


GUIDE TO WATER AND WASTE-WATER MANAGEMENT IN THE PELAGIC FISHING INDUSTRY

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Prepared for the

WATER RESEARCH COMMISSION

By

BINNIE & PARTNERS

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An investigation into the water and effluent management problems in the fishing industry: Effluent handling at fish-processing factories

that was carried out by Binnie and Partners.

DISCLAIMER

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FOREWORD

Intuitively the sea is conceived as a reservoir which can assimilate vast quantities of waste material. This is particularly so when the so-called waste material arises from an industry such as the fishing industry that works with organic products of marine origin. The implication is that the ocean should be able to assimilate such wastes in the same way as it would deal with materials that arise from natural phenomena, such as the death of organisms and the excretory products of marine species.

It may be deduced therefore that the problems that have been experienced around some fish-processing plants stem from the fact that relatively high concentrations of waste materials build up in localised areas. Occasionally this also occurs naturally, for example when a body of oxygen-depleted water for some reason rises to the surface and causes decimation of sea life adapted to waters with high oxygen content. On the other hand, large oil spills that arise from oil tankers and the effects of earlier dumping of solid wastes have made us aware of the reverse side of the coin, namely catastrophes involving heavy concentrations of materials foreign to the sea.

All the important South African and South West African fishing harbours are, naturally enough, situated in bays. This geographical location contributes to the potentially harmful effects of waste waters that find their way into the ocean, since the reduced effect of wave, wind and tidal action in such bays results in the wastes remaining concentrated in quantity and effect.

The organic matter in fish-meal factory waste water is of the same nature as the products arising from these plants. There is thus theoretically no objection to the utilisation of material recovered from the waste water for inclusion into the products of that factory. The objective of this guide is to suggest means of reducing marine pollution at the lowest possible costs and to recover organic matter from the waste waters in a usable form. As demonstrated, the costs involved can be recovered through the better conversion of fish raw material into product, in other words by reducing the loss of fish material via the factory waste water.

P E ODENDAAL
EXECUTIVE DIRECTOR
WATER RESEARCH COMMISSION

PREFACE

In recent years, interest in a number of maritime countries has been drawn to the problems faced by fisheries in complying with ever-stricter pollution control laws. South Africa, with its long coastline and important but scattered centres of the fishing industry, is no exception and in addition must cope with chronic and sometimes severe water shortages.

This guide is aimed at the management of factory processing in such a way as to minimise pollution, to recover valuable products from waste streams and, in particular, to conserve all sources of water so as to reduce waste-water volumes as well as to check pollution at source. In particular this publication focusses in a specific and quantitative manner on problems described in a previous publication of the Water Research Commission entitled "A Survey of Water and Effluent Management in the Fish-Processing Industry in South Africa" (ISBN 0 908356 12 9, prepared by Binnie and Partners on behalf of the Water Research Commission), which is a useful introduction to the present work.

A high degree of co-operation between the Water Research Commission, its consultants, various government departments and the fishing industry itself has led to the formulation of guidelines, expressed in this publication as management targets. These targets cover control of effluents from ship holds, off-loading water, stickwater and fishpit bloodwater as well as effluent segregation or combination in order to rationalise effluent treatment or improve product yields. One of the most valuable aspects of the study has been to show that attention to anti-pollution measures yields cash dividends and it is to be hoped that management will seize this chance to explore greater profitability.

Finally, the work described has an on-going character. The guidelines provide a tool for management to progressively implement pollution control measures, in the course of which it is hoped that the experience gained will lead to the further optimisation of water and waste-water management in the pelagic fishing industry.

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Irvin and Johnson, Paardeneiland, Cape Town

The preparation of this publication was constituted under the leadership of the following Editorial Committee:

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EXECUTIVE SUMMARY

The fishing industry in South Africa has long faced the problem that the levels of pollutants discharged at coastal factories producing fish-meal and canned products were in many cases unacceptably high for discharge into the marine environment. The Water Research Commission was approached by the industry and has sponsored factory surveys and pilot plant effluent treatment studies over a number of years to address the problem. This work has been described in a series of reports ("Water and Effluent Management in the Fishing Industry", Volumes 1 to 4, internal reports prepared by Binnie and Partners on behalf of the Water Research Commission), culminating in the present guide.

Achievable management targets for pollution loads arising from fish off-loading and factory processing are identified initially. Means of achieving these target levels are addressed firstly by considering improved housekeeping procedures to minimise effluent generation and secondly, by installation of effluent treatment processes which have been proven in pilot plant studies. Suitable effluent treatment processes are described on a modular basis, and design options for effluent treatment schemes are given.

The guide is designed to be a tool for management to progressively improve the quality and volume of the waste waters discharged by the industry, and it is urged that the recommendations contained be systematically applied as an on-going exercise towards minimising the marine pollution problems faced.

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INTRODUCTION

The local fish-processing industry is located along the west and south coasts of Southern Africa. The industry is regulated on a quota basis with the permissible total catch being set annually by the authorities and then allocated to the individual fish factories. In 1985 a total of 16 factories processed 440 000 t of brown fish, producing 112 000 t of fish meal and 27 000 t of fish oil. Eleven canneries associated with these factories processed 58 000 t of brown fish to canned products. Around 70% of the canning is carried out in the Walvis Bay area. Five canneries also process white fish to canned products, five factories process rock lobster and two factories process fresh and frozen white fish.

To establish the overall pattern of effluent discharges from the local fish-processing industry, to identify the scale of any resultant marine pollution and to propose and investigate means of minimizing such pollution, the Water Research Commission of South Africa instructed consulting engineers to survey the water usage and effluent generation by the industry on a national basis. Salient features of the major factories are summarized in Tables 1 and 2 for fish-meal plants and in Table 3 for fish canneries and processing plants for white fish, rock lobster and "perlemoen" (abalone).

