE

SOLUBILITY IN WATER vs TEMPERATURE

Reference: Seidell and Linke 1965

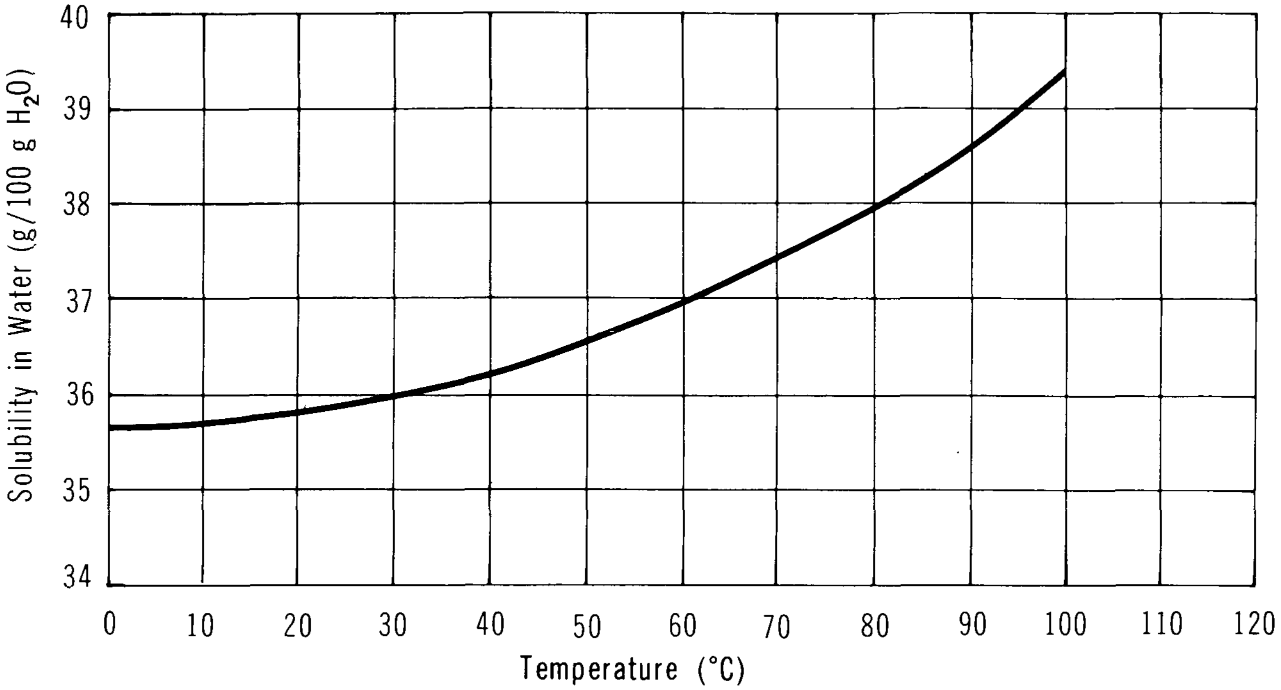
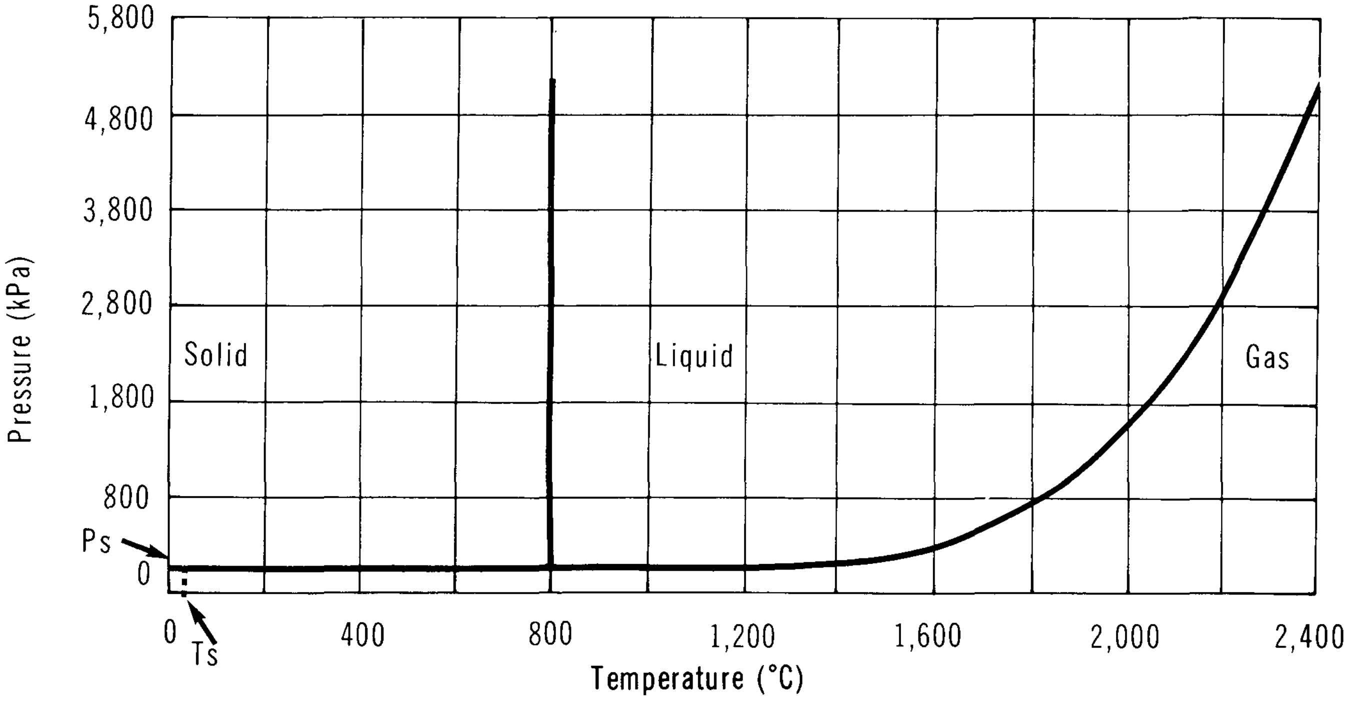


FIGURE 2

SODIUM CHLORIDE

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities (CMR 1979)

Salt is sold as crystals or white crystalline powder. It is available in a number of grades - industrial, common, table and fine. Fine salt has a purity of greater than 99.5 percent; industrial salt has a purity of greater than 97 percent.

3.2 Domestic Manufacturers (Corpus 1980; CBG 1980; CCPA 1981)

These are corporate headquarters' addresses and are not intended as spill response contacts.

Allied Chemical Canada Ltd.
201 City Centre Drive
Mississauga, Ontario
L5B 2J4
(416) 276-9211

Canadian Occidental Petroleum Limited
Hooker Chemical Division
700 4th Avenue S.W.
Calgary, Alberta
T2P 0K2
(403) 265-2390

Canadian Salt Company Limited
606 Cathcart Street
Montreal, Quebec
H3B 1L6
(514) 878-3511

Domtar Inc., Lime and Salt Division
C.P. 7212, Succ. A
395 Boul. de Maisonneuve O.,
Montreal, Quebec
H3C 3M3
(514) 282-5400

Dow Chemical of Canada Limited
P.O. Box 1012
Modeland Road
Sarnia, Ontario
N7T 7K7
(519) 339-3131

International Minerals & Chemical
Corporation (Canada) Limited
P.O. Box 310
Esterhazy, Saskatchewan
S0A 0X0
(306) 745-3931

Prince Albert Pulp & Paper Co.
Saskatoon Chemical Division
P.O. Box 1586
Saskatoon, Saskatchewan
S7K 3R3
(306) 652-9456

3.3 Other Suppliers (Corpus 1980)

Iroquois Salt Products Ltd.
360 St. James
Montreal, Quebec
H2Y 1P5
(514) 849-2474

Vancouver Salt Co. Ltd. (Domtar)
85 1st. Avenue West
Vancouver, B.C.
V5Y 1A1
(604) 874-3471

3.4 Major Transportation Routes (CMR 1979)

Current Canadian production of sodium chloride is in Southwestern Ontario, Saskatchewan, Manitoba, Alberta, New Brunswick, and Nova Scotia. Production is mainly concentrated in Eastern Canada.

Most of the rock salt mined in Canada is shipped in bulk by water, rail and road.

3.5 Production Levels (Corpus 1980; CMR 1979)

Company, Plant Location	Nameplate Capacity kilotonnes/yr (1980)
Allied Chemical Canada, Amherstburg, Ont.*	550
Canadian Occidental, Brandon, Man.*	100
Canadian Salt, Pugwash, N.S.	100
Canadian Salt, Pugwash, N.S. (Rock Salt Mining)	900
Canadian Salt, Ojibway, Ont. (Rock Salt Mining)	1,900
Canadian Salt, Windsor, Ont.	150
Canadian Salt, Belle Plaine, Sask.	150
Canadian Salt, Lindborgh, Alta.	120
Dennison, Clover Hill, N.B.	
Domtar, Amherst, N.S.	100
Domtar, Goderich, Ont. (Rock Salt Mining)	2,040
Domtar, Goderich, Ont.	115
Domtar, Unity, Sask.	180
Dow Chemical Canada, Sarnia, Ont.*	400
Dow Chemical Canada, Ft. Saskatchewan, Alta.*	900
International Minerals and Chemical, Esterhazy, Sask.	100
Potash Company of America, Sussex, N.B.	
Saskatoon Chemicals, Saskatoon, Sask.*	100
TOTAL	7,905
Domestic Shipments (1979)	6,700
Imports (1979)	1,400
TOTAL	8,100

* Primarily for captive use only

3.6 Future Development

Currently, only one salt mine in Canada is under expansion. Domtar's Sifto Salt Division, at its Goderich mine in Ontario, is to have a 55 percent capacity increase, bringing its annual production to 3,175 kt by February, 1983 (Corpus 1980).

Seleine Inc., a subsidiary of Quebec Mining Exploration Company (SOQUEM), is developing a mine on the Madeleine Islands, with start-up projected by 1982.

3.7 **Manufacture of Sodium Chloride** (CMR 1979)

3.7.1 General. Sodium chloride, or salt, occurs naturally in solution in seawater, in some spring and lake waters, in many subsurface waters, and in solid form in surface and underground deposits.

3.7.2 Manufacturing Process. Sodium chloride may be mined in two ways: directly by rock salt mining, or from brine wells (underground brining). Rock salt mining simply involves the removal of the material by conventional mining methods. Well brines are produced by injecting water into a salt deposit to dissolve the salt, then ejecting the resulting saturated salt solution to the surface. The brine is either evaporated to produce salt, or used directly in the manufacture of chemicals.

3.8 **Major Uses in Canada** (Corpus 1980; CMR 1979; Dow PS 1980)

The largest single market for salt in Canada is for snow and ice control. The second largest consumer is the industrial chemical industry for the manufacture of caustic soda and chlorine. It is also used in the manufacture of sodium bicarbonate, soda ash, sodium chlorate and sodium chlorite, and in pulp bleaching, food and fish processing, photography, and home water softeners.

3.9 **Major Buyers in Canada** (Corpus 1980; CBG 1980)

A & K Petro-Chem, Weston, Ont.
Abitibi-Price, Smooth Rock Falls, Ont.
Alberta Dept. of Transportation, Edmonton, Alta.
American Can, Marathon, Ont.
BC Ministry of Highways, Victoria, B.C.
BC Packers, Vancouver, B.C.
Burns Bros., Calgary, Alta.
CIL, Becancour, Que.; Cornwall, Ont.; Dalhousie, N.B.
Canada Packers, Toronto, Ont.
Canadian Canners, Hamilton, Ont.
Canadian International Paper, La Tuque, Que.
Canadian Occidental, Vancouver, B.C.
Canso Chemicals, New Glasgow, N.S.
Clayson, Regina, Sask.
Erco Industries, Buckingham, Que.
FMC Chemicals, Squamich, B.C.
Great Lakes Forest, Thunder Bay, Dryden, Ont.
Green Giant of Canada, Windsor, Ont.
Hamilton City, Ont.
Kimberly-Clark Canada, Terrace Bay, Ont.

Kingsley & Keith, Toronto, Ont.
Kraft Foods, Montreal, Que.
Libby McNeill & Libby, Chatham, Ont.
Mallinckrodt, Pt. Claire, Que.
Manitoba Dept. of Highways, Winnipeg, Man.
Ministère du Transport du Québec, Montreal, Que.
Montreal, Metro, Montreal, Que.
National Sea Products, Halifax, N.S.
New Brunswick Dept. of Transportation, Fredericton, N.B.
Newfoundland Dept. of Transportation, St. John's, Nfld.
Nova Scotia Dept. of Highways, Halifax, N.S.
Ontario Ministry of Transportation, Toronto, Ont.
Ottawa-Hull, Ont.
Proctor & Gamble Cellulose, Grande Prairie, Alta.
Quebec City, Que.
QueNord Chemicals, Magog, Que.
St. Anne Chemical, Nackawick, N.B.
Saskatchewan Dept. of Highways, Regina, Sask.
Shefford Chemicals, Granby, B.C.
Stanchem (PPG), Beauharnois, Que.
Swift Canadian, Toronto, Ont.
Thurso Pulp & Paper, Thurso, Que.
Toronto Metro, Toronto, Ont.
Weyerhaeuser Canada, Kamloops, B.C.
Vancouver Metro, Vancouver, B.C.
Winnipeg City, Man.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

4.1.1 Bulk Shipment. Solid sodium chloride is shipped in bulk, or in drums, bags and boxes, as further discussed in Section 4.1.2. A large portion of salt is shipped in open railway cars. Sodium chloride does not require Canadian Transport Commission or Department of Transportation classification (TCM 1979).

4.1.1.1 Railway cars. Railway cars typically used in the transportation of sodium chloride are of the hopper type LO and are described in Table 2 and Figure 3 (CLC 1974; AAR 1983).

4.1.2 Packaging. In addition to bulk shipments, solid sodium chloride is also transported in drums, bags and boxes. Drums (Figure 4) fabricated from a variety of construction materials are permitted. Table 3 lists drum types and descriptions (TDGC 1980).

The following packaging systems are also used:

- metal, wooden or fibreboard box with inner container fabricated from glass, metal, plastic or fibre;
- fibreboard box with inner paper bag;
- paper bag filled to weight with product and closed for shipment.

4.2 Compatibility with Materials of Construction

The compatibility of sodium chloride with materials of construction is indicated in Table 4. The unbracketed abbreviations are derived from Table 5. The rating system for this report is briefly described below.

Recommended: This material will perform satisfactorily in the given application.

Conditional: Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.

Not Recommended: Material will be severely affected in this application and should not be used.

