Department of Technical Co-operation for Development

ST/ESA/149 Not at VP

Natural Resources/Water Series No. 14

THE USE OF NON-CONVENTIONAL WATER RESOURCES IN DEVELOPING COUNTRIES

UNIV. of MICH. MAY 1 5 1985 Documents Center



United Nations New York, 1985

HC 186

CONTENTS

			Page
Foreword			iii
Explanat	ory n	otes	v
Conversi	on fa	ctors	xiv
Abbrevia	tions		xvi
INTRODUC	TION		1
Α.	Gen	eral	1
В	Dro	gress made over the past 20 years in the use of	
В.	non	-conventional sources of water	2
			3
	1.	Desalination	A
	2.	Transport of water	4
	3.	Water reuse	5
	4.	Enhancement of existing supplies or sources	Sec. Si
C	. Ob-	ectives of the International Drinking Water Supply and	
Sec.	Sar	nitation Decade	5
		Comprehensive service for all	. 6
	1.		6
	2.	Human resources development	7
	3.	Appropriate technology	7
	4.	Economic viability	
Chapter			
I. D	EVELO	PMENT OF BRACKISH AND SEA-WATER SOURCES	8
A	. In	troduction	8
		a second of hospital and	10
		Development of technology Development of markets	14
	2.		16
	3.		
В	. Di	stillation	17
	1.	Historical background	17
	2.	Technical considerations	18
	3.	Recent technological advances	19
	4.	Application in developing countries	23
	5.		29

Page

	c.	Elec	ctrodialysis	35
				35
		1.	Historical background	36
		2.	Technical considerations	
		3.	Recent technological advances	36
		4.	Application in developing countries	39
		5.	Generalized costs for electrodialysis plants	42
	D.	Rev	erse osmosis	45
4		1.	Historical background	45
		2.	Technical considerations	47
		3.	Recent technological advances	47
		2.2	Application in developing countries	49
		4.	Generalized costs for reverse osmosis plants	52
		1		57
	E.	Eco	nomic considerations	
		1.	Supply and demand evaluation	62
		2.	Factors related to process selection	62
		and a second	Energy considerations	70
		3.	Energy considerations	73
		4.	Dual purpose versus single purpose plants	77
		5.	Special considerations in developing countries	80
		6.	Cost evaluation	
1		7.	Process selection	84
	(i i		Desalination cost summary sheet and project information form	87
				92
	F.	Des	alination with renewable energy sources	1.5
		1.	Solar energy	92
		2.	Wind energy	104
			Ocean energy	107
		3.	Ocean energy	108
		4.	Human energy	108
		5.	Application in developing countries	109
12		6.	Economic considerations	107
2	G.	Sma	all-scale desalination units in rural areas	113
1		1.	Village desalting programmes	114
		2.	Examples of country programmes	116
11.	TR		ORT OF WATER	120
			and and the second s	120

			그는 그는 것은 것이 가지 않는 것이 같아요. 것은 것은 것이 많이 나라 가슴을 했다.	Page
	в.	Tan	kers	121
		1.	Historical background	121
		2.	Technical considerations	122
		3.	Recent technological advances	129
		4.	Application in developing countries	133
		5.	Economic considerations	141
	c.	Ice	bergs	149
	8	1.	Historical background	1 149
		2.	Technical considerations	151
		3.	Recent technological advances	155
				159
		4.	Application in developing countries	
		5.	Economic considerations	161
111.	WAT	TER R	EUSE	162
	A.	Int	roduction	162
	в.	Was	te-water reclamation	162
		1.	Historical background	163
		2.	Technical considerations	165
		3.		
			Recent technological advances	177
		4.	Application in developing countries	178
		5.	Economic considerations Definition of terms	183 187
			Definition of terms	101
IV.	ENH	HANCE	SMENT OF EXISTING SUPPLIES OR SOURCES	188
	Α.	Int	roduction	188
	в.	Wea	ather modification	189
		1.	Historical background	189
		2.	Technical considerations	192
		3.	Recent technological advances	202
		4.	Application in developing countries	203
		5.	Economic considerations	206
	c.	Eva	aporation suppression	211
				211
		1.	Historical background	STORES I
1.45		2.	Technical considerations	211
5 20		3.	Recent technological advances	213
		4.	Application in developing countries	213
		5.	Economic considerations	213

		Page
. c	ONCLUSIONS	214
A	. General	214
в	. Comparison of methods	215
Ċ	. Prospects for the future	218
	1. Desalination	218
	2. Transport by tanker	219
1.23	3. Transport by iceberg	219
	4. Water reuse	219
	5. Weather modification	219
	6. Summary	220
	Annexes	
I. D	DISTILLATION	221

DIS	TILLATION	221
А.	Technical background	221
	1. Vapour production	221
	2. Transportation of vapour to a condenser	221
	3. Condensation	222
в.	Process description	222
	1. Multiple-effect evaporation	222
	2. Multi-stage flash	225
	3. Vapour compression	229
	4. Waste heat recovery evaporator	231
	5. Hybrid systems	231
c.	Major engineering considerations	233
	1. Scale formation and control	233
	2. Heat transfer surface	235
	3. Materials of construction	236
	4. Corrosion	236
ELI	CTRODIALYSIS	238
Α.	Technical background	238
	1. Physical principles	238
	2. Elements of an electrodialysis unit	240

11.