From the results of the survey (reported in "Water and Effluent Management in the Fishing Industry", op.cit.), it is apparent that a very high proportion of the effluent discharged by the industry as a whole arises from fish meal production and the associated off-loading practices. Approximately 45% of the overall organic pollution load, measured as COD, arises from these areas of activity.

To date the fishing industry as a whole has found difficulty in achieving acceptable effluent quality standards for discharge to the ocean. In the course of the national survey carried out, the discharge qualities achieved by individual factories were found to vary widely. Marine self-purification also varies from location to location, depending on environmental factors such as local currents, sea temperature, tides, etc.

A conclusion of the various studies conducted was that minimum pollutant discharge levels can be achieved and maintained by all fish-processing factories by effective effluent management, including good housekeeping and appropriate effluent treatment practices.

TABLE I. SALIENT FEATURES OF FISH-MEAL PLANTS (1985)

Factory number	Process/Products								Annual quota	Number of Employees ' = Peak season	Type of off-loading system		Capacity of plant	Annual fresh water consumption	Steam consumption kg/h	Effluent volume	Type of effluent treatment						
	Fish-meal	Oil	Canning	White fish	Rock lobster	Crab	Pet food	Other	t		Dry	Wet	t/h	m³/a	m³/a		Dumped to land	Direct to sea	Screens	Dewatering reel	Settling tank	3-stage stick water evaporators	Scum tank
1	X	X	X						40 000	136 236'	X		92-132	30 000	20 450	772 000				X	X	X	
2	X	X							27 688	90	X		30	36 000	20 000	533 760			X	X		X	
3	X	X			X				41 500	325 451'	X R+H		37	20 000	20 000	875 000			X	X		X	
4	X	X	X		X				28 665	185	X	X	50	28 130	31 800	602 000					X	X	
5	X	X	X		X				34 300	150	X	X	30	23 725	28 000	309 000				X	X	X	
6	X	X	X					X frg	74 750	186 366'	X R+H		66	42 000	34 000	400 000						X	X
7					X				800	70	X		2,25 t/d	1 000	Nil	4 600			X				
8	X	X	X				X		24 610	138	X		35	16 000	22 000	326 000					X	X	
9				X					51 700	1 750	X		8	360 000	450	700 000			X				
10	X	X	X	X					39 078	120	X		38	90 000	18 180	212 000					X	X	
11	X	X	X						60 934	161		X	50	24 428	25 000	293 000						X	X
12	X	X	X						60 291	300	X	X	80	32 000	112 700	473 000						X	X
13	X	X	X						12 000	89		X	45	2 432 kℓ/m	15 000	-						X	X
14	X	X	X						42 128	100 800'		X	35	60 396	25 000	876 000						X	X
15	X	X							23 980	85		X	30	16 393	15 000	240 000						X	X
16	X	X		X				X	18 270	85		X	40	39 271	15 000	570 000						X	X
17				X					700	500'	X		25	7 kℓ/d	n/a	n/a	X						
18				X	X				700R.L. unlimited crab	210	X		25	1 200 kℓ/m	-	-	X	X					
19	X	X							40 200	98	X		50	15 000	20 000	413 000				X		X	
20	X	X	X						23 600	75	X	X	30	12 000	24 000	410 000				X			

TABLE 2. TYPICAL EFFLUENT QUALITY FROM FISH-MEAL PLANTS (1979/80)

South Africa

Factory number	Fish quota	Fresh water consumption		Effluent volume		Effluent COD			Effluent SS			Effluent TKN			Effluent FOG		
	t/a	m³/a	m³/t	m³/a	m³/t	mg/ℓ	t/a	kg/t	mg/ℓ	t/a	kg/t	mg/ℓ	t/a	kg/t	mg/ℓ	t/a	kg/t
1	40 000	30 787	0,77	772 000	19,3	533	411	10,29	290	224	5,60	19	14,7	0,37	56	43,2	1,08
2	27 688	36 000	1,30	533 760	20,0	302	161	5,82	126	67	2,42	6,7	3,6	0,13	4	2,2	0,08
3	41 500	20 000	0,48	875 000	21,1	460	403	9,70	305	267	6,43	10	8,8	0,21	85	74,4	1,79
4	28 665	28 130	0,98	602 000	21,0	1 450	873	30,45	1 010	608	21,21	16	9,6	0,34	250	150,5	5,25
5	34 300	23 725	0,69	309 000	9,0	570	176	5,14	145	45	1,31	60	18,5	0,54	12	3,7	0,11
6	74 750	42 000	0,56	400 000	5,4	4 672	1 869	25,00	460	184	2,46	26	10,4	0,14	210	84,0	1,12
8	24 610	16 000	0,65	326 000	13,3	590	192	7,82	312	102	4,13	24	7,8	0,32	13	4,2	0,17
10	39 078	90 000	2,30	212 000	5,4	2 477	525	13,44	1 086	230	5,89	171	36,3	0,93	488	103,4	2,65
19	40 200	15 000	0,37	413 000	10,3	495	204	5,09	230	95	2,36	26	10,7	0,27	60	24,8	0,62
20	23 600	12 000	0,51	410 000	17,4	1 531	628	26,60	930	381	16,6	35	14,4	0,61	180	73,8	3,13
Totals & averages	374 391	313 642	0,84	4 811 000	12,9	1 308	5 442	14,54	490	2 203	5,88	39	134,8	0,36	136	564,2	1,51
Walvis Bay																	
11	60 934	24 428	0,40	793 000	13,0	2 400	1 903	31,23	1 600	1 269	51,94	300	238	3,90	n.a.	-	-
12	60 291	32 626	0,54	473 000	7,8	2 900	1 372	22,75	870	412	6,83	250	118	1,96	n.a.	-	-
14 (+18)	42 128	60 396	1,53	876 000	20,8	2 500	2 190	51,98	1 050	920	21,83	110	96	2,29	n.a.	-	-
15	23 980	16 393	0,68	240 000	10,0	4 860	1 166	48,64	1 100	264	11,01	500	120	5,00	n.a.	-	-
16	18 270	39 271	2,15	570 000	31,2	3 000	1 710	93,60	930	530	29,02	180	103	5,62	n.a.	-	-
Totals & averages	205 603	173 114	0,84	2 952 000	14,4	3 132	8 341	40,57	1 110	3 395	16,51	268	675	3,28	n.a.	-	-