TABLE 2 TYPICAL RAILWAY HOPPER CAR SPECIFICATIONS - AAR CLASS LO (CLC 1974)

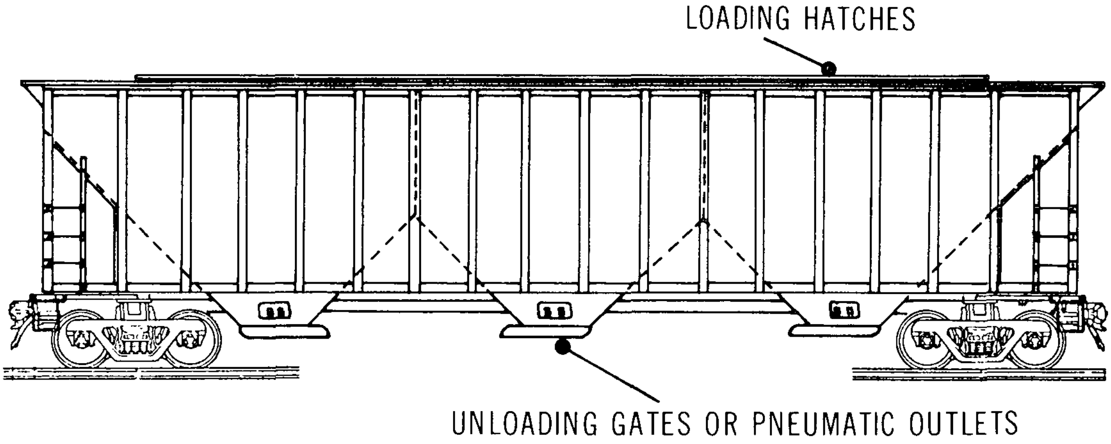
Description	Hopper Car Size 5,800 (cu. ft)	4,700 (cu. ft)
Overall		
Nominal capacity	164 m^3 (5,800 cu. ft)	133 m^3 (4,700 cu. ft)
Weight capacity	89,000 kg (190,000 lb.)	86,000 kg (196,000 lb.)
Car weight- empty	45,000 kg (99,000 lb.)	45,000 kg (99,000 lb.)
Car weight- (max.)	119,000 kg (262,000 lb.)	119,000 kg (262,000 lb.)
Hoppers/Compartments		
Number	4	3
Material	Steel	Steel
Inside length (Typical)	410 cm (161 in.)	460 cm (181 in.)
Inside width (Typical)	300 cm (118 in.)	300 cm (118 in.)
Spacing between outlets	4 m (13 ft)	5 m (16 ft)
Slope angle	40-45°	40-45°
Approximate Dimensions		
Coupled length	21 m (69 ft)	18 m (59 ft)
Length over strikers	20 m (66 ft)	17 m (56 ft)
Length of truck centres	16 m (52 ft)	14 m (46 ft)
Clearance height	5 m (16 ft)	5 m (15 ft)
Height to top of running board	5 m (16 ft)	4 m (13 ft)
Overall width	3.1 m (123 in.)	3.2 m (126 in.)
Inside length	19 m (62 ft)	17 m (56 ft)

Loading/Unloading Fixtures

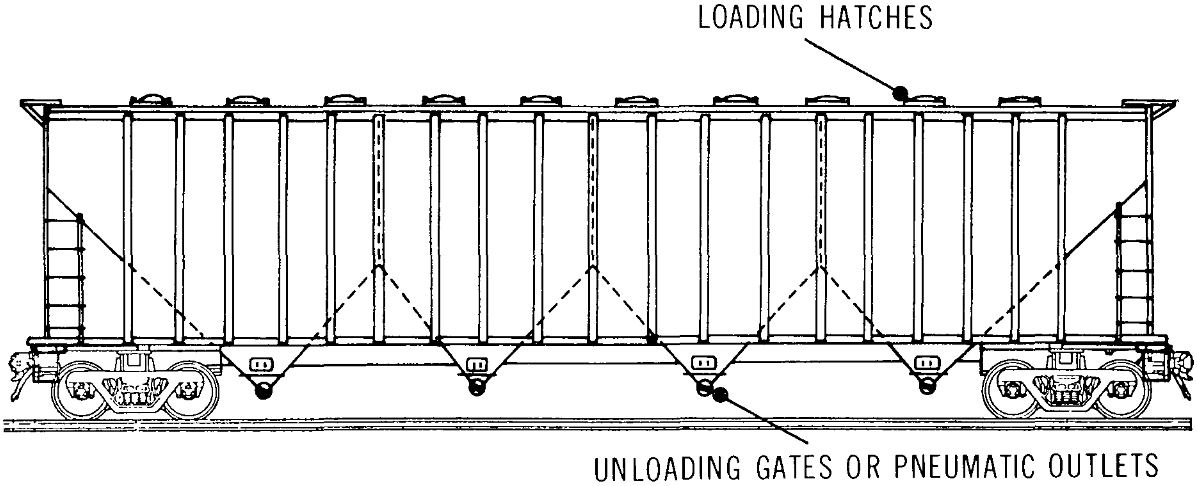
Loading Hatches:	Cars typically equipped with 4 to 12 loading hatches. Typical dimensions of these are 36-61 cm (14-24 in.) in diameter or square dimensions.
Unloading Fixtures:	Equipped with unloading gates at bottom of 36-61 cm (14-24 in.) square or pneumatic unloading connections of 10-20 cm (4-8 in.) in diameter.

COVERED HOPPER CARS - AAR CLASS LO

(Reference - CLC 1974; AAR 1983)



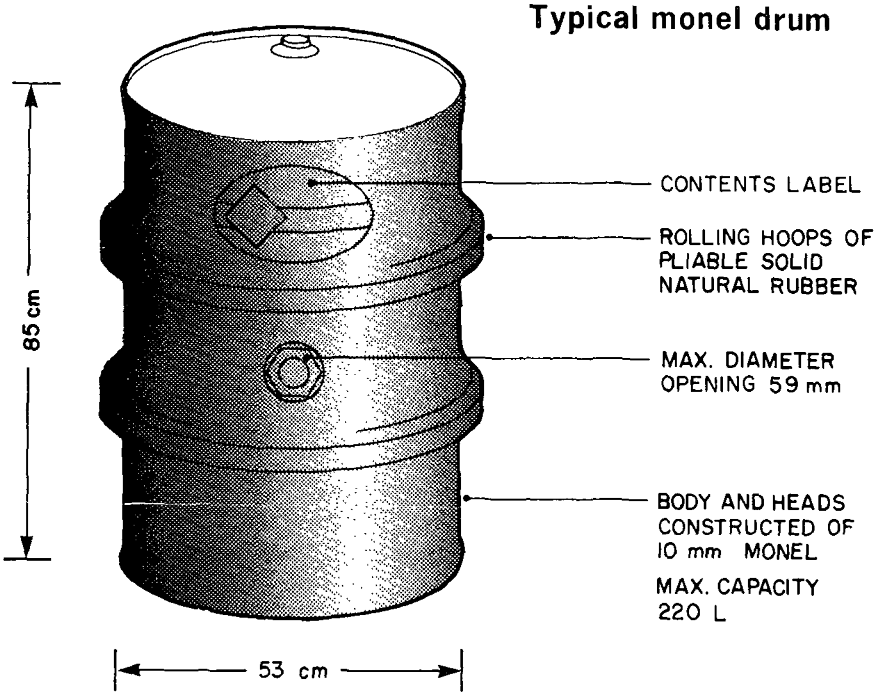
Typical 3 - Compartment Hopper Car



Typical 4 - Compartment Hopper Car

TYPICAL DRUM CONTAINERS

Typical monel drum



Typical steel drum

Typical aluminum drum

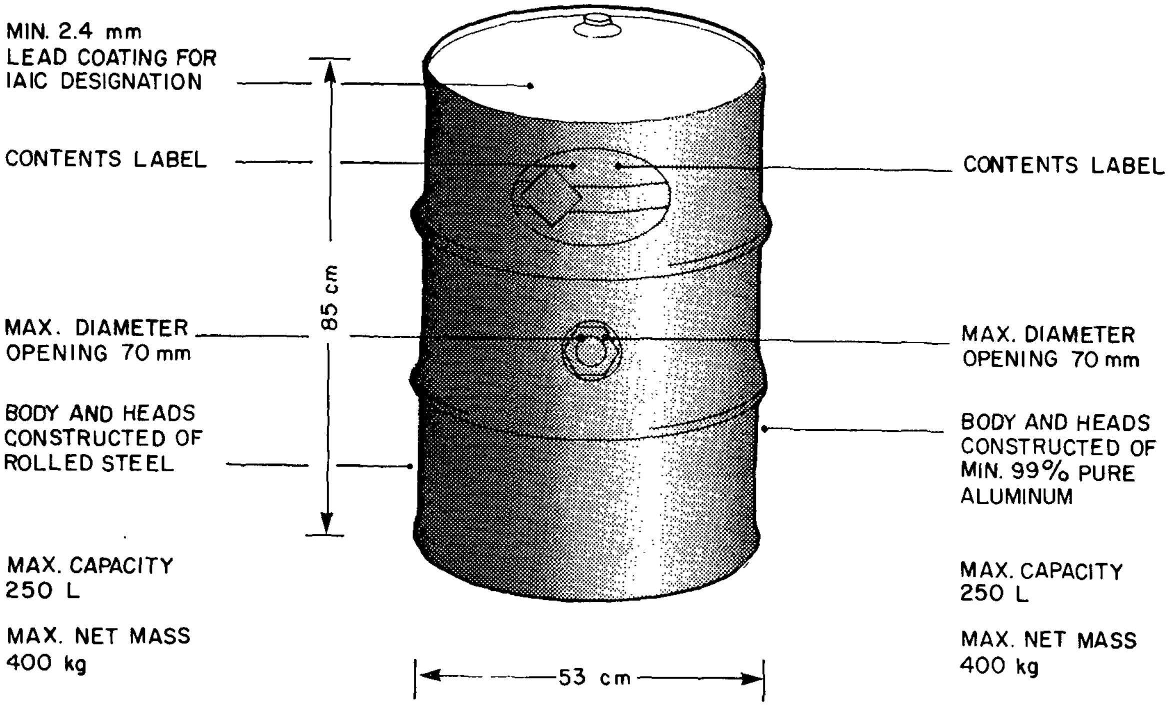


TABLE 3 DRUMS FOR SODIUM CHLORIDE

Type	Designation	Description	Figure No. (If Any)
Steel	1A1	Nonremovable head, reusable	4
	1A1A	1A1 with reinforced chime	4
	1A1B	1A1 with welded closure flange	4
	1A1C	1A1 with lead coating	4
	1A1D	1A1 with coating (other than lead)	4
	1A2	Removable head, reusable	4
	1A2A	1A2 with reinforced chime	4
	1A2B	1A2 with lead coating	4
	1A3	Nonremovable head, single use only	4
	1A4	Removable head, single use only	4
Monel*	TC5M		4
Aluminum	1B1	Nonremovable head	4
	1B2	Removable head	4
Plywood	1D2		
Fibreboard	1G1	Convolutely wound plies. Maximum capacity 250 L (55 gal.). Maximum net mass 400 kg (882 lb.)	
Plastic	1H1	Nonremovable head. Maximum capacity 250 L (55 gal.). Maximum net mass 400 kg (882 lb.)	
	1H2	Same as 1H1 except head removable	
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (49 gal.)	
Plywood with inner plastic receptacles	6HD1	Outer plywood in shape of drum. Inner plastic receptacle. Maximum capacity 225 L (49 gal.)	
Fibreboard Drums with inner plastic receptacles	6HG1	Outer containers of convolutely wound plies of fibreboard. Inner plastic in shape of drum. Maximum capacity of 225 L (49 gal.)	

*See Section 4.2 of this report.

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings	All	21	All SS (DCRG 1978)		
		49	PE (DPPED 1967)		
		60	PVC I PVC II (DPPED 1967)		
		71	ABS (DPPED 1967)		
		79	PVDC (DCRG 1978)		
		107	PP (DCRG 1978)		
		121	Chlorinated Polyether (DCRG 1978)		
		135	PVDF (DCRG 1978)		
		To operating limit of material	PVC I ABS PE (MWPP 1978)		
2. Valves	20 to 30%	Boiling	SS 316 (JSSV 1979)		
	All	21	All SS		
3. Pumps	<3% NaCl	Cold	All Bronzes All Irons CI (HIS 1969)		
	>3% NaCl	Cold	All Bronzes SS 304 SS 316 CI Monel (HIS 1969)		
	>3%	Hot NaCl	SS 316 High Silicon Cast Iron Monel (HIS 1969)		
4. Others	Saturated	20	SS 316 (ASS)	SS 302 SS 304 (ASS)	SS 410 SS 430 (ASS)

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (cont'd)

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
4. Others (cont'd)	Saturated	60	uPVC PE PP POM NR NBR IIR EPDM CR FPM CSM (GF)		
	Saturated	80	PP NBR IIR EPDM CR FPM CSM (GF)	PE POM (GF)	uPVC NR (GF)
	Saturated	100	PP NBR IIR EPDM CR FPM CSM (GF)		uPVC PE POM NR (GF)
	Saturated	Boiling	SS 316 (ASS)	SS 302 SS 304 (ASS)	SS 410 SS 430 (ASS)
		60	PVC (TPS 1978)		
		82	PP (TPS 1978)		
		100	CPVC (TPS 1978)		
		121	PVDF (TPS 1978)		
			NR* SBR CR NBR IIR CSM Si EPDM (GPP)		

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (cont'd)

Application	Chemical Conc.	Chemical Temp. (°C)	Material of Construction Recommended	Conditional	Not Recommended
4. Others (cont'd)	10-30%	24-100	Glass (CDS 1967)		
	10-30%	38	Concrete (CDS 1967)		
	100%	100	Concrete (CDS 1967)		
	10-40%	24-100	Wood (CDS 1967)		

*This material has been given a lower rating in a similar application by another reference.

TABLE 5 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Aluminum
	Bronze
CI	Cast Iron, Austenitic
	Cast Iron, High Silicon
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene)
CS	Carbon Steel
CSM	Chlorosulphonated Polyethylene (Hypalon)
	Concrete
EPDM	Ethylene Propylene Rubber
FPM	Fluorine Rubber (Viton)
	Glass
	Iron
IIR	Isobutylene/Isoprene (Butyl)
NBR	Acrylonitrile/Butadiene Rubber (Nitrile, Buna N)
NR	Natural Rubber
	Nickel
	Nickel - Copper Alloy (Monel)
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PVC (Followed by grade, if any)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
Si	Silicon
SBR	Styrene/Butadiene (GR-5, Buna S)
SS (Followed by grade)	Stainless Steel
uPVC	Unplasticized Polyvinyl Chloride
	Wood

5 CONTAMINANT TRANSPORT

5.1 General Summary

Sodium chloride is transported as a solid, in crystalline form. When spilled in water, it will dissolve very rapidly. When spilled on soil, as a liquid it will spread on the surface and penetrate into the soil at a rate dependent on the soil type and its water content. Transport of sodium chloride toward the water table may be an environmental concern.

Because sodium chloride is essentially nonvolatile, dispersion in air is not a problem.

Factors considered for the transport of a sodium chloride spill in water and soil are as follows:

Contaminant Transport
- Water — Diffusion rate
- Soil — Depth and time of penetration

It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different, and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

5.2 Dispersion in the Air

Because sodium chloride is essentially nonvolatile, there is no significant potential for dispersion in air.

5.3 Behaviour in Water

5.3.1 Introduction. When spilled in water, sodium chloride will dissolve very rapidly. For the purposes of nomogram presentation, it is assumed that the spilled sodium chloride will be entirely and rapidly dissolved. Mixing takes place and the spill is diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence, while in calm water mixing takes place by molecular diffusion.

To estimate pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The model employed is strictly applicable to neutrally buoyant liquids and solids that dissolve in water. As sodium chloride is denser than water, the maximum concentration would be expected near the bottom.

The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 ($W/d < 100$) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

5.3.2 Nomograms. The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

Non-tidal Rivers

Figure 6: time versus distance for a range of average stream velocities

Figure 7: hydraulic radius versus channel width for a range of stream depths

Figure 8: diffusion coefficient versus hydraulic radius for a range of average stream velocities

Figure 9: alpha* versus diffusion coefficient for various time intervals

Figure 10: alpha versus delta* for a range of spill sizes

Figure 11: maximum concentration versus delta for a range of river cross-sectional areas

Lakes or Still Water Bodies

Figure 12: volume versus radius for the hazard zone for a range of lake depths

Figure 13: average concentration versus volume for the hazard zone for a range of spill sizes

---

*Alpha and delta are conversion factors only and are of no significance other than to facilitate calculation of downstream concentrations.

The flow chart in Figure 5 outlines the steps required to estimate the downriver concentration after a spill and identifies the nomograms to be used. These nomograms (Figures 6 through 11) are described in the following sub-sections.

5.3.2.1 Nomograms for a non-tidal river.

Figure 6: Time versus distance. Figure 6 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average stream velocity (U), the time (t) to reach any point of interest, at some distance (X) downstream of the spill, can be readily obtained from Figure 6.

Figure 7: Hydraulic radius versus channel width. The model used to estimate downstream pollutant concentration is based on an idealized rectangular channel of width (W) and depth (d). The hydraulic radius (r) for the channel is required in order to estimate the longitudinal diffusion coefficient (E). The hydraulic radius (r) is defined as the stream cross-sectional area (A) divided by the wetted perimeter (P). Figure 7 is a nomogram for computation of the hydraulic radius (r) using the width and depth of the idealized river cross-section.

Figure 8: Diffusion coefficient versus hydraulic radius. Figure 8 permits calculation of the longitudinal diffusion coefficient (E), knowing the hydraulic radius (r) from Figure 7 and the average stream velocity (U).