Page

5				
	в.	Process	description	243
		l. Elec	ctrodialysis	243
		2. Elec	ctrodialysis reversal	244
1. A.	с.	Major en	ngineering considerations	244
		1. Spec	cific energy usage	244
		2. Pre-	-treatment	\$ 245
6		3. Post	t-treatment	245
-			ipment optimization	245
			rating problems	246
111.	REV	ERSE OSMO	OSIS	248
	Α.	Technic	al background	248
	А.	Technica	al backylound	
		1. Over	rall system	248
		2. Meml	branes	250
			brane characteristics	250
11.15				
	в.	Process	description	251
		1. Mem	brane assemblies	251
		2. Proc	cess configurations	255
	с.	Major e	ngineering considerations	259
			• • • • • • • • • • • • • • • • • • •	259
	-		water source	259
			-treatment	259
			-treatment	261
			erials of construction	261
				262
		6. Rec	overy	262
			ne disposal	262
		o. Ope	rating problems	
REFE	RENCI	s		264
WATE	R RES	OURCES :	LIST OF UNITED NATIONS PUBLICATIONS	277
			tick of tables	14 H.
	*		List of tables	- 6
1.	Desa	ination	plants installed or sold during the period 1951-1980	12
2.	Dist:	llation:	sea-water desalting cost estimates	31
3.			nptions used in the Oak Ridge National Laboratory	33
	stud	on desa	alination costs	33

Page

BDE.		
4.	Electrodialysis reversal: brackish water desalting cost	43
ах. ЭХ.	estimates	45
a long to	Reverse osmosis: sea-water desalting cost estimates	54
6.	Reverse osmosis: brackish water desalting cost estimates	56
7.	A comparison of cost estimates for representative 3,800 m ³ /d (1 mgd) and 19,000 m ³ /d (5 mgd) sea-water desalination facilities	58
8.	A comparison of cost estimates for representative 3,800 m^3/d (1 mgd) and 19,000 m^3/d (5 mgd) brackish water desalination facilities	60
9.	Water conveyance costs: method for calculation	70
10.	Desalination plants: estimated percentage of costs expended on energy	71
11,	A method to calculate dual purpose steam costs	76
12.	Estimated range of capital costs and water costs from experimental desalination plants using renewable sources of energy	110
13.	Countries and areas with significant lengths of very arid coastlines	124
14.	Some potential fresh water loading ports	134
15.	Summary of transportation costs of water transported by tankers, tugs and barges	143
16.	Typical composition of domestic waste water	165
17.	Physical and chemical characteristics of domestic waste waters	166
18.	Expected quality of water recovered after rapid infiltration in a spreading basin	170
19.	Guidelines for interpretation of water quality for irrigation	175
20.	Water savings effected by planned reclamation of process	176

		Page
21.	Suggested treatment required for domestic waste water before	
	industrial reuse	176
22.	Design parameters for typical ponds	181
23.	Design and performance data for ponds in developing countries	184
24.	Design parameters for planning artificial wetland waste-water treatment systems	185
25.	Estimated unit costs for various waste-water treatment	1.5
	processes	186
26.	Comparison of non-conventional water resources: technical,	
	economic and political criteria	216
	List of figures	
	I. Growth in desalination capacity, 1950-1981	9
I	I. Distribution of desalination capacity by region, 1980	15
II	I. Capital equipment cost: sea-water desalting by	
	distillation	34
I	V. Schematic of a dual purpose plant	74
,	V. Basic elements of a solar still	96
v	. Shuttle service transportation costs, by ship size and	
	round-trip distance	145
VII	. Fresh water backhaul transportation costs for 250,000 and	
	350,000 dwt tankers	148
VIII	. Intentional reuse of waste water	164
IJ	C. Denver's water reuse treatment process	169
x	Conceptual diagram of a submerged tube (ST)	
	multiple-effect distillation plant	223
XI	. Conceptual diagram of a vertical-tube evaporator (VTE)	224
XII	and a subject of a norreor cube mutcipie effect	
	(HTME) distillation plant	226
XIII	. Conceptual diagram of the multi-stage flash (MSF) process	227

SE.C

Page

XIV.	Simplified flow diagram for a spray-film vapour-compression	
	process	230
xv.	A waste heat recovery evaporator	232
XVI.	Movement of ions in the electrodialysis process	239
XVII.	Basic components of an electrodialysis unit	241
XVIII.	Three types of spacers	242
XIX.	Elements of a reverse osmosis system	249
xx.	Flow diagram of a reverse osmosis system	249
XXI.	Construction of a plate and frame membrane	253
XXII.	Construction of a tubular membrane	253
XXIII.	Spiral membrane cut-away view with elements in a	
	pressure vessel	254
XXIV.	Permeator assembly for hollow fine fibre membrane	256
xxv.	Single stage RO plant configurations	257
XXVI.	Multi-stage RO plant configurations	258

List of maps

1.	Desert and	very	arid coastal	areas of	the world	 125
2.	Potential	water	transportatio	on routes		 137