Note: n.a. = not analysed

TABLE 3. FISH CANNING, FISH FREEZING AND CRUSTACEAN PROCESSING

<table>
<tr><th>Description</th><th>Cannery</th><th>White Fish</th><th>Rock lobster (crayfish)</th><th>Perlemoen (abalone)</th></tr>
<tr><td>1. Quota</td><td>RSA fish. 10 400 t/a raw
SWA fish. 60 000 t/a raw</td><td>145 000 t - RSA vessels
16 000 t - other vessels</td><td>5 374 t live weight</td><td>200 t</td></tr>
<tr><td>2. No. of processing plants</td><td>RSA 9
SWA 4</td><td>2 Major companies with 4 plants and several smaller companies</td><td>14</td><td>4</td></tr>
<tr><td>3. Fresh water consumption</td><td>Not derived</td><td>3,06 kℓ/t to 8,5 kℓ/t
Average 6,5 kℓ/t which results in 1 036 Mℓ/a used.</td><td>Not derived</td><td>2,5 Mℓ/a</td></tr>
<tr><td>4. Sea water consumption</td><td>2,0 kℓ/t. Average for off-loading 70 Mℓ/d</td><td>10 kℓ/h</td><td>24 kℓ/t
129 Mℓ/a</td><td></td></tr>
<tr><td>5. Water usage</td><td>Off-loading
Transportation fluming
Washing of floors and equipment</td><td>
<table>
<tr><th></th><th>Factory A</th><th>Factory B</th></tr>
<tr><td></td><td>kℓ/t</td><td>kℓ/t</td></tr>
<tr><td>Fresh water refrigeration condensers</td><td colspan="2">0,41 incl. in process</td></tr>
<tr><td>Ice making</td><td>1,02</td><td>1,5</td></tr>
<tr><td>Processing plant</td><td>1,53</td><td>4,27</td></tr>
<tr><td>Cloakroom</td><td>-</td><td>1,85</td></tr>
<tr><td>Other use (in factory)</td><td></td><td>0,88</td></tr>
<tr><td>Sea water</td><td>9,97</td><td>-</td></tr>
<tr><td></td><td>12,93</td><td>8,5</td></tr>
</table>
Note: Factory B several km from sea therefore higher sea water usage not possible.</td><td>Product washing
Transportation fluming (washwater used for flumes)
Floor and equipment washing</td><td>Sea water used for product washing and all equipment and floor washing. Rate 4 kℓ/h. Fresh water-packing purposes and steam generation 0,9 kℓ/h. Fresh water usage 0,45 kℓ/t (7,5 kℓ/d) Sea water usage 2,0 kℓ/t (36 kℓ/d)</td></tr>
<tr><td>6. Liquid effluent</td><td>Effluent generated based upon data from one factory
<table>
<tr><th>Wet off-loading water</th><th>Cannery effluent (incl. all fluming and washing water)</th></tr>
<tr><td>102 kℓ/h for 100 h p.a. giving 10 200 kℓ/a 18% of total effluent</td><td>90 kℓ/h for 500 h p.a. giving 45 000 kℓ/a 80% of total effluent</td></tr>
</table></td><td>Mainly originating from washing and fish transportation. Estimated effluent discharges are:
Sea water: 100% of sea water consumption
Fresh water: 90% of fresh water consumption
Specific effluent volumes:
<table>
<tr><th></th><th>Sea water</th><th>Fresh water</th></tr>
<tr><td>Factory A
Factory B</td><td>9,9 kℓ/t
-</td><td>1,84 kℓ/t
6,3 kℓ/t</td></tr>
</table>
Ice - used for cooling purposes while melting during fish transportation (factory B)
Trawler capacity 70 t
Total load of ice 110 t
Size of catch 67,7 t;20 t;10 t
Ice recovered-5t; 40t; 60t melting
Thus ice can generate up to 6 kℓ/t of effluent of a white-fish processing plant.</td><td>All originates from fluming and washing, the latter comprising product washing and equipment and floor washing. Marine products based on 120 hrs. operation p.a.
<table>
<tr><th></th><th colspan="2">Volume</th></tr>
<tr><td></td><td>kℓ/h</td><td>kℓ/h</td></tr>
<tr><td>Lobster body flume</td><td>12</td><td>1 440</td></tr>
<tr><td>Lobster tail washing</td><td>12</td><td>1 440</td></tr>
<tr><td>Lobster plant floor wash</td><td>1,5</td><td>180</td></tr>
</table>
33,75 t Frozen tails generated Specific effleunt generation
<table>
<tr><th>Factory no.</th><th>Live intake weight</th><th>Frozen tails</th></tr>
<tr><td></td><td>kℓ/t</td><td>kℓ/t</td></tr>
<tr><td>5
3</td><td>90,7
65,8</td><td>27,8
20,9</td></tr>
</table></td><td>Discharge to sea at rate of 4,8 kℓ/h; most of water originates from washing operation. Related to raw intake the effluent discharged amounts to ± 2,4 kℓ/t</td></tr>
</table>

TABLE 3 (CONTD.)