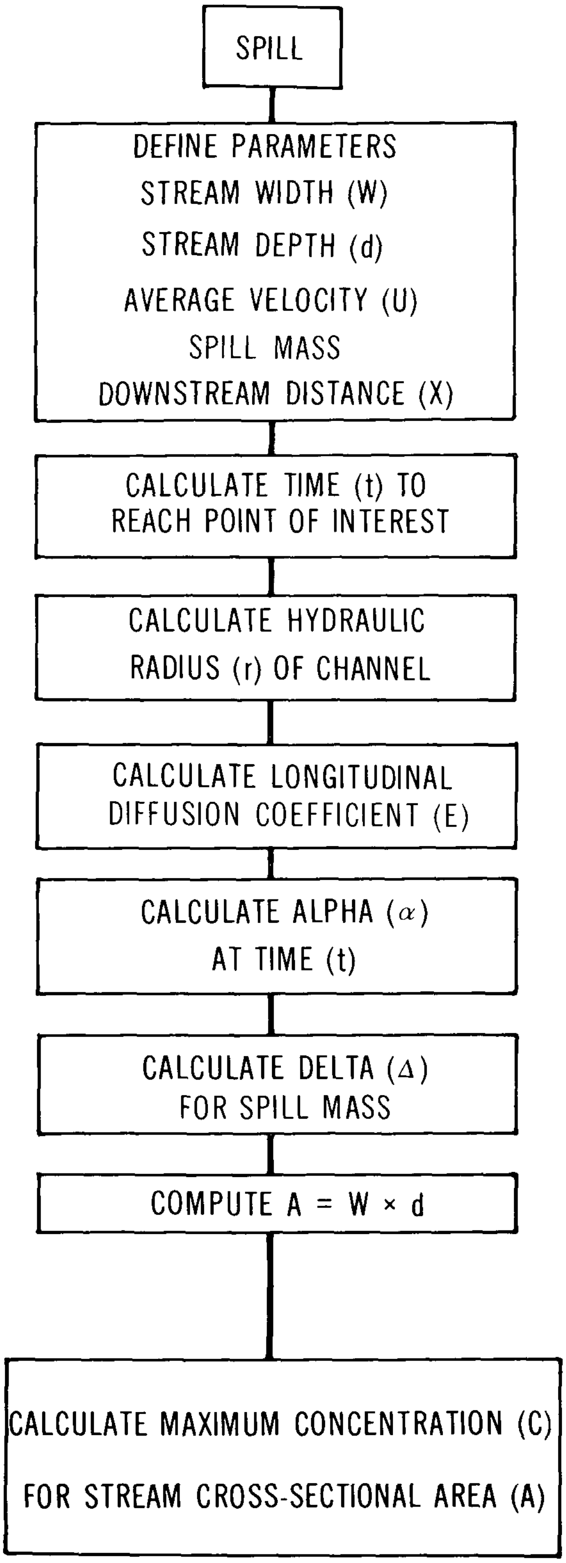
Figure 9: Alpha versus diffusion coefficient. Figure 9 is used to estimate a conversion factor alpha (α), which is a function of the diffusion coefficient (E) and the time (t) to reach the point of interest downstream of the spill.

Figure 10: Alpha versus delta. A second conversion factor, delta (Δ), must be estimated from Figure 10 to allow determination of pollutant concentration at the point of interest. Delta (Δ) is a function of alpha (α) and the spill size.

Figure 11: Maximum concentration versus delta. Figure 11 represents the final step for calculation of the maximum downstream pollutant concentration (C) at the point of interest. Using the factor delta (Δ) and knowing the stream cross-sectional area (A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 11 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

FIGURE 5

FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS



Step 1: Observed or Estimated

$W =$ __________ m

$d =$ __________ m

$U =$ __________ m/s

MASS = __________ tonnes

$X =$ __________ m

Step 2: Use Figure 6

$t =$ __________ minutes

Step 3: Use Figure 7

$r =$ __________ m

Step 4: Use Figure 8

$E =$ __________ m^2/s

Step 5: Use Figure 9

$\alpha =$ __________

Step 6: Use Figure 10

$\Delta =$ __________

Step 7: Compute stream cross-sectional Area (A)

$A = W \times d$ _____ m^2

Step 8: Use Figure 11

$C =$ __________ ppm

SODIUM CHLORIDE

TIME vs DISTANCE

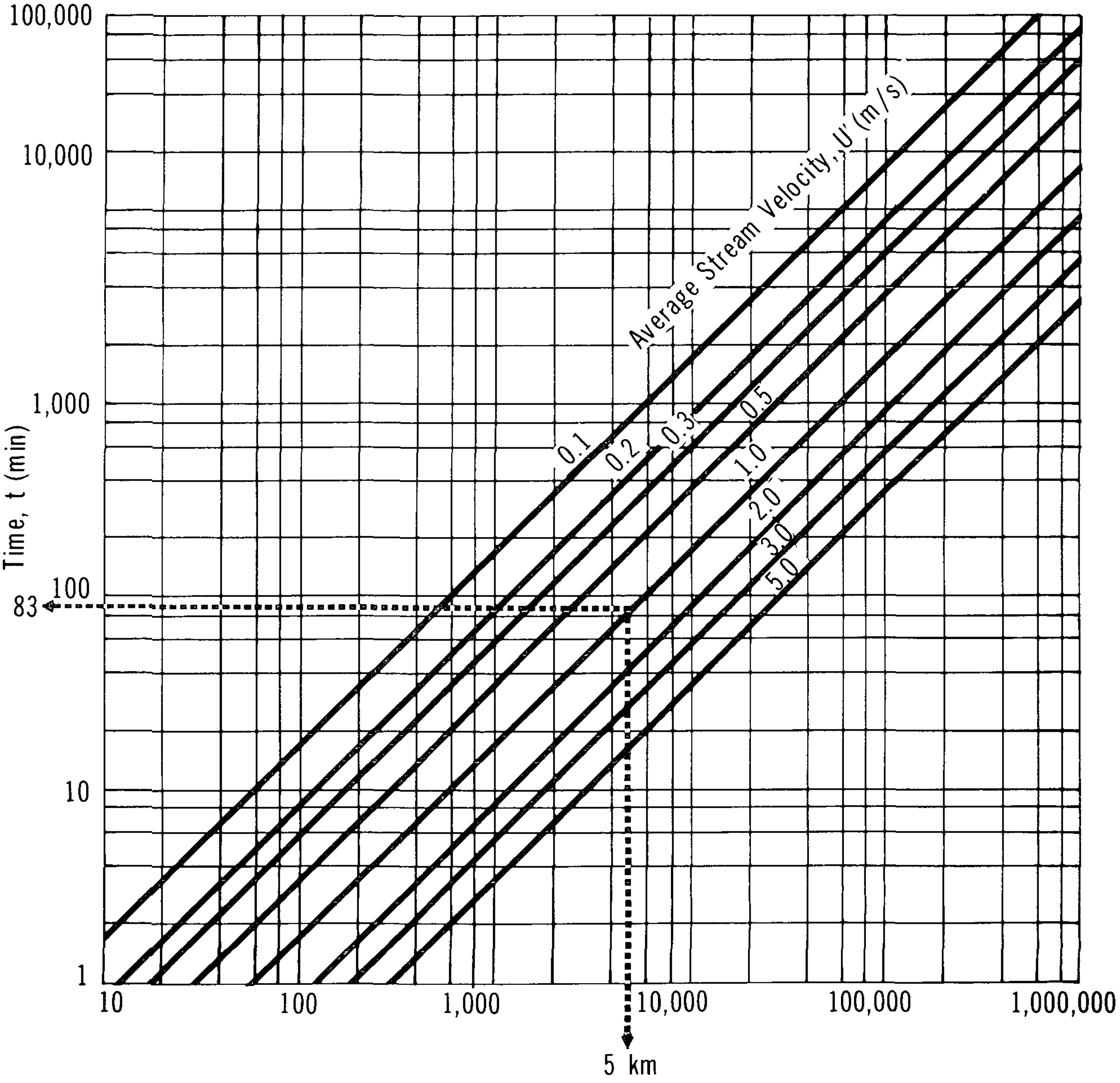


FIGURE 7

HYDRAULIC RADIUS VS CHANNEL WIDTH

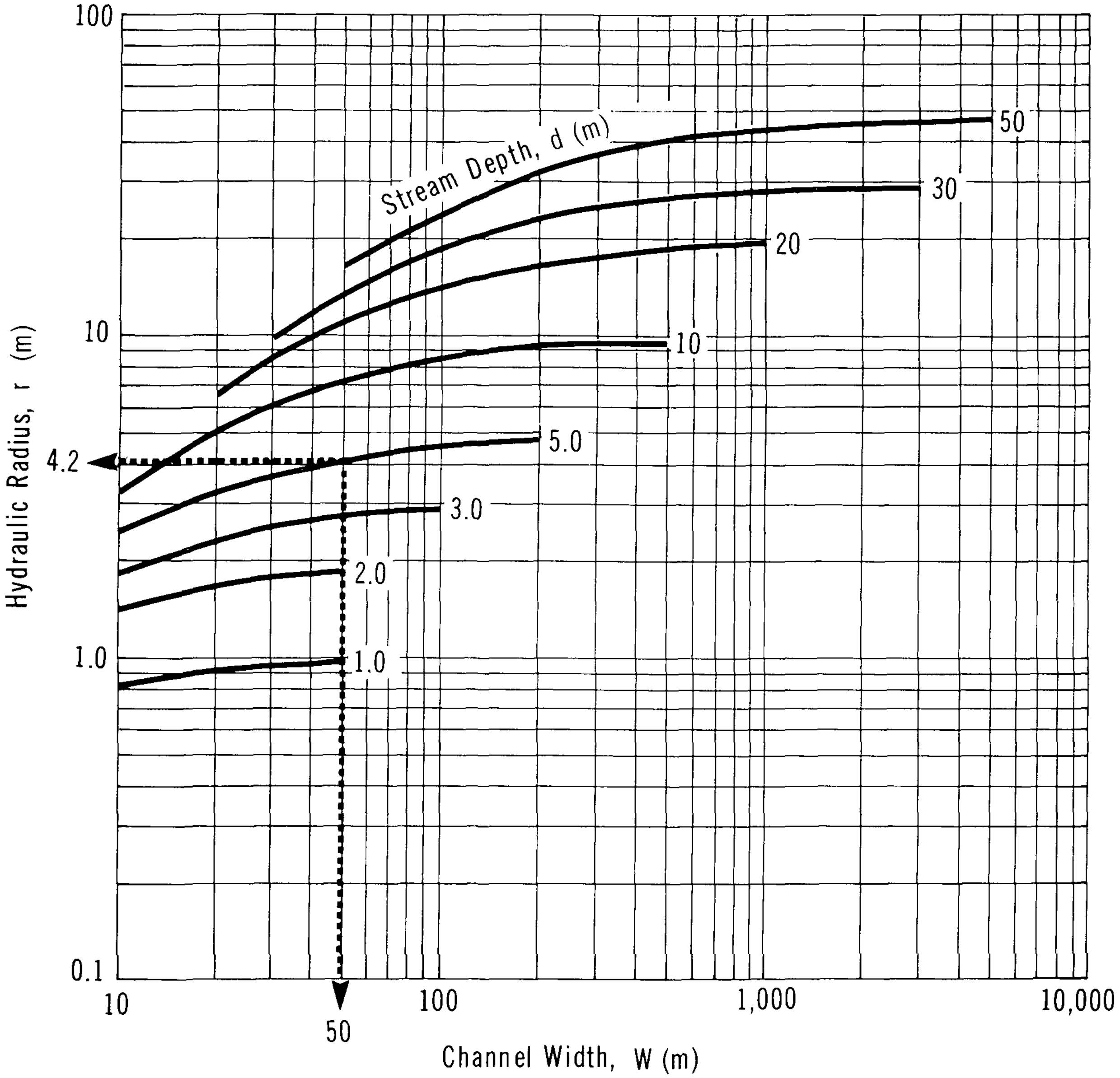


FIGURE 8

SODIUM CHLORIDE

DIFFUSION COEFFICIENT VS HYDRAULIC RADIUS

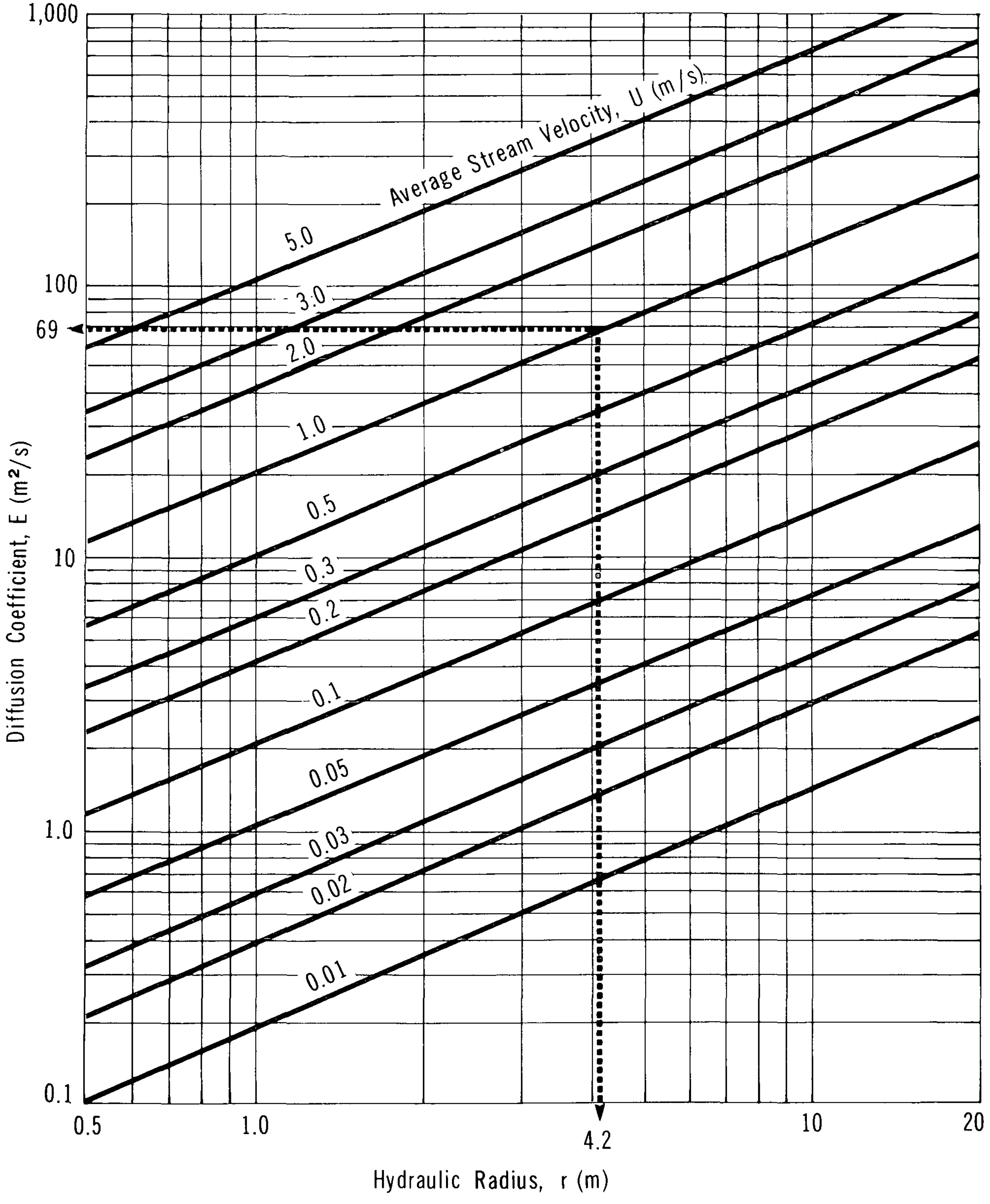
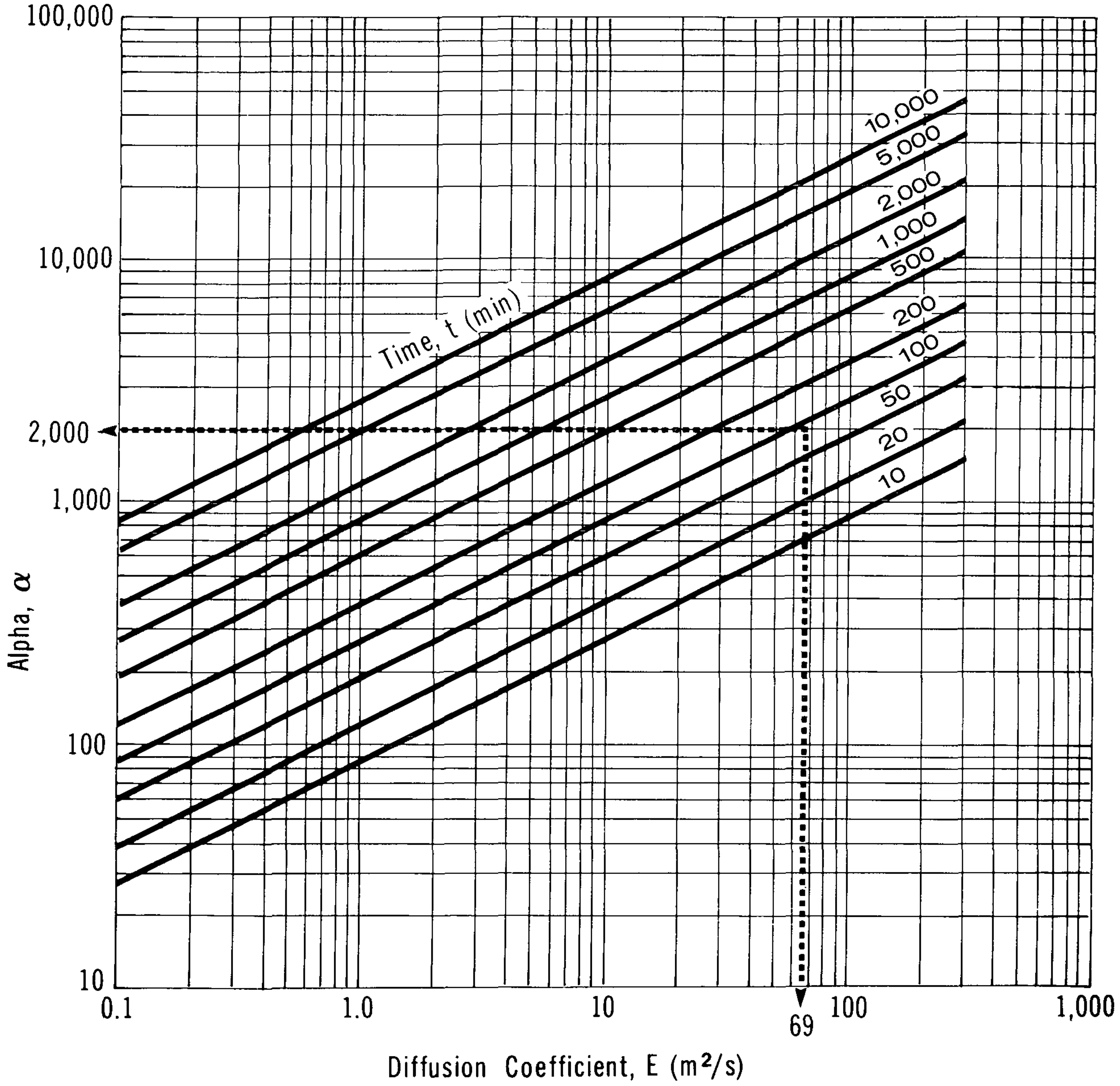


FIGURE 9

SODIUM CHLORIDE

ALPHA vs DIFFUSION COEFFICIENT



SODIUM CHLORIDE

ALPHA vs DELTA

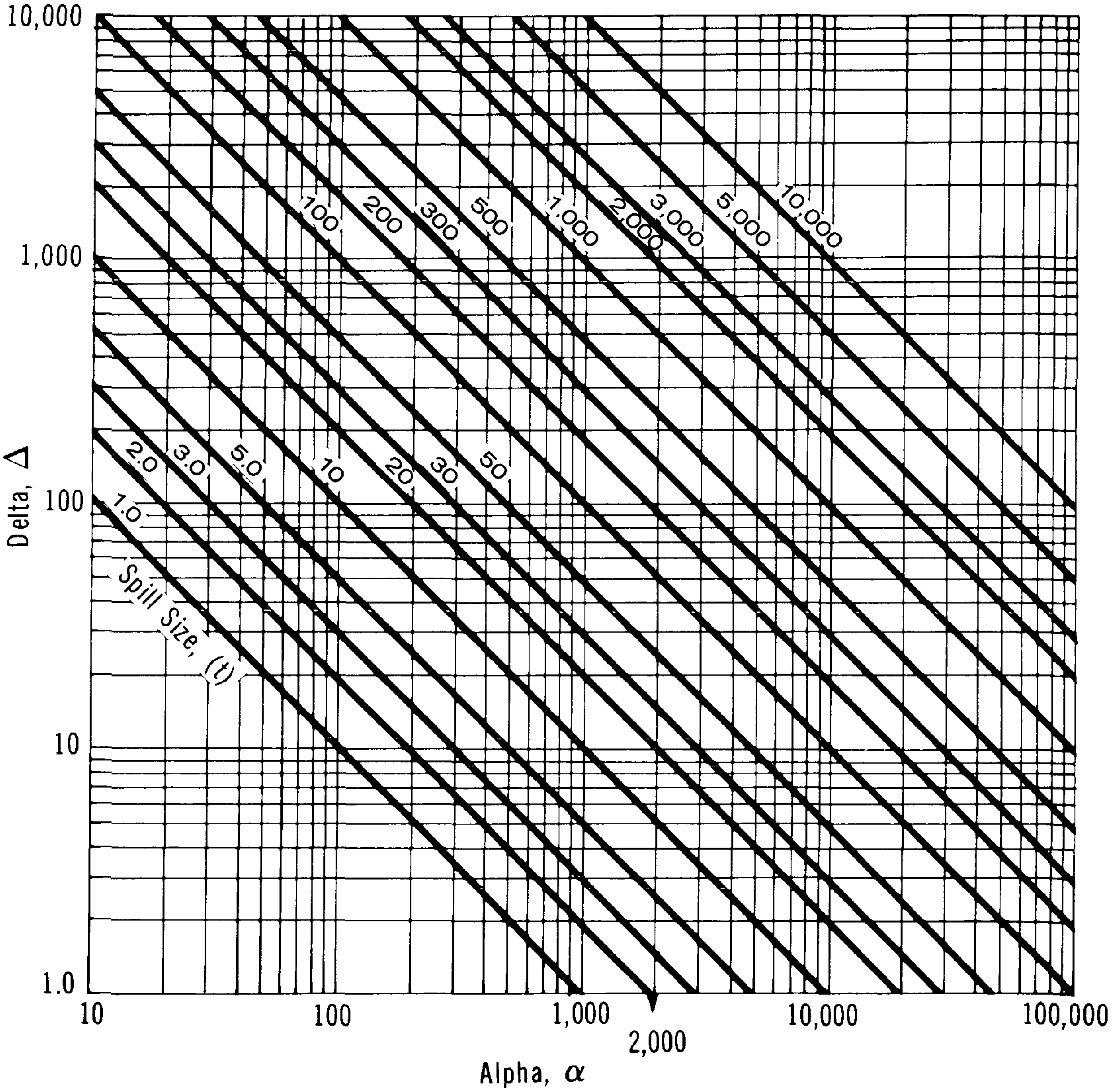
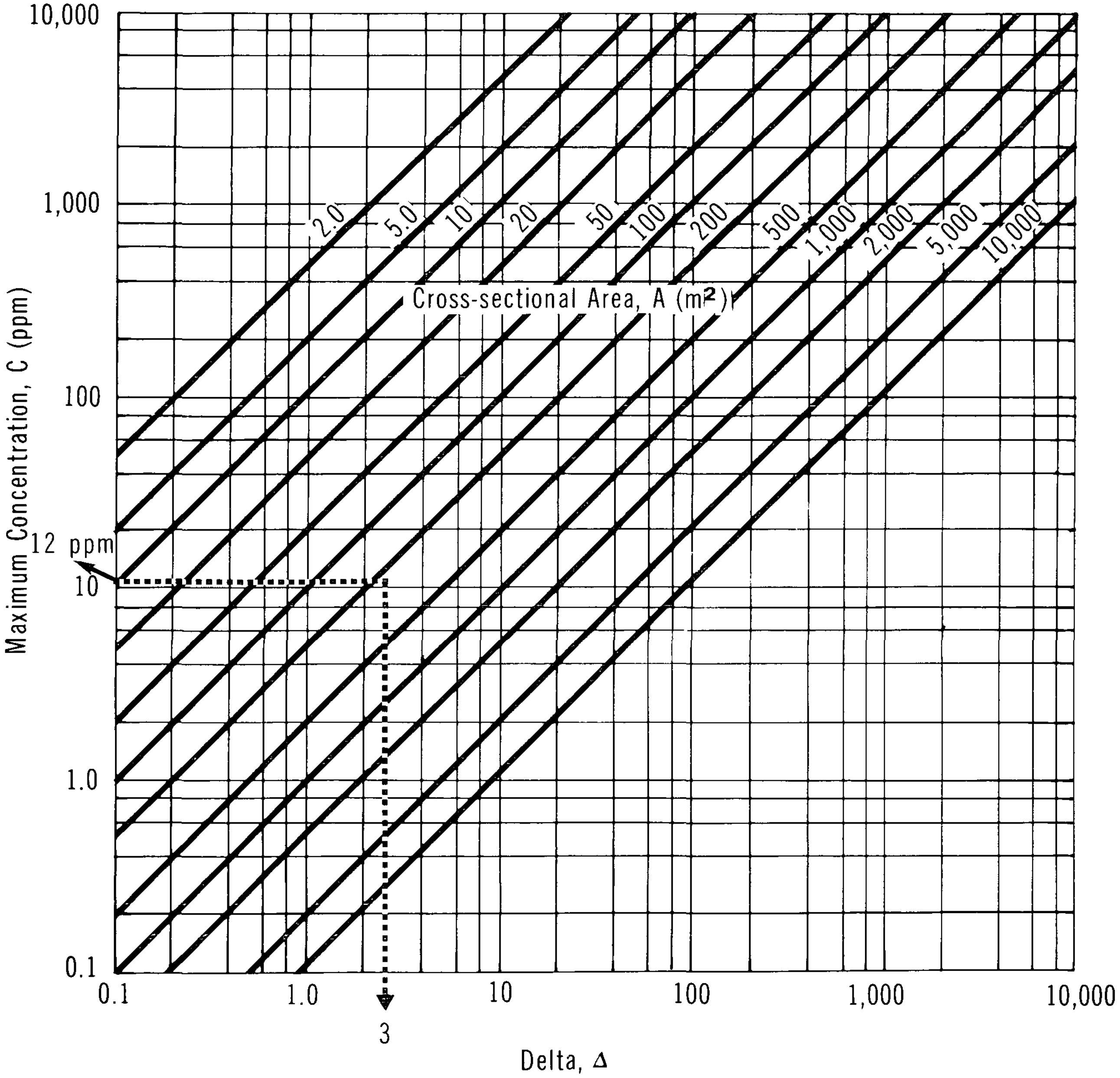


FIGURE 11

SODIUM CHLORIDE

MAXIMUM CONCENTRATION vs DELTA



5.3.2.2 Nomograms for lakes or still water bodies.

Figure 12: Volume versus radius. The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius (r) and length (d), equivalent to the depth of the lake at the point of the spill. The volume of water in the cylinder can be obtained from Figure 12. The radius (r) represents the distance from the spill to the point of interest.

Figure 13: Average concentration versus volume. For a known volume of water (within the idealized cylinder of radius (r) and length (d)), the average concentration of pollutant (C) can be obtained from Figure 13 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

5.3.3 Sample Calculations.

5.3.3.1 Pollutant concentration in a non-tidal river. A 6 tonne spill of sodium chloride has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

Solution

Step 1: Define parameters

- W = 50 m
- d = 5 m
- U = 1 m/s
- mass = 6 tonnes of sodium chloride
- X = 5,000 m

Step 2: Calculate time to reach point of interest

- Use Figure 6
- With X = 5,000 m and U = 1 m/s, t = 83 min

Step 3: Calculate hydraulic radius (r)

- Use Figure 7
- With W = 50 m and d = 5 m, r = 4.2 m

FIGURE 12

SODIUM CHLORIDE

VOLUME vs RADIUS

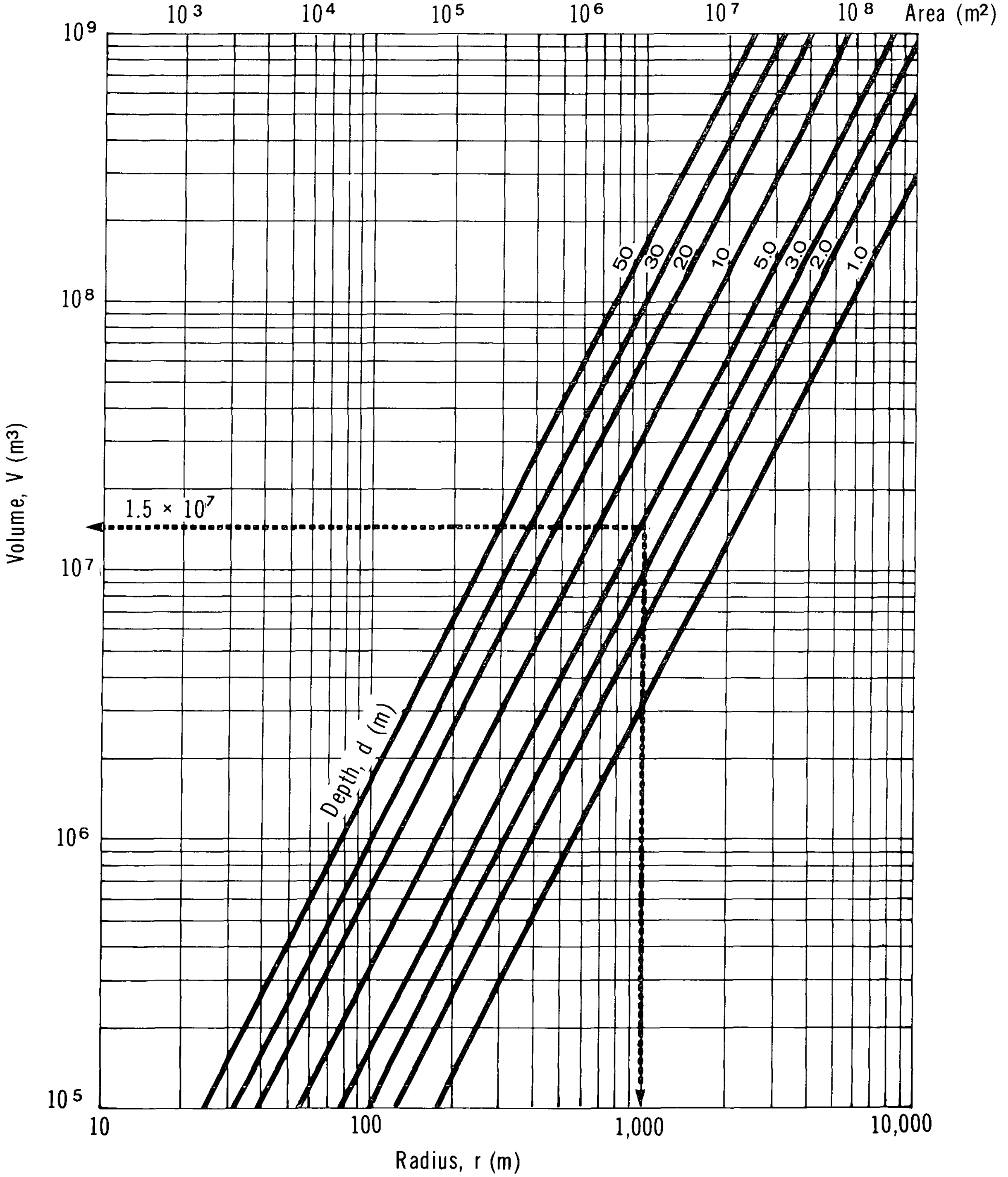
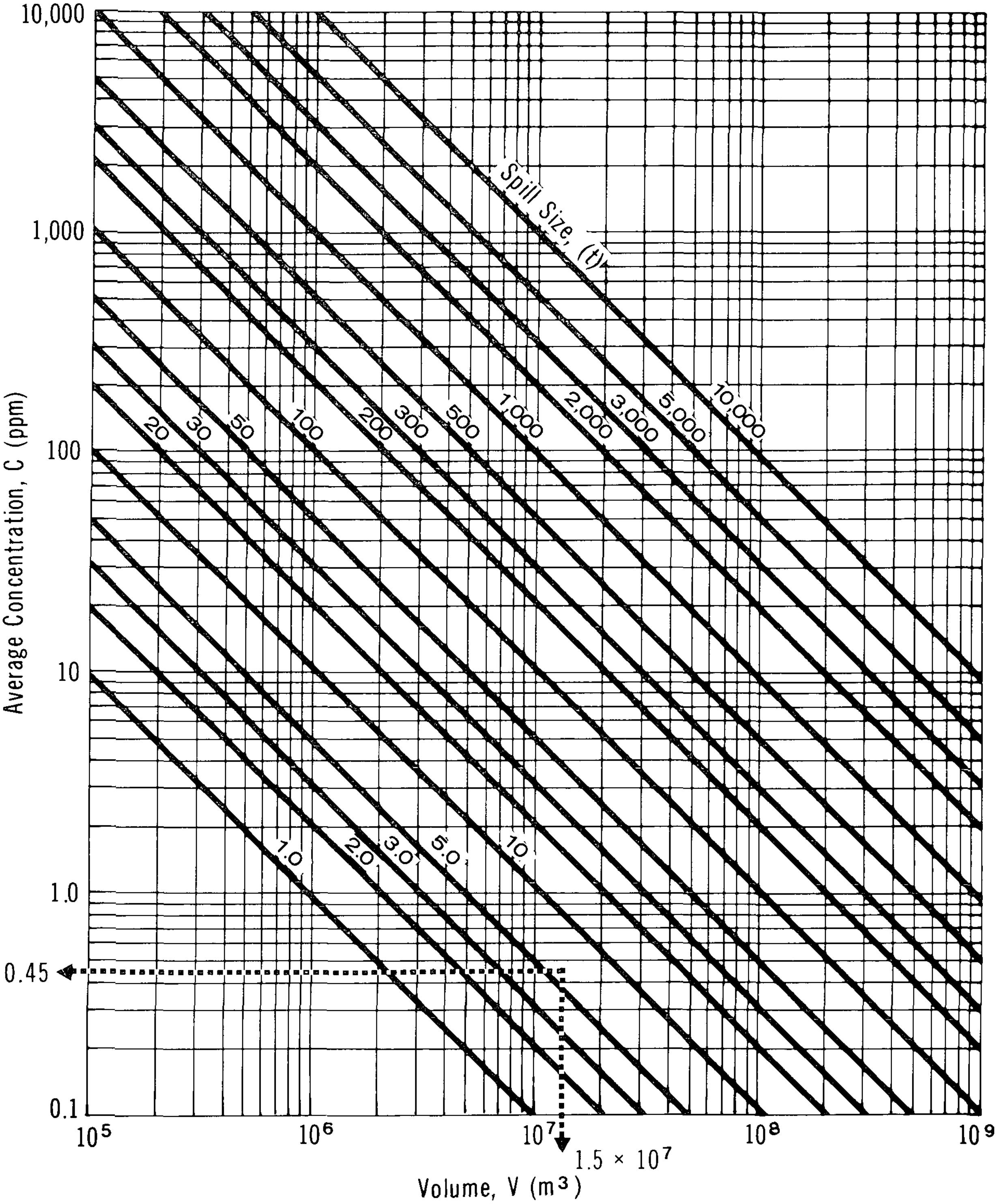