<table>
<tr><th>Description</th><th>Cannery</th><th>White fish</th><th>Rock lobster (crayfish)</th><th>Perlemoen (abalone)</th></tr>
<tr>
<td>7. Effluent strength</td>
<td>Based upon figures from factory No. 5
<table>
<tr><th>Strength</th><th>Wet off-loading water</th><th>Cannery</th></tr>
<tr><td>COD (mg/ℓ)
N (mg/ℓ)
SS (mg/ℓ)
Fats(mg/ℓ)</td><td>6 400
236
7 300
42</td><td>4 700
330
7 100
38</td></tr>
<tr><td>Total load
COD (kg/h)
N (kg/h)
SS (kg/h)
Fats</td><td>
652,8
24,07
744,6
4,28</td><td>
423
29,7
639
3,42</td></tr>
<tr><td>% Load split
FL
COD
N
SS
Fats</td><td>
18
24
14
19
20</td><td>
82
76
86
81
81</td></tr>
</table>
</td>
<td>Based upon data from on plant
<table>
<tr><th></th><th>COD</th><th>SS</th></tr>
<tr><td>Filleting dept.</td><td>3 600 mg/ℓ</td><td>102 mg/ℓ</td></tr>
<tr><td>Readymeal dept.</td><td>10 500 mg/ℓ</td><td>670 mg/ℓ</td></tr>
<tr><td>Smoking dept.</td><td>900 mg/ℓ</td><td>76 mg/ℓ</td></tr>
<tr><td>Fish dept.</td><td>300 mg/ℓ</td><td>20 mg/ℓ</td></tr>
<tr><td>Preparation section</td><td>320 mg/ℓ</td><td>30 mg/ℓ</td></tr>
<tr><td>Final (composite) effluent</td><td>3 200 mg/ℓ</td><td>200 mg/ℓ</td></tr>
<tr><td>Total specific load</td><td>16,48 kg/t</td><td>1,03 kg/t</td></tr>
</table>
</td>
<td>Based upon data from factory no. 8 and assuming 120 h/a operation. 110,25 t live lobster production p.a. @ 33,75 t frozen tails
<table>
<tr><th>Parameter</th><th>Lobster body fluming</th><th>Tail fluming water</th></tr>
<tr><td>COD (mg/ℓ)
N (mg/ℓ)
SS (mg/ℓ)
Fats(mg/ℓ)
COD (kg/a)
N (kg/a)
SS (kg/a)
Fats(kg/a)</td><td>68
9
5 280
34
97,9
12,9
7 603
48,9</td><td>100
12
30
26
144
17,3
43,2
40,3</td></tr>
</table>
<table>
<tr><th>Parameter</th><th>Floor wash water</th></tr>
<tr><td>COD (mg/ℓ
N (mg/ℓ)
SS (mg/ℓ)
Fats(mg/ℓ)
COD (kg/a)
N (kg/a)
SS (kg/a)
Fats(kg/a)</td><td>209
29
140
4
37,6
5,2
25,2
0,72</td></tr>
</table>
<table>
<tr><th colspan="2">Totals kg/a</th><th></th><th></th></tr>
<tr><td>COD
279,5</td><td>N
35,38</td><td>SS
7 671,4</td><td>Fats
82,92</td></tr>
</table>
<table>
<tr><th></th><th>Final product kg/t</th><th>Live intake weight kg/t</th></tr>
<tr><td>COD
N
SS
Fats</td><td>8,28
1,05
227,3
2,66</td><td>2,54
0,32
65,58
0,75</td></tr>
</table>
</td>
<td>Strength
COD 320 mg/ℓ
SS 170 mg/ℓ

Load

Volume 2,4 kℓ/t
COD 0,77 kℓ/t
SS 0,41 kℓ/t</td>
</tr>
<tr>
<td>8. Solids disposal</td>
<td>All factories have fish-meal plants and solid wastes discharged from the canning plants are transferred to the fish-meal plant for processing</td>
<td>The large factories have fish-meal plants and the solid wastes discharged from these plants are transferred to the fish-meal plant for processing</td>
<td>Approximately 2,3 tons of lobster waste is dumped on land per ton of frozen tails (yield 31%). Chitosan can be produced from lobster shells</td>
<td></td>
</tr>
</table>

CHAPTER 2

POLLUTANT LOADS ARISING FROM FISH OFF-LOADING

2.1 Methods of off-loading

Two methods of off-loading fishing vessels are commonly employed, and are referred to as "wet" and "dry" off-loading respectively. Wet off-loading uses sea water as the transport medium while dry off-loading relies on air flow. In dry off-loading however, water is sometimes added to the hold to improve suction, to assist in fluidizing the catch and thereby to accelerate the off-loading process (semi-dry off-loading). Wet off-loading is generally used for off-loading fish for canning. When boats have to travel long distances before off-loading, the catches are often in a poor state by the time they are off-loaded. Wet off-loading such catches, which are by their nature destined for fish-meal production, produces large volumes of highly polluted effluent. The South African industry has generally adopted semi-dry off-loading for fish-meal processing, but the volume of water added to the hold is in some cases close to zero.

Wet off-loading is accomplished by fluidizing the catch in the boat hold and pumping or sucking out the load; the suction is created either by a Kimmerle-type pump or by high-volume water pumping through banks of venturi ejectors. The fish so extracted are conveyed to the process plant in flumes which float the catch in the off-loading water. This process generally creates the minimum of fish damage which is important where fish are to be canned. Wet off-loading systems are simple to construct and operate, and are fast and relatively efficient. For some fish-canning plants, the catch is kept fresh by filling the hold with cold sea water, obtained either by mechanical refrigeration (for RSW boats) or by ice-chilling (for CSW boats). Figure 1 shows a diagram of a typical wet off-loading system.

Various designs of dry off-loading systems exist but the fundamental principles of operation remain the same. Figure 2 shows a typical system, where a vacuum is drawn by air blowers and applied to the catch via a cyclone, hose and nozzle. The fish sucked from the hold are discharged via an airlock to conveyor belts, which transport the catch to the processing plant. The main variations found in the system are in the suction nozzle design, where air velocities vary widely, and in the type of airlock used beneath the separation cyclone; some plants employ sliding shuttle valves and others use rotary airlocks. When water is used to assist in breaking up compacted or arched loads, the resultant effluent is extremely strong.

2.2 Effluent sources in off-loading processes

"Bloodwater" is the generic term for all liquid arising from the fish prior to cooking. This liquid arises during passage at sea, off-loading to shore and storage in fish pits prior to processing. These bloodwaters constitute a major potential source of pollution, and, for purposes of definition, are considered here to be included with the off-loading effluents.

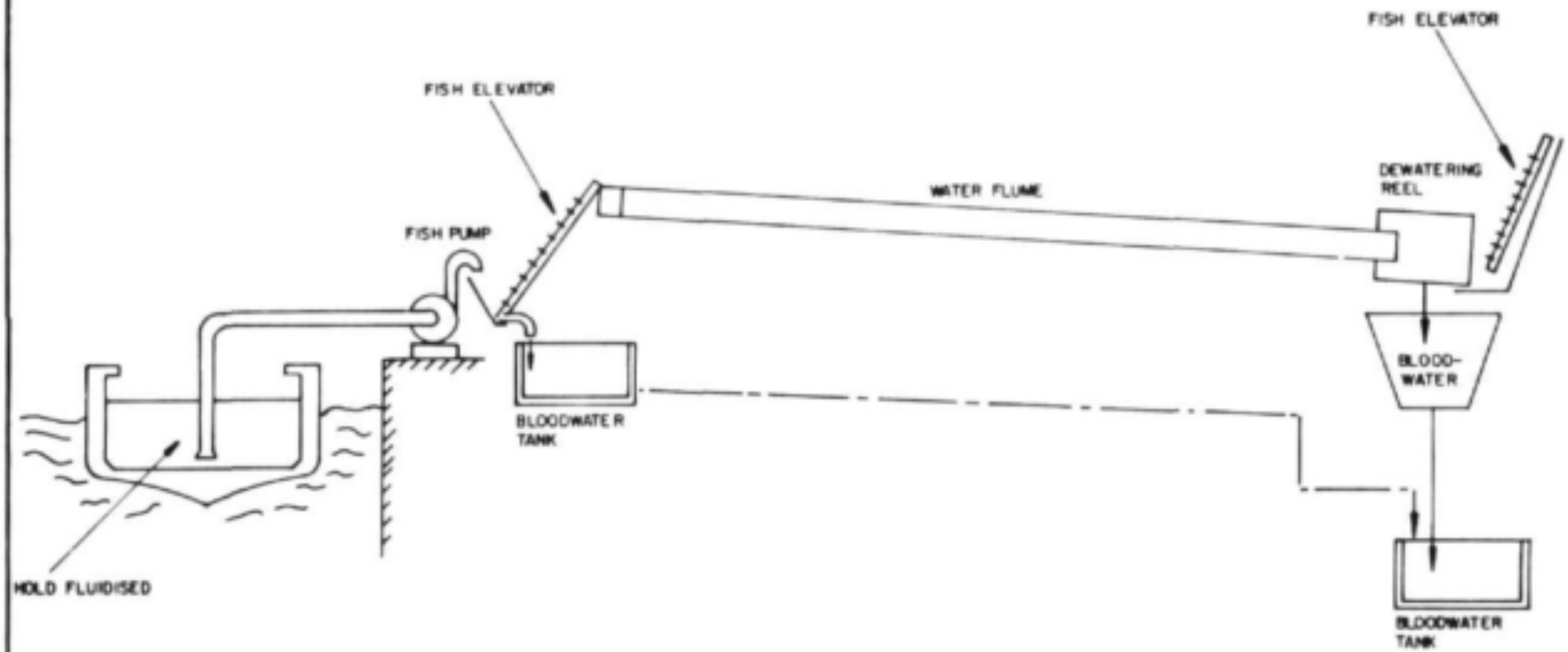


Figure 1. Typical wet off-loading system

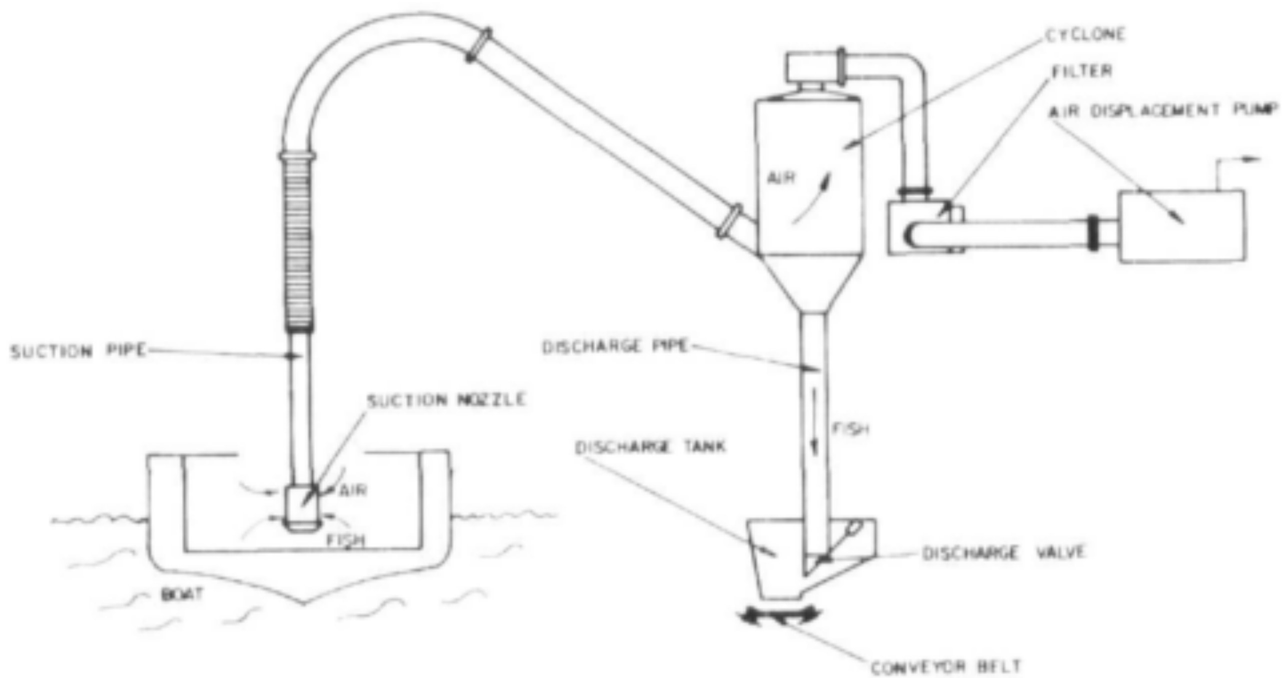


Figure 2. Typical dry off-loading system

Depending on the method of off-loading employed, these effluents arise as a result of the following:

(a) water taken into boat holds during catching and passage at sea;

(b) release of fish body liquids in boat holds, during off-loading, or in fish pits;

(c) water added to boat holds to facilitate off-loading;

(d) water used for fluming.