FIGURE 13

SODIUM CHLORIDE

AVERAGE CONCENTRATION vs VOLUME



Step 4: Calculate longitudinal diffusion coefficient (E)

- Use Figure 8
- With r = 4.2 m and U = 1 m/s, E = 69 m^2/s

Step 5: Calculate alpha (α)

- Use Figure 9
- With E = 69 m^2/s and t = 83 min, α = 2,000

Step 6: Calculate delta (Δ)

- Use Figure 10
- With alpha (α) = 2,000 and mass = 6 tonnes (pure sodium chloride), delta (Δ) = 3

Step 7: Compute stream cross-sectional area (A)

- $A = W \times d = 50 \times 5 = 250\ m^2$

Step 8: Calculate maximum concentration (C) at point of interest

- Use Figure 11
- With Δ = 3 and A = 250 m^2, C = 12 ppm

5.3.3.2 Average pollutant concentration in lakes or still water bodies. A 6 tonne spill of sodium chloride has occurred in a lake. The point of interest is located on the shore approximately 1,000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

Solution

Step 1: Define parameters

- d = 5 m
- r = 1,000 m
- mass = 6 tonnes (pure sodium chloride)

Step 2: Determine the volume of water available for dilution

- Use Figure 12
- With r = 1,000 m, d = 5 m, the volume is approximately $1.5 \times 10^7\ m^3$

Step 3: Determine the average concentration

- Use Figure 13
- With V = $1.5 \times 10^7\ m^3$ and mass = 6 tonnes, the average concentration is 0.45 ppm

5.4 Subsurface Behaviour: Penetration into Soil

5.4.1 Mechanisms. The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of salt (sodium chloride) onto soil and the transport downward through the soil are presented here.

Sodium chloride is conveyed as a solid and when spilled, a limited groundwater contamination hazard exists if the soil is dry and if no precipitation occurs prior to cleanup. However, if moisture is present prior to cleanup, groundwater contamination must be expected. The situation covered here deals with the production of an aqueous solution of sodium chloride (20 percent by weight) which can infiltrate the soil.

Since evaporation will be minimal, virtually all of the chemical will infiltrate the soil. Interaction between the soil and sodium chloride will occur to some degree in the form of ion exchange. However, much of the material plus exchanged ions will migrate downward.

If the soil surface is saturated with moisture at the time of the spill, as might be the case after a rainfall, the spilled chemical can run off. For this work, the soils have been assumed to be at field capacity. This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents a typical analysis.

Upon reaching the groundwater table, the solution will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with diffusion and dispersion serving to reduce the concentration somewhat. This is shown schematically in Figure 14.

5.4.2 Equations Describing Sodium Chloride Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.4.3 Saturated Hydraulic Conductivity of Sodium Chloride in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

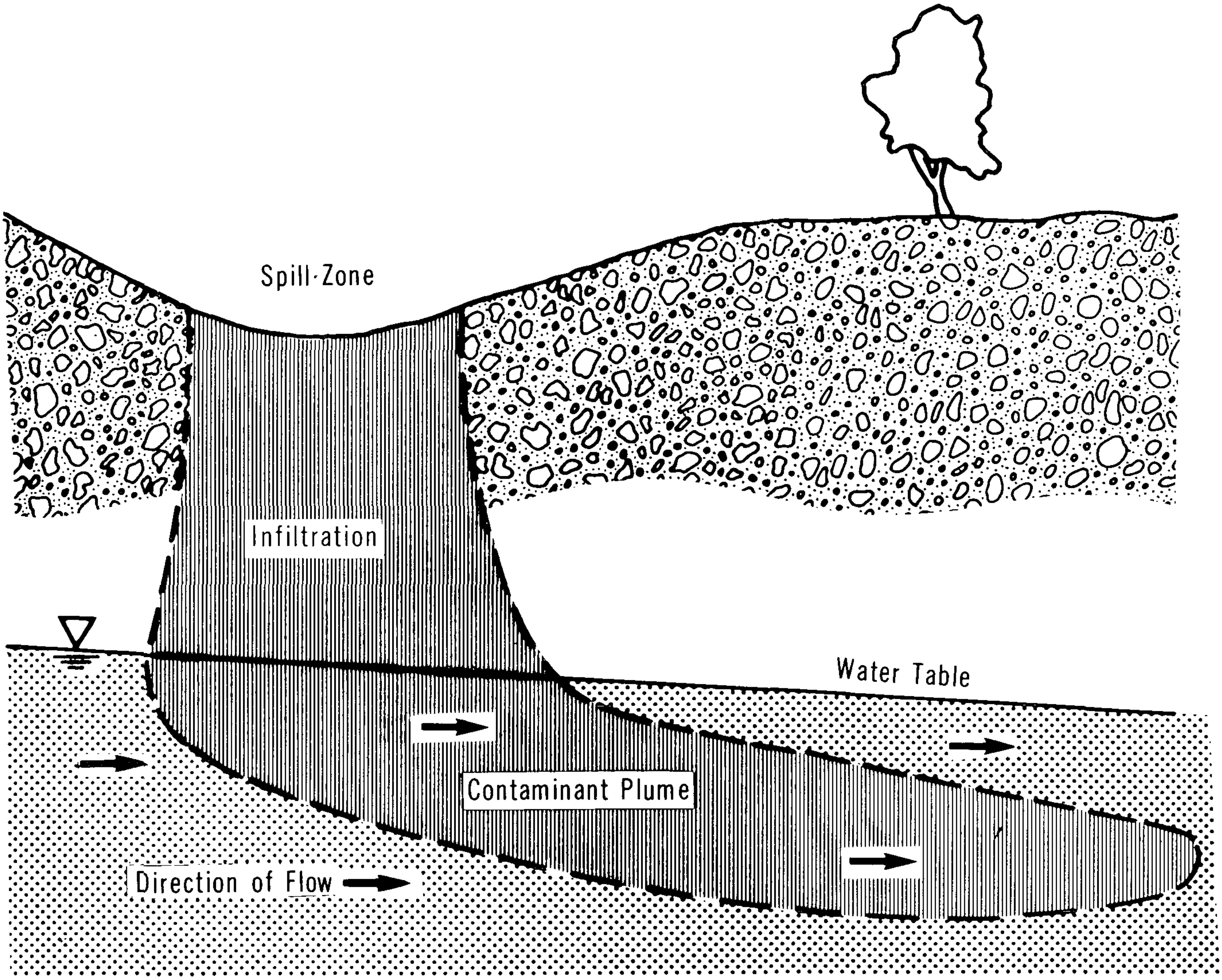
where:

k = intrinsic permeability of the soil (m2)

FIGURE 14

SODIUM CHLORIDE

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand
–Porosity (n) = 0.35
–Intrinsic Permeability (k) = 10^{-9} m^2
–Field Capacity (θ_{fc}) = 0.075

ρ = mass density of the fluid (kg/m^3)
μ = absolute viscosity of the fluid (Pa•s)
g = acceleration due to gravity = 9.81 m/s^2

The fluids involved are 20 percent sodium chloride by weight, and water. The water calculations represent the extreme as sodium chloride is diluted.

	Sodium Chloride (20%)		Water
Property	20°C	4°C	20°C
Mass density (ρ), kg/m^3	1,148	1,154	1,000
Absolute viscosity (μ), Pa•s	2.3×10^{-3}	3.2×10^{-3}	1.0×10^{-3}
Saturated hydraulic conductivity (K_o), m/s	$(0.49 \times 10^7)k$	$(0.35 \times 10^7)k$	$(0.98 \times 10^7)k$

5.4.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

	Soil Type		
Property	Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45

5.4.5 Penetration Nomograms. Nomograms for the penetration of sodium chloride into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time (t_p) plotted against depth of penetration (B). Because of the methods and assumptions used, the penetration depth should be considered as a maximum depth, in time t_p. A flowchart for the use of the nomograms is presented in Figure 15. The nomograms are presented as Figures 16, 17 and 18. The water line on the nomograms

FIGURE 15

FLOWCHART FOR NOMOGRAM USE

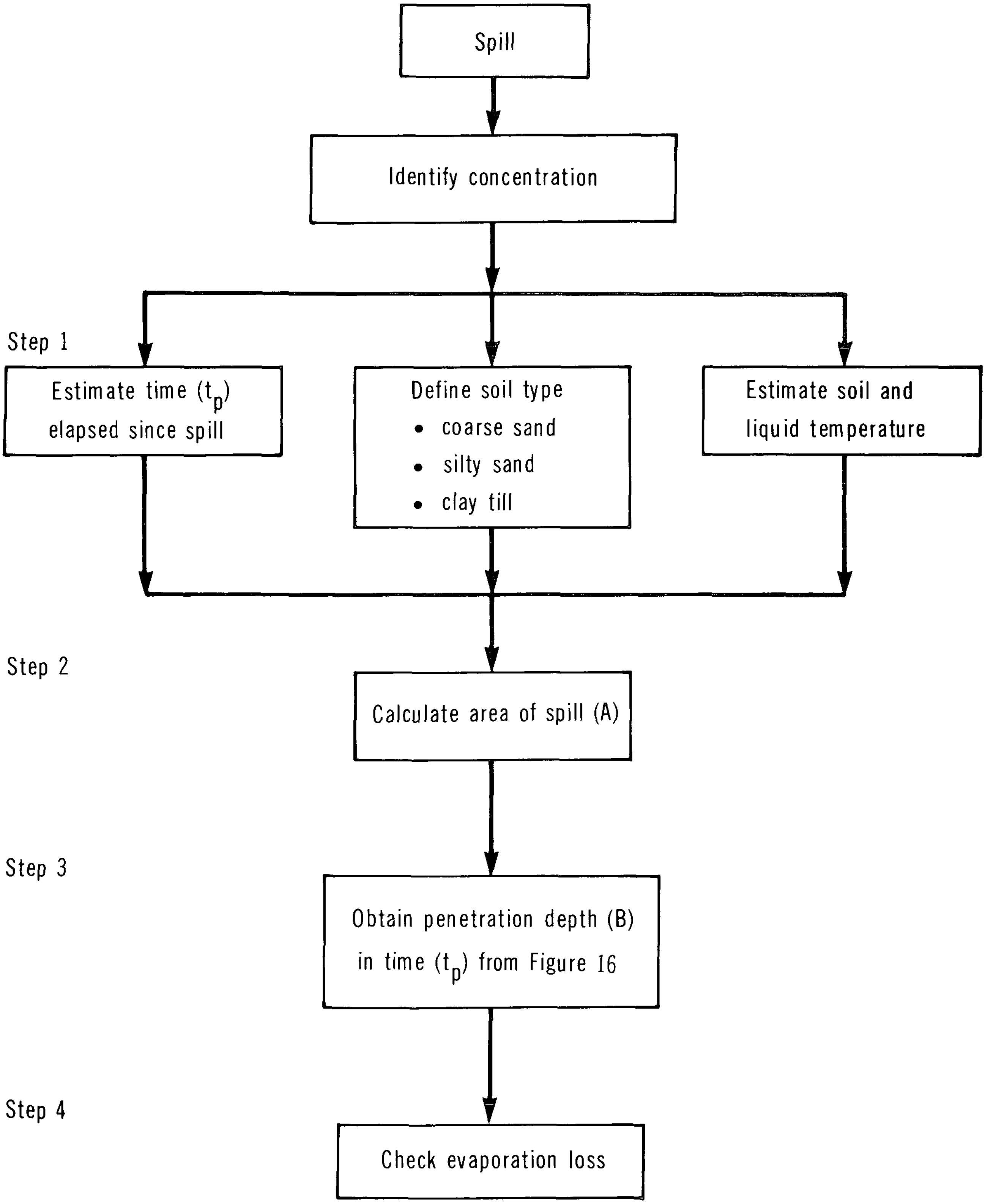
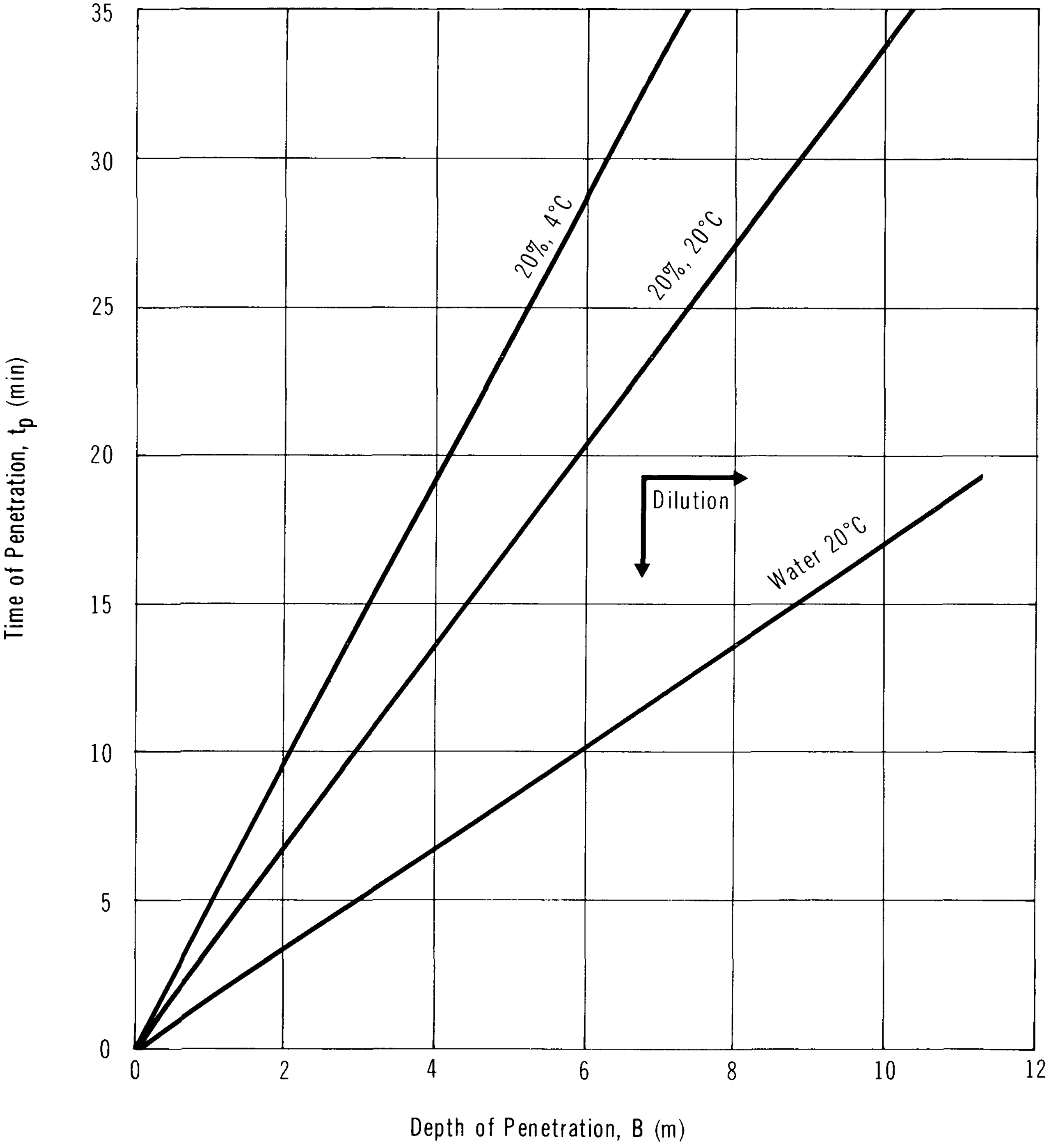