In general, effluents associated with wet off-loading are of higher volume but lower strength in comparison with dry off-loading or semi-dry off-loading effluents. This difference is firstly because the greater water usage in wet off-loading gives a substantial dilution of the resultant effluent and secondly because wet off-loading is generally used on better-quality fish destined for canning and less fish damage is usually caused, although dry off-loading or semi-dry off-loading systems can be operated at comparably low fish damage ratios.

For comparison purposes, Table 4 gives typical pollutant values for wet off-loading and dry off-loading effluents. Depending on the quantity of water used, the strength and volume of semi-dry off-loading effluents are intermediate between the wet off-loading and dry off-loading values given.

TABLE 4. TYPICAL POLLUTANT VALUES FOR WET OFF-LOADING AND DRY OFF-LOADING EFFLUENTS

Parameter	WOL		DOL	
	Range	Typical	Range	Typical
Specific effluent volume, m^3/t	2 - 5	3	0 - 0,5	0,1
COD concentration, mg/ℓ	3 000 - 15 000	5 000	5 000 - 350 000	40 000
Specific COD load, kg/t	6 - 30	15	0 - 50	4
SS * concentration, mg/ℓ	1 000 - 8 000	2 000	1 000 - 40 000	5 000
Specific SS * load, kg/t	2 - 16	6	0 - 20	0,5

* Includes filterable crude oil fractions

2.3 Wet off-loading

A typical wet off-loading sequence is shown in block diagram form in Figure 3. Sea water is used for fluidization of the catch in the hold, for fluming and for washdown. The resultant effluent volume, which includes the bloodwater associated with the fish, is dewatered on elevators and/or reels and then generally passed to a scum tank before discharge to the ocean. The total effluent volume from wet off-loading discharged annually by the local industry is around 10 000 m^3 per season.

In surveys carried out ("Water and Effluent Management in the Fishing Industry", op.cit.), effluent volumes from wet off-loading systems were found to range from 2 to 5 m^3/t of fish off-loaded. Where anchovy is wet off-loaded for processing to pet food, the specific effluent volumes generated tend to be slightly lower than for pilchard off-loading for canning, due to

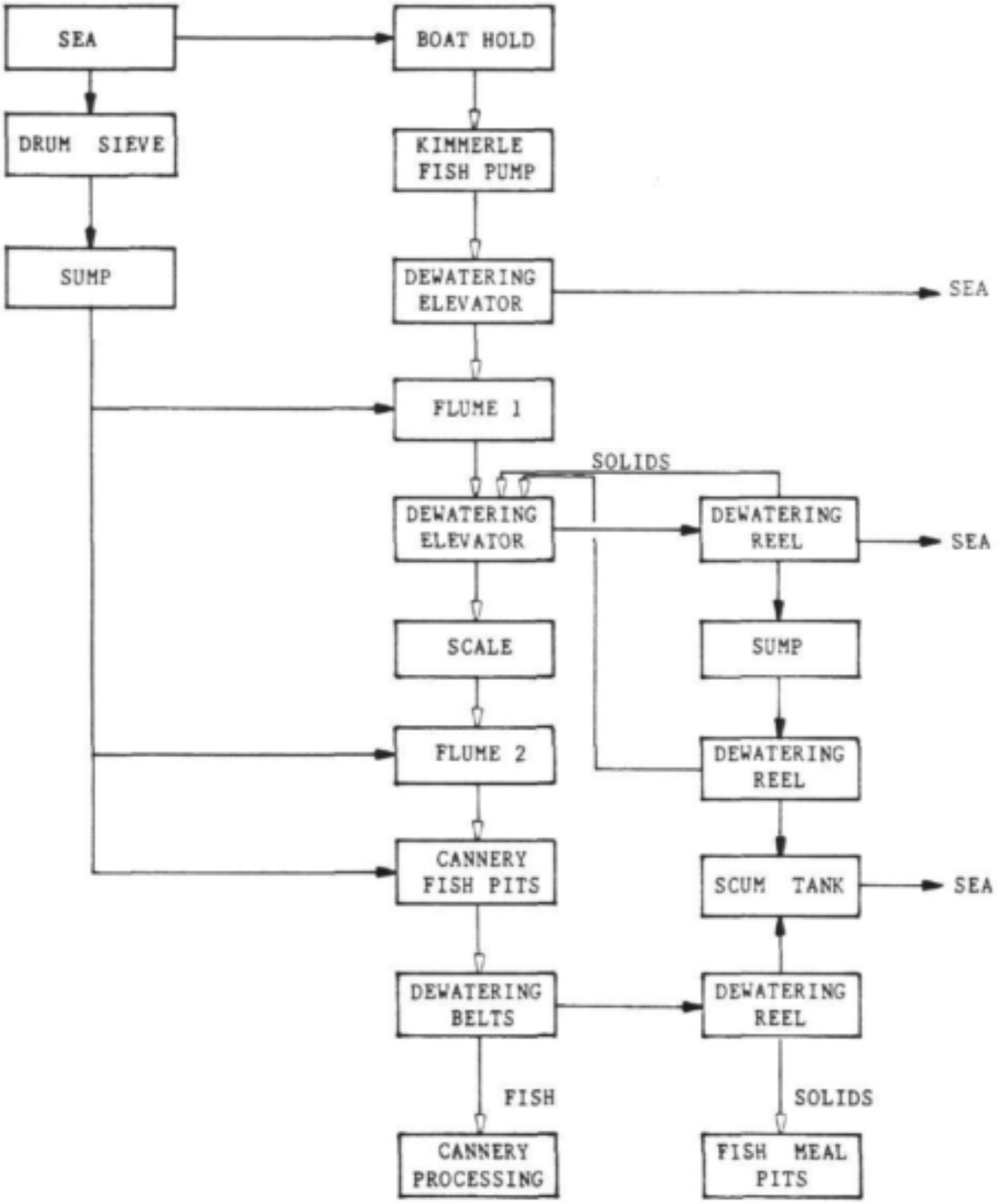
(a) a higher off-loading rate, typically 30 t/h for anchovy compared with 25 t/h for pilchard; and

(b) a smaller volume of fluidization water added to the hold, typically 0,5 m^3/t for anchovy compared with 1,3 m^3/t for pilchard.

The raw effluent quality from wet off-loading is very dependent on the volume of water used for fluidization of the hold and for flume transport. Table 5 shows typical pollutant values for wet off-loading effluents as measured at a local factory.

TABLE 5. TYPICAL POLLUTANT VALUES FOR WET OFF-LOADING EFFLUENTS

Parameter	Units	Value
Specific effluent volume	m^3/t	5,1
COD concentration	mg/ℓ	6 400
COD specific mass load	kg/t	32,6
SS concentration	mg/ℓ	236
SS specific mass load	kg/t	1,2
N concentration	mg/ℓ	7 300
N specific mass load	kg/t	37,2
FOG concentration	mg/ℓ	42
FOG specific mass load	kg/t	0,21



NOTES:

1. —▷ RAW MATERIAL OR PRODUCT FLOW
2. —► WATER OR EFFLUENT FLOW
3. SPECIFIC EFFLUENT VOLUME (PILCHARDS) - 9,5 m^3/t
4. SPECIFIC EFFLUENT VOLUME (ANCHOVY) - 7,4 m^3/t