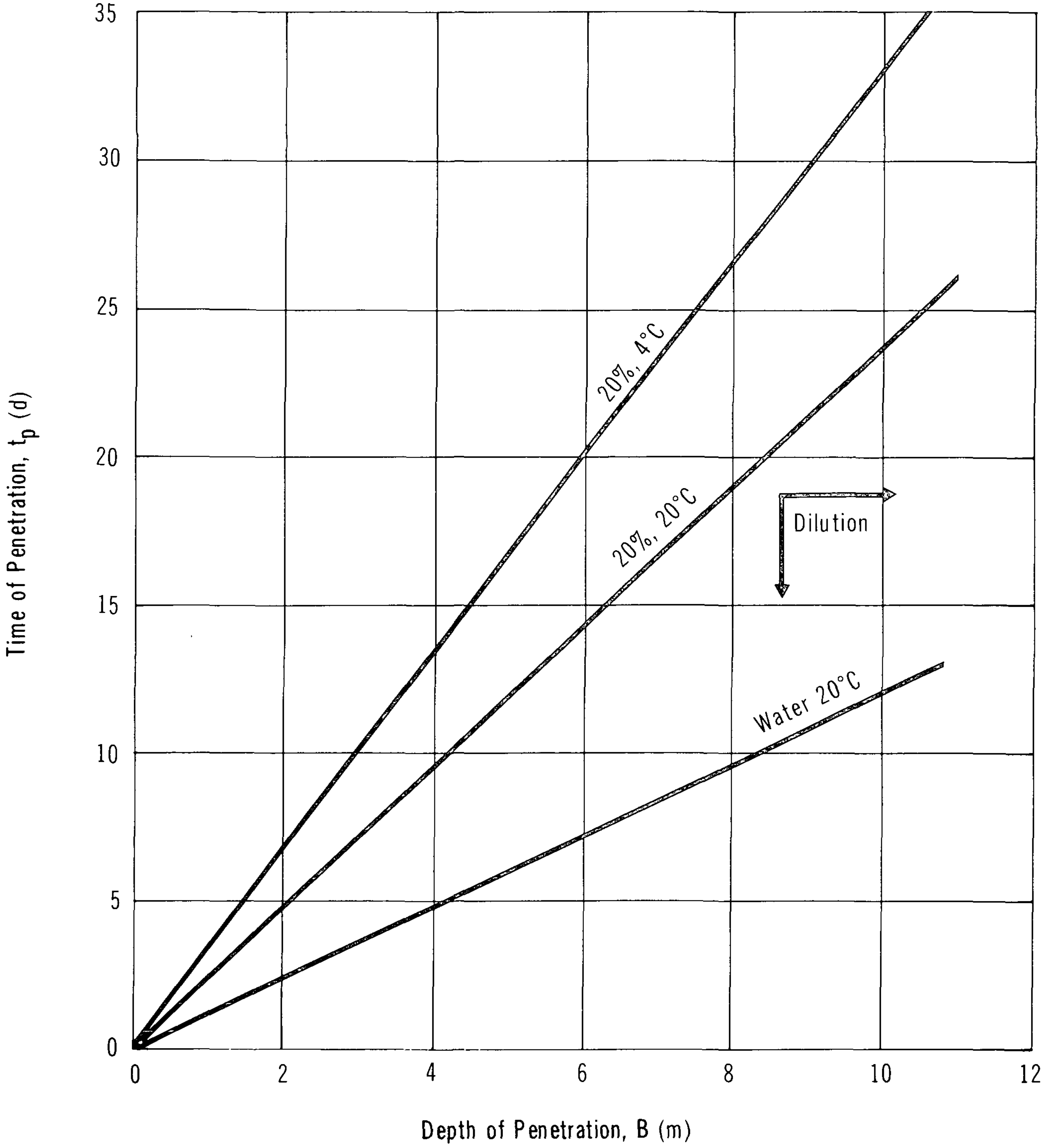
FIGURE 16

SODIUM CHLORIDE

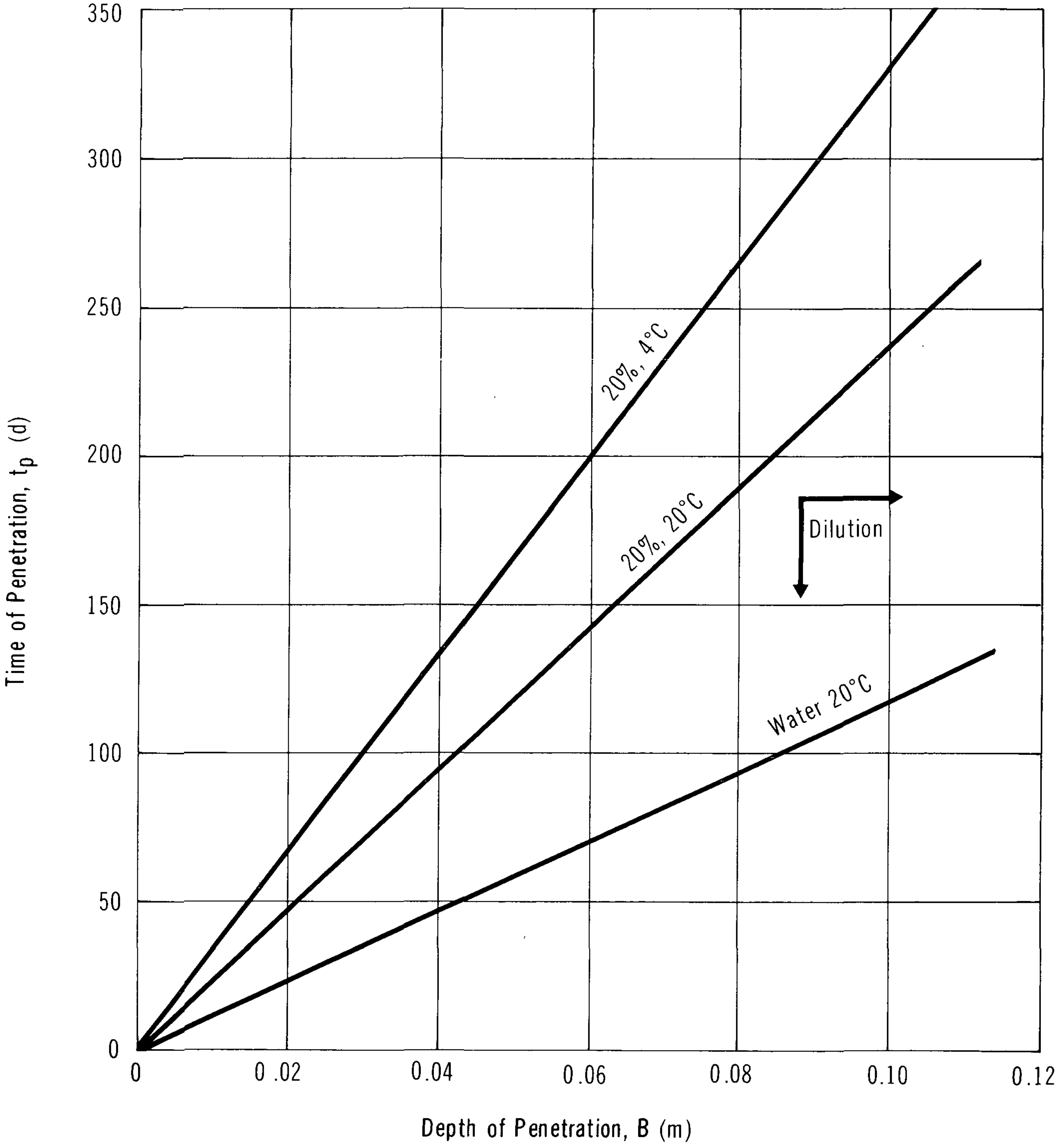
PENETRATION IN COARSE SAND



PENETRATION IN SILTY SAND



PENETRATION IN CLAY TILL



represents the maximum penetration of water at 20°C, in time t_p. It is a limiting condition as sodium chloride becomes diluted with water.

5.4.6 Sample Calculation. A 20 tonne spill of sodium chloride has occurred on coarse sand. Heavy precipitation follows this event and a 20 percent aqueous solution of sodium chloride results. The temperature is 20°C; the spill radius is 8.6 m. Calculate the depth of penetration 35 minutes after the spill and check the corresponding evaporation loss.

Solution

Step 1: Define parameters

- Mass spilled = 20,000 kg (20 tonnes)
- T = 20°C
- r = 8.6 m
- Soil = coarse sand
- Groundwater table depth (d) = 13 m
- Time since spill (t_p) = 35 min

Step 2: Calculate area of spill

- $A = \pi r^2 = 232\ m^2$

Step 3: Estimate depth of penetration (B) at time (t_p)

- For coarse sand, B = 10.3 at t_p = 35 min
- Groundwater table has not been reached in this time

Step 4: Check evaporation loss

The evaporation of 20 percent sodium chloride spilled is negligible under conditions of the spill

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Drinking Water.

6.1.1.1 Canada. The maximum acceptable concentration for domestic, agricultural and industrial uses is 250 mg Cl^-/L (GCDWQ 1978). The desirable concentration in drinking water is less than 250 mg Cl^-/L (WQS 1979). Greater than 250 mg/L of chloride in water is found to impart undesirable tastes to water and to beverages prepared from water (GCDWQ 1978). Appropriate health authorities should be notified if the sodium concentration exceeds 20 mg/L in drinking water (GCDWQ 1978).

For irrigation, the permissible water quality standards are 150 mg Cl^-/L; the desirable limit is less than 70 mg Cl^-/L (NRCC 1980).

6.1.1.2 Other. The U.S. surface water criterion (1968) for public water supplies is a permissible limit of 250 mg/L of chloride. The desirable limit is less than 25 mg/L. The recommended drinking water standard (U.S., 1962) for chloride is 250 mg/L (WQCDB-2 1971).

6.1.2 Air. No limits or guidelines have been found. Emissions to air from mining and refining are 3,000 tonnes per year (813 tonnes from brine processes and 2,200 tonnes from rock salt mining) (NRCC 1980).

6.2 Aquatic Toxicity

6.2.1 Canadian Toxicity Rating. No recommendations for chloride have been set in Canada to protect aquatic life (WQS 1979). As salinity in natural waters begins to exceed 3,000 mg/L, aquatic life will be affected; as salinity increases, species will begin to be eliminated (NRCC 1980).

Road salt has affected the quality of the Great Lakes water by increasing the chloride levels in Lakes Erie and Ontario from 7 mg/L (in 1900) to 25 mg/L (in 1960), to 28 mg/L (in 1978) (NRCC 1980).

6.2.2 U.S. Toxicity Rating. Sodium chloride has been assigned a TL_m96 (4-day median lethal toxicity rating) of over 1,000 mg/L (RTECS 1979).

6.2.3 Measured Toxicities.

6.2.3.1 Freshwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Toxicity Tests					
17.9	96	American eel (glass eel stage)	LC_{50}	pH 7.2 to 7.6; 22°C	Spehar 1981
2,900	192 to 216	Sticklebacks	LC_{50}		NRCC 1980
30 (Na^+)	96	Bluegill sunfish	LC_{50}	$NaAsO_2$, 13-14°C	WQCDB-5 1973
12,940	96	Bluegill sunfish	LC_{50}	synthetic dilution water	WQCDB-5 1973
18,100	48	Mosquito fish	LC_{50}	turbid water	WQC 1972
13,750	24	Minnows	LC_{50}		WQC 1972
420 (Na^+)	48	Mosquito fish	LC_{50}	turbid; $Na_2Cr_2O_7$	WQC 1972
26 (Na^+)	96	Rainbow trout	LC_{50}	$NaAsO_2$, 13-24°C	WQC 1972
29 (Na^+)	48	Spottail shiner	LC_{50}	$NaAsO_2$	WQC 1972
Fish Kill Data					
5% solution	15 min	Brook trout	death		Spehar 1981
2,500	216 to 576	River shiner	lethal		NRCC 1980
Microorganisms					
2,430	5 days	*Nitzchia linearis* (diatom)	LC_{50}	synthetic dilution water	WQCDB-5 1973
1.4	not stated	Daphnids (*Simocephalus*)	threshold of immobilization	26°C	WQC 1972

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
3,630	64	*Daphnia magna*	50% immobilization	Lake Erie water, 25°C	WQCDB-3 1971

Conc. (mg/L)	Species	Result	Water Conditions	Reference
Plants				
4,800	*A. falcatus* (green algae)	50% growth inhibition	lake	Nriagu 1979
29,000	*A. falcatus* (green algae)	100% growth inhibition	lake	Nriagu 1979
4 (Na^+)	Zooplankton	significant reduction	$NaAsO_2$, lake	WQC 1972
4 (Na^+)	Pondweed	complete decomposition in 2 weeks	lake	WQC 1972
4 (Na^+)	*Cladophora* (green algae)	complete decomposition in 2 weeks	lake	WQC 1972
9,000	*Potamogeton* (Pondweed)	completely inhibited growth of plants 1 week		WQCDB-3 1971
15,000	Pondweed	reduced growth completely; fatal to some		WQCDB-3 1971

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Invertebrates					
50,000 to 60,000	not stated	Water boatmen	death	lake	NRCC 1980

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
5 to 40% salinity	not stated	Crab larvae	45 to 100% mortality	15 to 19°C	Jorgensen 1979
15 to 48% salinity	not stated	Crab larvae	100% mortality	14°C	Jorgensen 1979
6,200	96	Snails	LC_{50}		WQC 1972
9,000	24	Caddis flies	LC_{50}	soft	WQC 1972
45	96	Stone flies	LC_{50}	$NaAsO_2$, 15.5°C	WQC 1972
895	24	Amphipoda (scuds)	LC_{50}	$NaSiO_3$	WQC 1972
1.0%	36 min	*Nais* sp. (worms)	median survival time	hard	WQCDB-3 1971

6.3 Toxicity to Other Biota

6.3.1 Livestock.

Conc. (mg/L)	Species	Result	Water Conditions	Reference
1.0 to 2.1 g/kg	Turkey (3 mo. old)	physiological level in liver		Kacmar 1980
2.5 g/kg	Turkey poults (1 to 12 d of age)	high mortality; edema and ascites occurred	90 or 105 mM NaCl in tap water	Pang 1979
5% NaCl in protein supplement	Cattle	2 of 6 died, CNS derangement		Sandals 1978
7,000 (360 mg/kg/d)	Cattle	reduction in weight	drinking water	WQCDB-2 1971
15,000 (800 mg/kg/d)	Cattle	reduced water intake	drinking water	WQCDB-2 1971

Conc. (mg/L)	Species	Result	Water Conditions	Reference
15 to 17,600 (8 to 900 mg/kg/d)	Cattle	sickened or killed	drinking water	WQCDB-2 1971

6.3.2 Avian.

Conc. (g/kg)	Species	Result	Reference
0.95 to 2.37	Pheasants	physiological level in liver	Kacmar 1980
3.4; 5	Pheasants	2.5- to 6-fold increased concentration in liver	Kacmar 1980

6.3.3 Plants.

Conc. (mg/g)	Species	Result	Reference
not started (deicing salt)	White cedar	necrosis of foliage, with relative humidity at 91 to 100%	Foster 1980
>4 (Cl^-)	Conifers	injured trees, increased chloride in foliage	NRCC 1980
4 to 10	Maples	injured trees, increased chloride in foliage	NRCC 1980
5	Kentucky 31 Fescue (grass)	slightly injured	NRCC 1980
10% (after 28 days of flowering)	Rice	reduced yield to 41%	Samantaray 1979
12 g/L	Sunflower	inhibited germination by 40%	Gharsalli 1979

6.4 Effect Studies

6.4.1 Livestock. An acute excess of sodium in the diet of animals is accompanied by a gain in body water content leading to an increase in fluid volume, intracellular dehydration, and eventually in death, since the normal concentration of sodium which the kidney can eliminate in the urine is below that of the fluid ingested. Dietary requirements and toxic levels of sodium are impossible to define without a quantitative knowledge of other dietary components.

The sodium level in various animal feeds are: (i) fresh grass, 0.2 to 2.5 g/kg (depending on level of potash fertilization); (ii) cereal grains, 0.1 to 0.7 g/kg; and (iii) fresh leguminous crops, 2 to 8 g/kg (NRCC 1980).

In general, animals can tolerate quite high levels of salt in their diets provided there is a plentiful supply of nonsaline water available. Excess salts in the drinking water are harmful (Sandals 1978).

Quality of saline water (dissolved solids) for livestock is: good - 100 mg/L; poor (but usable) - 2,500 to 4,000 mg/L; and toxic - greater than 10,000 mg/L (NRCC 1980).

6.4.2 Plants. Certain fruit crops are sensitive to elevated chloride levels in irrigation water supplies. Large amounts of sodium are also injurious to these plants (WQS 1979).

Vegetation growing near roadways is adversely affected by road salt through: (i) absorption of salts through roots in both summer and winter, and (ii) salt splashing directly onto the aerial portions of the plant during winter.

Grasses are more tolerant to high salt concentrations than are trees. Injury to most grasses is evident when soil sodium chloride exceeds 1 g/kg (NRCC 1980).

Studies have shown that in various tree species, the frequency of changes in concentrations of essential elements in response to salt occurred as often in the salt-tolerant as in the salt-sensitive species (Townsend 1980).

6.5 Soil

6.5.1 Effects on Soil Chemistry (NRCC 1980). The main sources of environmental exposure to sodium chloride are mining and road salt use. The presence of excessive amounts of sodium and chloride ions in soils results in reduced soil fertility.

Repeated applications of road salt result in increased saline concentration in the soil along the roadways and produce a deterioration of the physical properties of the soil.

6.6 Other Effects

Crude sodium chloride may be stored in large, above-ground piles where leaching by rain water may contaminate groundwater and nearby surface water (NRCC 1980).

7 HUMAN HEALTH

Sodium chloride is a metabolically essential compound. It is a common household chemical and is, generally speaking, a material of low health risk. At standard temperature and pressure, it is a stable crystal. Inhalation of the finely divided powder may cause local irritation. Its principal systemic effect is to increase blood pressure, which may be a hazard to individuals susceptible to hypertension. There is no information available to date on the mutagenic or carcinogenic effects of sodium chloride exposure. One study reported a teratogenic effect on mice at the level of 1,900 mg/kg.

No monographs or studies dealing with the toxic effects of sodium chloride were found. The data summarized here are representative of information available in current handbooks and on-line toxicity data bases.

The toxicological data summarized here have been extracted from reliable standard reference sources only. It should be noted that some of the data are for chronic (long-term), low level exposures and may not be directly applicable to spill situations. Only acute (short-term) exposure data are given for non-human mammalian species, to support interpretation of the human data where appropriate.

7.1 Recommended Exposure Limits

There are no recommended exposure standards for sodium chloride.

7.2 Irritation Data

7.2.1 Skin Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rabbit		
500 mg/kg (24 h)	Mild irritation	RTECS 1979
50 mg/kg (24 h)	Mild irritation	RTECS 1979

7.2.2 Eye Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rabbit		
100 mg	Mild irritation	RTECS 1979
100 mg (24 h)	Severe irritation	RTECS 1979

7.3 Threshold Perception Properties

7.3.1 Odour. No data.

7.3.2 Taste.

Parameter	Media	Concentration (in Moles/Litre)	Reference
Detection Threshold	In water	4.7×10^{-3}	ASTM 1978
Recognition Threshold	In water	2×10^{-3}	ASTM 1978
Recognition Threshold	In water	7.4×10^{-3}	ASTM 1978
Recognition Threshold	In water	6.8×10^{-3}	ASTM 1978
Recognition Threshold	In water	5.6×10^{-3}	ASTM 1978
Recognition Threshold	In water	2.2×10^{-3}	ASTM 1978
Taste Threshold	In water	210 - 500 mg/L	GCDWQ 1978

7.4 Long-term Studies

7.4.1 Inhalation. No data.

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
12,357 mg/kg	TD_{LO}, Blood pressure effects	RTECS 1979
8,200 mg/kg (23 d)	TD_{LO}, Blood pressure effects	ITII 1981
SPECIES: Rabbit		
8,000 mg/kg	LD_{LO}	RTECS 1979

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
3,000 mg/kg	LD_{50}	RTECS 1979
SPECIES: Mouse		
4,000 mg/kg	LD_{50}	RTECS 1979

7.4.3 Subcutaneous.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Guinea Pig		
2,160 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Rat		
3,500 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Mouse		
3,150 mg/kg	LD_{50}	RTECS 1979
1,900 mg/kg	TD_{LO}, Teratogen in mice 10 to 11 days pregnant	RTECS 1979

7.4.4 Intravenous.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Dog		
2,000 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Rabbit		
1,100 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Guinea Pig		
2,910 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Mouse		
645 mg/kg	LD_{50}	RTECS 1979

7.4.5 Intraperitoneal.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Dog		
364 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Mouse		
2,602 mg/kg	LD_{50}	RTECS 1979

7.4.6 Carcinogenicity and Mutagenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Mouse		
1,900 mg/kg (subcutaneous)	TD_{LO}, Teratogen in mice 10 to 11 days pregnant	RTECS 1979

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their sources indicated.

7.5.1 Inhalation. Sodium chloride salts have a very low level of toxicity. The following symptoms will occur only when large amounts of fine dust are inhaled:

1. Slight nose irritation.
2. Sneezing.

7.5.2 Ingestion.

1. Disagreeable taste.
2. Nausea and vomiting.
3. Gain in body water, hypertoxicity (NRCC 1980).
4. In infants, excessive amounts cause coma and convulsions which may be persistent due to vascular injury (Dreisbach 1980).
5. Hypertension.

7.5.3 Skin Contact. The following symptoms may occur only when concentrated solutions remain in contact with skin:

1. Irritation.
2. Inflammation.
3. Small ulcerations.

7.5.4 Eye Contact.

1. Mechanical irritation.
2. Watering of eyes.
3. Inflammation of conjunctiva.
4. If sodium chloride is heated to high temperature, it emits a vapour which is irritating to the eyes.

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Sodium Chloride with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
<u>GENERAL</u>														
Water										•		•		Kaufmann 1960
Heat						•						•	Salt will decompose at 820°C	Kaufmann 1960
<u>SPECIAL CHEMICALS</u>														
Bromine Trifluoride												•		Sax 1979
Lithium		•											Sodium chloride extinguishers should not be used on lithium fires as sodium forms and results in a more violent fire	NFPA 1978
Sulphuric, nitric, boric or oxalic acids						•	•						Sodium chloride is decomposed by these acids to yield a sodium compound and chlorine or hydrochloric acid	Kaufmann 1960

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a review of the literature. To avoid any deviation from the intended meaning, the wording of the original source has been presented essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. These procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Sodium chloride is a noncombustible material. In case of fire involving sodium chloride, use extinguishing measures suited for the material that is burning. Avoid spraying water on sodium chloride if possible as this will complicate cleanup.

9.1.2 Spill Actions.

9.1.2.1 General. Stop or reduce discharge of material if this can be done without risk.

9.1.2.2 Spills on land. When spilled, solid sodium chloride can be promptly shovelled into steel drums for recovery or disposal. Aqueous solutions can be pumped into tank trucks for recovery or disposal.

For spills of aqueous solutions (Teal 1981; McLean 1981; Webster 1975):

(i) On organic soils (typically forested areas and some agricultural areas): recover any surface pool if possible and then flush with water to dilute. Immediately counteract with chemicals (preferably a mixture of calcium nitrate and gypsum (calcium sulphate) in a ratio of 1:4) in order to obtain a concentration of 1 Ca^{++} for 3 Na^{+}. If a poor ground cover exists, cover with peat moss.

(ii) On surface or groundwater spills: flush with great amounts of water and counteract with gypsum (calcium sulphate) in order to obtain a concentration of 1 Ca^{++} for 4 Na^{+}. When chloride concentrations are below 1,000 ppm, discontinue flushing and monitor for damage.

(iii) On mineral soils (typically agricultural areas): do not flush but counteract with chemicals as in (i) in order to obtain a concentration of 1 Ca^{++} for 3 Na^{+}. Do not use calcium nitrate if the spill is near a stream containing fish. Following the chemical treatment, spread a 5 cm layer of manure, peat moss or old hay on the surface of the spill site.

10 PREVIOUS SPILL EXPERIENCE

Although frequent spills of sodium chloride have occurred, no documentation of spill experiences which offers good cleanup information has been located.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for analyses of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g. commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Methods for the Detection of Sodium Chloride in Air

11.1.1 Specific Ion Electrode (NIOSH 1977). The range of concentrations of chloride which may be determined is 0.1 to 1,750 mg/m^3 when a 200 L air sample is taken (0.04 to 732 ppm sodium chloride).

A measured volume of air, approximately 200 L, is drawn through an impinger containing 10 mL of acetate buffer at a flow rate of 2.0 L/min. The sample is transferred to a 50 mL beaker and the pH is adjusted to 5 with acetate buffer or acetic acid. The acetate buffer is prepared by dissolving 41 g of sodium acetate in 1 L of water and adjusting the pH to 5 with acetic acid. The chloride ion concentration is measured using a chloride ion electrode and double junction reference electrode. To avoid interference, the chloride level must be 300 times the bromide level, 100 times the thiosulphate level and 8 times the ammonia level. Poisoning of the electrode may result if sulphide ion is present. The method is quite simple and rapid.

11.1.2 Titration (APHA 1977). This procedure is applicable to extracting solutions containing between 2 and 240 mg/L chloride. This is equivalent to 0.3 to 40 ppm chloride in air when a 200 L air sample is taken.

Gaseous chlorides in air are collected using fritted glass absorbers or impingers. Particulate chlorides are collected by filtration, impingement or electrostatic precipitation. The sample is extracted with water. The volume of water should be less than 50 mL and the extract should contain between 12 and 0.1 mg of chloride ion in solution. (Dilution may be necessary.) The solution is titrated with 0.014 N mercuric nitrate solution using a mixed diphenylcarbazone-bromophenol blue indicator to a blue-violet end point. The upper limit of detection can be extended indefinitely by using more concentrated or larger volumes of titrant or by appropriate aliquotting. Heavy metal ions can change the colour of the end point but do not affect the accuracy. No more than 2.5 mg of ferric ion plus chromate ion may be present. Sulphites and sulphides, if present, must be discharged using hydrogen peroxide. Iodide, bromide, cyanide and thiocyanate are titrated and reported as chloride. The method is simple and uses standard laboratory equipment.

11.2 Qualitative Method for the Detection of Sodium Chloride in Air

The sample is collected as described in Section 11.1.2 above and extracted with water. The presence of a halogen may be determined by the formation of a white precipitate when 0.1 N silver nitrate is added to the acidified solution.

The precipitate is insoluble in acid but soluble in a slight excess of ammonia (Moeller 1958). A flame may be used to detect sodium. The presence of an intense, yellow flame indicates that sodium is present in the solution (Moeller 1958).

11.3 Quantitative Methods for the Detection of Sodium Chloride in Water

11.3.1 Colourimetric (ASTM 1979). Chloride concentrations ranging from 0.02 to 10 ppm in water may be determined.

Representative samples of at least 50 mL are collected in glass bottles. Ferric alum solution is prepared by dissolving 5 g of ferrous ammonium sulphate in 20 mL of water, adding 38 mL of concentrated nitric acid and diluting to 100 mL. Mercuric thiocyanate solution is prepared by dissolving 0.30 g of mercuric thiocyanate in 100 mL of methanol and allowing the solution to stand for 24 hours. 5 mL of ferric alum solution and 2.5 mL of mercuric thiocyanate solution are mixed with 25 mL of sample and allowed to stand for 10 minutes. The colour developed is measured on a spectrophotometer at 466 nm. Bromides, iodides, thiosulphates, cyanides and nitrites interfere with the analysis. The method is sensitive and rapid. It is easily adapted for automated analyses.

11.3.2 Mercuric Nitrate Titration (AWWA 1976). This method is suitable for the detection of 0.15 to 10 mg chloride in the portion of the sample titrated. When a 50 mL sample is titrated, this is 3 to 200 ppm chloride in water.

A 50 mL sample, or a suitable aliquot of sample, is obtained. A mixed indicator consisting of 5 g diphenylcarbazone and 0.5 g bromophenol blue in 750 mL isopropyl or ethyl alcohol is used. The pH is adjusted with 0.1 N nitric acid to the yellow end point. The sample is titrated with 0.141 N mercuric nitrate.

The relative standard deviation is 3.3 percent and the relative error is 2.9 percent. This method cannot be used with turbid or highly coloured water since the end point is obscured. Bromide, cyanide and iodide are determined as chloride. Chromate, ferric and sulphate ions interfere when present in excess of 10 mg/L. This method is fast and simple. The end point is easily determined.

11.3.3 Potentiometric Titration (AWWA 1976). This method is suitable for the detection of 0.15 to 10 mg chloride in the portion of the sample titrated. When a 50 mL sample is titrated, this is 3 to 200 ppm chloride in water.

The solution is acidified with nitric acid and titrated with silver nitrate using a glass and silver/silver-chloride electrode system. The end point is determined potentiometrically. The system is standardized with standard sodium chloride solution. There are numerous interferences. Bromide, iodide and cyanide are determined as chloride. Ferricyanide, chromate and dichromate interfere and must be removed. When there are no interfering substances present, this method is accurate to within 2.5 percent of the amount of chloride present. If pretreatment is necessary to remove interferences, the accuracy is reduced to within 5 percent of the amount present. This method is suitable for coloured or turbid samples in which colour-indicated end points may be difficult to observe. It is the method of choice when ferric ions, chromic, phosphate and ferrous and other heavy metal ions are present.

11.4 Qualitative Method for the Detection of Sodium Chloride in Water

The presence of chloride may be determined by the formation of a white precipitate when 0.1 N silver nitrate is added to the acidified sample. The precipitate is insoluble in acid but soluble in a slight excess of ammonia (Moeller 1958). The colourimetric method in Section 11.3.1 may be used without a spectrophotometer. The colour development indicates the presence of chloride or interfering compounds. The presence of sodium may be determined using the flame test. The solution produces a strong yellow flame when burned (Moeller 1958).

11.5 Quantitative Methods for the Detection of Sodium Chloride in Soil

11.5.1 Argentometric Titration (Hesse 1972). This method is suitable for 0.15 to 10 mg chloride in the aliquot of extract taken for titration.

A suitable weight, about 20 g, of 2 mm soil is weighed into a bottle and shaken with 100 mL of water for 30 minutes. This is allowed to settle for 15 minutes, centrifuged, and filtered. An aliquot of the extract is made neutral or slightly alkaline with sodium hydrogen carbonate. It is titrated with 0.02 M silver nitrate using 1 mL of potassium chromate as the indicator. Bromide, iodide and cyanide interfere since they are determined as chloride. Although this method is fast and simple, the end point may be difficult to determine.

11.5.2 Potentiometric Titration (AWWA 1976). An aliquot of the extract containing 0.15 to 10 mg chloride ion is suitable for analysis by this method.

The soil extract is prepared as in Section 11.5.1 above. It is titrated with 0.02 N silver nitrate using a glass and silver/silver-chloride electrode system to determine the end point potentiometrically. The system is standardized with standard sodium chloride solution. There are numerous interferences. Bromide, iodide and cyanide are determined as chloride. Ferricyanide, chromate and dichromate interfere and must be removed. When there are no interfering substances present, this method is accurate to within 2.5 percent of the amount of chloride present. If pretreatment is necessary to remove interference, the accuracy is reduced to within 5 percent of the amount present. This method is suitable for coloured or turbid samples in which colour-indicated end points may be difficult to observe. This end point is easier to determine than the potassium chromate end point described in Section 11.5.1. This is a method of choice when ferric, chromic, phosphate and ferrous and other heavy metal ions are present.

11.6 Qualitative Method for the Detection of Sodium Chloride in Soil

The soil sample is prepared by extraction as described in Section 11.5.1 above. Chloride or any halogen may be identified by the formation of a white precipitate when 0.1 N silver nitrate is added to an acidified portion of the extract. The precipitate is insoluble in acid but is soluble in a slight excess of ammonia (Moeller 1958). The presence of sodium may be determined using the flame test. The solution produces a strong yellow flame when burned (Moeller 1958).

12 REFERENCES AND BIBLIOGRAPHY

12.1 References

AAR 1983: Association of American Railroads, Personal Communication, G. Meier. (January, 1983).

APHA 1977: Katz, M. (ed.), Methods of Air Sampling and Analysis, Second Edition, American Public Health Association, Washington, D.C., Method 201. (1977).

ASS: Atlas Steel, Atlas Stainless Steels, Toronto, Ontario. Not dated.

ASTM 1978: American Society for Testing and Materials, Compilation of Odor and Taste Threshold Values Data, ASTM, Philadelphia, Pennsylvania, ASTM Data Series DS-48A. (1978).

ASTM 1979: American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31: Water, ASTM, Philadelphia, Pennsylvania, D512-67. (1979).

AWWA 1976: American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, Washington, D.C., Method 408 B,C. (1976).

CBG 1980: Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, Vol. 64, No. 9, Don Mills, Ontario. (December, 1980).

CCPA 1981: The Canadian Chemical Producers' Association, List of Members, Toronto, Ontario. (October, 1981).

CDS 1967: National Association of Corrosion Engineers, Corrosion Data Survey, Houston, Texas. (1967).

CLC 1974: The Car and Locomotive Cyclopedia of American Practices, Third Edition, Association of American Railroads - Mechanical Division, Simmons-Boardman Publishing Corporation, Omaha, Nebraska. (1984).

CMR 1979: Barry, G.S., "Salt", Canadian Mineral Reviews, Canadian Government Publishing Centre, Hull, Quebec. (1979).

Corpus 1980: Corpus Information Services Ltd., "Sodium Chloride", Chemical Product Profiles, Don Mills, Ontario. (31 October 1980).

CRC 1980: Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, Cleveland, Ohio. (1980).

DCRG 1978: Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, Michigan. (1978).

Doc. TLV 1981: American Conference of Governmental Industrial Hygienists (ACGIH), Documentation of Threshold Limit Values, Fourth Edition, Cincinnati, Ohio. (1981).

Dow PS 1980: Dow Chemical Company, Dow Products and Services for Industry Farm and Home, Midland, Michigan. (1980).

DPPED 1967: DOM-X, DOX-X Plastic Pipe Engineering Data, Toronto, Ontario. (1967).

Dreisbach 1980: Dreisbach, R.H., Handbook of Poisoning: Prevention, Diagnosis, and Treatment, Tenth Edition, Lange Medical Publications, Los Altos, California. (1980).

Foster 1980: Foster, A.C., Maun, M.A., "Effect of Two Relative Humidities on Foliar Absorption of Sodium Chloride," Canadian Journal of Plant Science, Vol. 60, No. 2, pp. 763-773. (1980).

GCDWQ 1978: Health and Welfare Canada, Guidelines for Canadian Drinking Water Quality, Prepared by the Federal-Provincial Working Group on Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, Hull, Quebec, pp. 53-54, 46. (1978).

GF: GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, California. Not dated.

Gharsalli 1979: Gharsalli, M., Cherif, A., "Effect of Sodium Chloride on the Growth and Lipid Content of the Sunflower (*Helianthus annus*)", Physiol. Veg., Vol. 17, No. 2, pp. 215-229. (1979).

GPP: Uniroyal, Guide to Polymer Properties, Uniroyal Inc., Mishawaka, Indiana. Not dated.

Hesse 1972: Hesse, P.R., A Textbook of Soil Chemical Analysis, Chemical Publishing Co. Inc., New York, New York, p. 85. (1972).

HIS 1969: Hydraulic Institute, Hydraulic Institute Standards, 12th Edition, New York, New York. (1969).

ITII 1981: International Technical Information Institute, Toxic and Hazardous Industrial Chemicals Safety Manual for Handling and Disposal with Toxicity and Hazard Data, Japan. (1981).

Jorgensen 1979: Jorgensen, S.E. (ed.), Handbook of Environmental Data and Ecological Parameters, International Society for Ecological Modelling, Pergamon Press, Oxford, England, p. 564. (1979).

JSSV 1979: Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, New York. (1979).

Kacmar 1980: Kacmar, P., Samo, A., Knezik, J., "Chemical Diagnosis of Sodium Chloride Poisoning in Purebred Fur-bearing Animals (Fox, Coypu) and in Turkeys and Pheasants", Vet. Med. (Prague), Vol. 25, No. 12, pp. 733-738. (1980).

Kaufmann 1960: Kaufmann, D.W., Sodium Chloride, The Production and Properties of Salt and Brine, Reinhold Publishing Corp., New York, New York. (1960).

Lange's Handbook 1979: Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th Edition, McGraw-Hill Book Co., New York, New York. (1979).

Lefèvre 1980: Lefèvre, M.J., Becker, E.O., First Aid Manual for Chemical Accidents -For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson, and Ross Inc., Stroudsburg, Pennsylvania. (1980).

McLean 1981: Mitigation of Salt Spills, Petroleum Institute for Training Service, Edmonton, Alberta. (1981).

Merck 1976: Windholz, M., Budavari, S., Stroumtsos, L.Y., Fertig, M.N. (ed.), The Merck Index, Ninth Edition, Merck & Co. Inc., Rahway, New Jersey. (1976).

Moeller 1958: Moeller, T., Qualitative Analysis, McGraw-Hill Book Co. Inc., New York, New York, pp. 397, 476. (1958).

MWPP 1978: Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec. (1978).

NFPA 1978: National Fire Protection Association, Fire Protection Guide on Hazardous Materials, Seventh Edition, Boston, Massachusetts. (1978).

NIOSH 1977: National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 1, Cincinnati, Ohio, P&CAM 115. (April, 1977).

NRCC 1980: National Research Council of Canada, Executive Reports: Effects of Chromium, Alkali Halides, Arsenic, Asbestos, Mercury, Cadmium in the Canadian Environment, NRCC No. 17585, Ottawa, Canada. (1980).

Nriagu 1979: Nriagu, J.O., Environmental Biogeochemistry, Metal Transfer and Ecological Mass Balance, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, Vol. 2, pp. 743-761. (1979).

Pang 1979: Pang, C.Y., Phillips, G.D., Campbell, L.D., "The Toxic Effects of Saline Drinking Water on Young Turkey Poults", British Poultry Science, Vol. 20, pp. 1-7. (1979).

Partington 1958: Partington, J.R., General and Inorganic Chemistry for University Students, Third Edition, MacMillan Publishing, New York, New York. (1958).

Rosenstock 1977: Rosenstock, H.M., Draxl, K., Steiner, B., Herron, J.T., Energetics of Gaseous Ions, National Bureau of Standards, Washington, D.C. (1977).

RTECS 1979: Lewis, R.J., Tatken, R.L., Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio. (September, 1980).

Samantaray 1979: Samantaray, R.N., Dash, A.B., Ladh, S.B., "Effect of Sodium Chloride Spray on the Technological Quality of Rice Grain", Oryza, Vol. 15, No. 2, pp. 151-156. (1979).

Sandals 1978: Sandals, W.C.D., "Acute Salt Poisoning in Cattle", Canadian Veterinary Journal, Vol. 19, No. 5, pp. 136-137. (May, 1978).

Sax 1979: Sax, N.I., Dangerous Properties of Industrial Materials, Fifth Edition, Van Nostrand Reinhold Company, New York, New York. (1979).

Sax 1981: Sax, J.R., Dangerous Properties of Industrial Mat [illegible] Report, Vol. 1, No. 4, p. 79. (May/June, 1981).

Seidell and Linke 1965: Seidell, A., Linke, W.F., Solubilities - Inorganic and Metal Organic Compounds, Fourth Edition, American Chemical Society, Washington, D.C. (1965).

Spehar 1981: Spehar, R.L., Lemke, A.E. et al., "Effects of Pollution on Freshwater Fish", Journal Water Pollution Control Federation, Vol. 53, No. 6, pp. 1028-1076. (June, 1981).

Sussex 1977: Pedley, J.B., Rylance, J., Sussex-N.P.L. Computer Analysed Thermochemical Data: Organic and Organometallic Compounds, University of Sussex, Sussex, Brighton, England. (1977).

TCM 1979: General American Transportation Corporation, Tank Car Manual, Chicago, Illinois. (May, 1979).

TDGC 1980: Transport Canada, Transportation of Dangerous Goods Code, Vol. 1 (Lists), Vol. 2, Ottawa, Canada. (June, 1980).

Teal 1981: Teal, A.R. Mitigation of Salt Water Spills, Petroleum Institute for Training Service, Edmonton, Alberta. (1981).

Townsend 1980: Townsend, A.M., "Response of Selected Tree Species to Sodium Chloride", J. Am. Soc. Hortic. Sci., Vol. 105, No. 6, pp. 878-883. (1980).

TPS 1978: GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, California. (1978).

Webster 1975: Webster, G.R., Salt Spills, Proceedings of the Conference on the Environmental Effects of Oil and Saltwater Spills on Land, Alberta Environment, pp. 21-25. (1975).

WQC 1972: National Academy of Sciences, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences, Washington, D.C., pp. 457-467. (1972).

WQCDB-2 1971: Environmental Protection Agency, Water Quality Criteria Data Book: Inorganic Chemical Pollution of Freshwater, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 2, pp. 117, 236-239. (July, 1971).

WQCDB-3 1971: Environmental Protection Agency, Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 3, pp. A-128-130. (May, 1971).

WQCDB-5 1973: Environmental Protection Agency, Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 5, pp. A-404-405. (September, 1973).

WQS 1979: McNeily, R.N., Neimans, V.P., Dwyer, L., Water Quality Sourcebook: A Guide to Water Quality Parameters, Inland Waters Directorate, Water Quality Branch, Environment Canada, Ottawa, Canada, pp. 16, 17, 53, 77-81. (1979).

12.2 Bibliography

Association of American Railroads, Personal Communication, G. Meier. (January, 1983).

Association of American Railroads - Mechanical Division, The Car and Locomotive Cyclopedia of American Practices, Third edition, Simmons-Boardman Publishing Corporation, Omaha, Nebraska. (1974).

American Conference of Governmental Industrial Hygienists (ACGIH), Documentation of Threshold Limit Values, Fourth Edition, Cincinnati, Ohio. (1981).

American Society for Testing and Materials, Compilation of Odor and Taste Threshold Values Data, ASTM, Philadelphia, Pennsylvania, ASTM Data Series DS-48A. (1978).

American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31: Water, ASTM, Philadelphia, Pennsylvania, D512-67. (1979).

American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, Washington, D.C., Method 408 B,C. (1976).

Atlas Steel, Atlas Stainless Steels, Toronto, Ontario. Not dated.

Barry, G.S., "Salt", Canadian Mineral Reviews, Canadian Government Publishing Centre, Hull, Quebec. (1979).

The Canadian Chemical Producers' Association, List of Members, Toronto, Ontario. (October, 1981).

Corpus Information Services Ltd., "Sodium Chloride", Chemical Product Profiles, Don Mills, Ontario. (31 October 1980).

Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th Edition, McGraw-Hill Book Co., New York, New York. (1979).

DOM-X, DOX-X Plastic Pipe Engineering Data, Toronto, Ontario. (1967).

Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, Michigan. (1978).

Dow Chemical Company, Dow Products and Services for Industry Farm and Home, Midland, Michigan. (1980).

Dreisbach, R.H., Handbook of Poisoning: Prevention, Diagnosis, and Treatment, Tenth Edition, Lange Medical Publications, Los Altos, California. (1980).

Environmental Protection Agency, Water Quality Criteria Data Book: Inorganic Chemical Pollution of Freshwater, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 2, pp. 117, 236-239. (July, 1971).

Environmental Protection Agency, Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 3, pp. A-128-130. (May, 1971).

Environmental Protection Agency, Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, Environmental Protection Agency, Water Quality Office, Washington, D.C., Vol. 5, pp. A-404-405. (September, 1973).

Foster, A.C., Maun, M.A., "Effect of Two Relative Humidities on Foliar Absorption of Sodium Chloride", Canadian Journal of Plant Science, Vol. 60, No. 2, pp. 763-773. (1980).

General American Transportation Corporation, Tank Car Manual, Chicago, Illinois. (May, 1979).

GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, California. Not dated.

Gharsalli, M., Cherif, A., "Effect of Sodium Chloride on the Growth and Lipid Content of the Sunflower (*Helianthus annus*)", Physiol. Veg., Vol. 17, No. 2, pp. 215-229. (1979).

GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, California. (1978).

Health and Welfare Canada, Guidelines for Canadian Drinking Water Quality, Prepared by the Federal-Provincial Working Group on Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, Hull, Quebec, pp. 53-54, 46. (1978).

Hesse, P.R., A Textbook of Soil Chemical Analysis, Chemical Publishing Co. Inc., New York, New York, p. 85. (1972).

Hydraulic Institute, Hydraulic Institute Standards, 12th Edition, New York, New York. (1969).

International Technical Information Institute, Toxic and Hazardous Industrial Chemicals Safety Manual for Handling and Disposal with Toxicity and Hazard Data, Japan. (1981).

Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, New York. (1979).

Jorgensen, S.E. (ed.), Handbook of Environmental Data and Ecological Parameters, International Society for Ecological Modelling, Pergamon Press, Oxford, England, p. 564. (1979).

Kacmar, P., Samo, A., Knezik, J., "Chemical Diagnosis of Sodium Chloride Poisoning in Purebred Fur-bearing Animals (Fox, Coypu) and in Turkeys and Pheasants", Vet. Med. (Prague), Vol. 25, No. 12, pp. 733-738. (1980).

Katz, M. (ed.), Methods of Air Sampling and Analysis, Second Edition, American Public Health Association, Washington, D.C., Method 201. (1977).

Kaufmann, D.W., Sodium Chloride, The Production and Properties of Salt and Brine, Reinhold Publishing Corp., New York, New York. (1960).

Lefèvre, M.J., Becker, E.O., First Aid Manual for Chemical Accidents - For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson, and Ross Inc., Stroudsburg, Pennsylvania. (1980).

Lewis, R.J., Tatken, R.L., Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio. (September, 1980).

McLean, B.N., Mitigation of Salt Spills, Petroleum Institute for Training Service, Edmonton, Alberta. (1981).

McNeily, R.N., Neimans, V.P., Dwyer, L., Water Quality Sourcebook: A Guide to Water Quality Parameters, Inland Waters Directorate, Water Quality Branch, Environment Canada, Ottawa, Canada, pp. 16, 17, 53, 77-81. (1979).

Moeller, T., Qualitative Analysis, McGraw-Hill Book Co. Inc., New York, New York, pp. 397, 476. (1958).

National Academy of Sciences, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences, Washington, D.C., pp. 457-467. (1972).

National Association of Corrosion Engineers, Corrosion Data Survey, Houston, Texas. (1967).

National Fire Protection Association, Fire Protection Guide on Hazardous Materials, Seventh Edition, Boston, Massachusetts. (1978).

National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 1, Cincinnati, Ohio, P&CAM 115. (April, 1977).

National Research Council of Canada, Executive Report: Effects of Chromium, Alkali Halides, Arsenic, Asbestos, Mercury, Cadmium in the Canadian Environment, NRCC No. 17585, Ottawa, Canada. (1980).

Nriagu, J.O., Environmental Biogeochemistry, Metal Transfer and Ecological Mass Balance, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, Vol. 2, pp. 743-761. (1979).

Pang, C.Y., Phillips, G.D., Campbell, L.D., "The Toxic Effects of Saline Drinking Water on Young Turkey Poults", British Poultry Science, Vol. 20, pp. 1-7. (1979).

Partington, J.R., General and Inorganic Chemistry for University Students, Third Edition, MacMillan Publishing, New York, New York. (1958).

Pedley, J.B., Rylance, J., Sussex-N.P.L. Computer Analysed Thermochemical Data: Organic and Organometallic Compounds, University of Sussex, Sussex, Brighton, England. (1977).

Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec. (1978).

Rosenstock, H.M., Draxl, K., Steiner, B., Herron, J.T., Energetics of Gaseous Ions, National Bureau of Standards, Washington, D.C. (1977).

Samantaray, R.N., Dash, A.B., Ladh, S.B., "Effect of Sodium Chloride Spray on the Technological Quality of Rice Grain", Oryza, Vol. 15, No. 2, pp. 151-156. (1979).

Sandals, W.C.D., "Acute Salt Poisoning in Cattle", Canadian Veterinary Journal, Vol. 19, No. 5, pp. 136-137. (May, 1978).

Sax, J.R., Dangerous Properties of Industrial Materials Report, Vol. 1, No. 4, p. 79. (May/June, 1981).

Sax, N.I., Dangerous Properties of Industrial Materials, Fifth Edition, Van Nostrand Reinhold Company, New York, New York. (1979).

Seidell, A., Linke, W.F., Solubilities - Inorganic and Metal Organic Compounds, Fourth Edition, American Chemical Society, Washington, D.C. (1965).

Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, Vol. 64, No. 9, Don Mills, Ontario. (December, 1980).

Spehar, R.L., Lemke, A.E. et al, "Effects of Pollution on Freshwater Fish", Journal Water Pollution Control Federation, Vol. 53, No. 6, pp. 1028-1076. (June, 1981).

Teal, A.R. Mitigation of Salt Water Spills, Petroleum Institute for Training Service, Edmonton, Alberta, (1981).

Townsend, A.M., "Response of Selected Tree Species to Sodium Chloride", J. Am. Soc. Hortic. Sci., Vol. 105, No. 6, pp. 878-883. (1980).

Transport Canada, Transportation of Dangerous Goods Code, Vol. 1 (Lists), Vol. 2, Ottawa, Canada. (June, 1980).

Uniroyal, Guide to Polymer Properties, Uniroyal Inc., Mishawaka, Indiana. Not dated.

Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, Cleveland, Ohio. (1980).

Webster, G.R., Salt Spills, Proceedings of the Conference on the Environmental Effects of Oil and Saltwater Spills on Land, Alberta Environment, pp. 21-25. (1975).

Windholz, M., Budavari, S., Stroumtsos, L.Y., Fertig, M.N. (ed.), The Merck Index, Ninth Edition, Merck & Co. Inc., Rahway, New Jersey. (1976).

EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immision concentration
min	minute or minimum
mm	millimetre
MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_c	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_s	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_c	critical temperature
TC_{LO}	toxic concentration low
Td	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
Ts	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight
μg	microgram
μm	micrometre
°Be	degrees Baumé (density)