Figure 3. Block diagram : Wet off-loading for canning

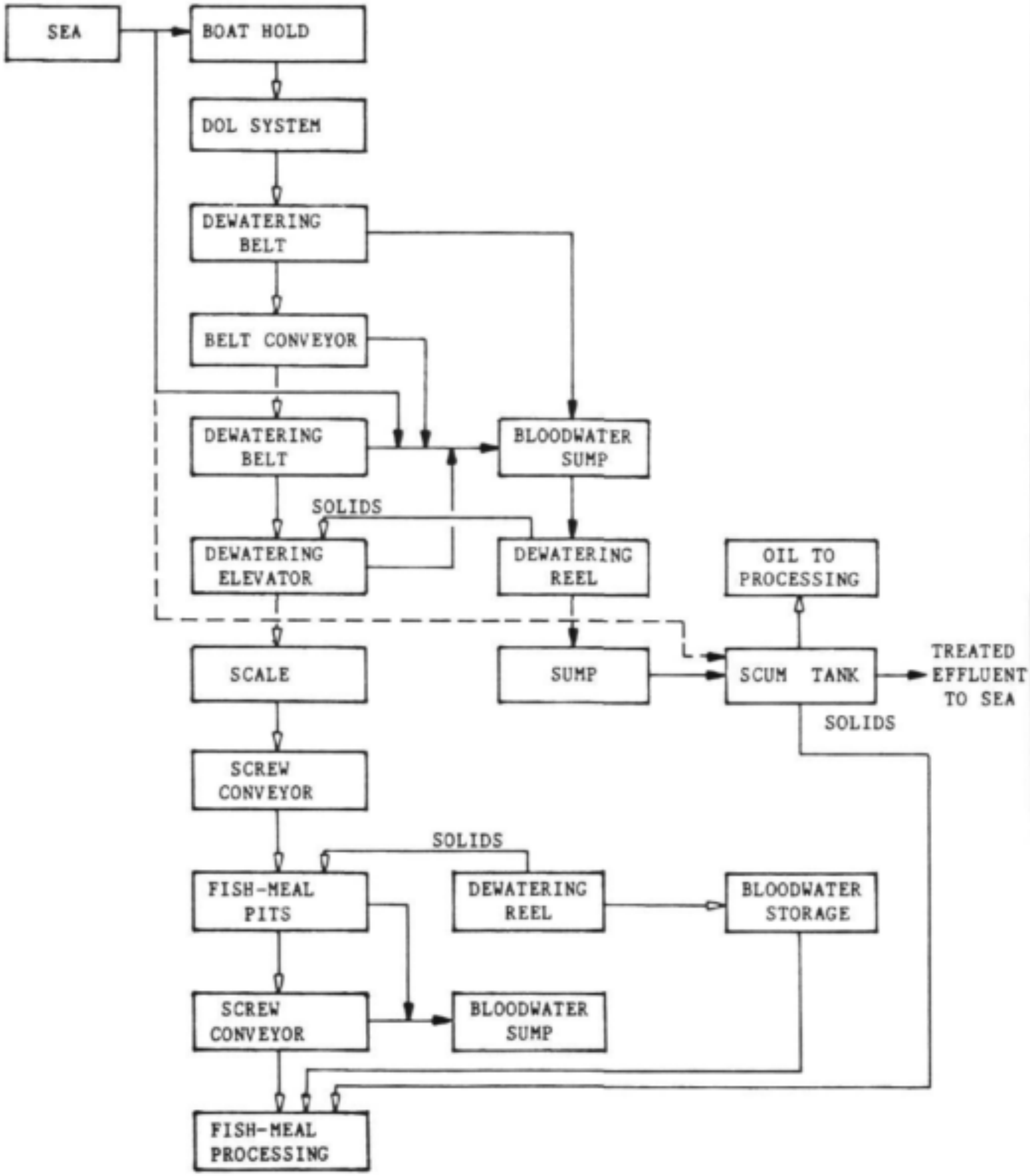
2.4 Dry off-loading

Figure 4 illustrates a typical dry off-loading sequence in block diagram form. The effluent volume arises from the bloodwater associated with the catch, from water added to the hold during catching and passage at sea and from water added to the hold or conveying equipment during off-loading. The resultant effluent varies widely in strength depending on the type of fish, its condition when off-loaded, and the quantity of water added. Typical pollutant values for dry off-loading effluents are given in Table 6.

TABLE 6. TYPICAL POLLUTANT VALUES FOR DRY OFF-LOADING EFFLUENTS

Parameter	Units	Value	
		Range	Typical
Specific effluent volume	m^3/t	0 - 0,5	0,1
COD concentration	mg/ℓ	5 000 - 350 000	40 000
COD specific mass load	kg/t	0 - 50	4
BOD concentration	mg/ℓ	1 000 - 70 000	8 000
BOD specific mass load	kg/t	0 - 10	1
SS concentration	mg/ℓ	1 000 - 40 000	5 000
SS specific mass load	kg/t	0 - 20	0,5
NH_3 - N concentration	mg/ℓ	200 - 500	300
NH_3 - N specific mass load	kg/t	0 - 0,2	0,03
Protein concentration	mg/ℓ	5 000 - 20 000	10 000
Protein specific mass load	kg/t	0 - 10	1

The organic strength of bloodwater generated from the off-loading of anchovy is generally considerably higher than that from pilchards or maasbanker. When processing fresh anchovy, 1 t of fish-meal is produced from around 4 t of fish, while the same yield is only achieved from around 5 t of older, poorer quality fish unless all the bloodwater is evaporated and added to the product. At the lower product yield, greater quantities of solid and liquid wastes are produced; specifically, more bloodwater and stickwater are generated.



NOTES:

1. —▷ RAW MATERIAL OR PRODUCT FLOW
2. —► WATER OR EFFLUENT FLOW

Figure 4. Block diagram : Dry off-loading for fish-meal processing

The volume of bloodwater generated from dry and semi-dry off-loading averages around 0,13 m^3/t of fish off-loaded, which is about 2% of the total effluent volume from fish-meal plants. The corresponding specific pollutant loads are however around 5 kg COD/t and 2 SS/t, each representing around 40% of the total pollutant mass loads generated in the factory. Effective management of the bloodwaters from dry or semi-dry off-loading is thus particularly important.

Raw bloodwater should never be discharged from fish factories. In practice, handling of bloodwater ranges from screening and settling in a scum tank before discharging to the ocean, to evaporation along with the stickwater i.e. zero discharge of raw or treated bloodwater. At one factory the bloodwater is collected, heat-treated and then desludged in a decanter to recover the coagulated solids for processing to fish-meal. The strength of the raw bloodwater is reduced by around 60% by this process.

CHAPTER 3

POLLUTANT LOADS ARISING FROM FISH PROCESSING

3.1 Fish-meal production

Figure 5 illustrates a typical sequence for fish-meal production and shows the points in the process at which water is used and where effluents are generated. Fresh water is used for boiler feed make-up and domestic use, while sea water is used for off-loading, condenser cooling, oil polishing and plant washdown.

From surveys conducted at fish-meal plants, ("Water and Effluent Management in the Fishing Industry", op.cit.), the pollutant sources in fish-meal production, excluding any off-loading effluents, are shown in Table 7.

TABLE 7. POLLUTANT SOURCES IN FISH-MEAL PRODUCTION

Effluent source	Volume		Effluent COD			Effluent SS		
	m^3/t	% of total	kg/m^3	kg/t	% of total	kg/m^3	kg/t	% of total
Oil polishing	0,07	0,9	25,3	1,77	72,6	1,0	0,07	16,3
Evaporator condensates	0,41	5,1	1,3	0,53	21,7	0,6	0,25	58,1
Plant washdown	0,02	0,3	7,0	0,14	5,7	5,5	0,11	25,6
Boiler blowdown	0,01	0,1	0	0	0	0	0	0
Condenser cooling	7,50	93,6	0	0	0	0	0	0
TOTALS	8,01	100	33,6	2,44	100	7,1	0,43	100

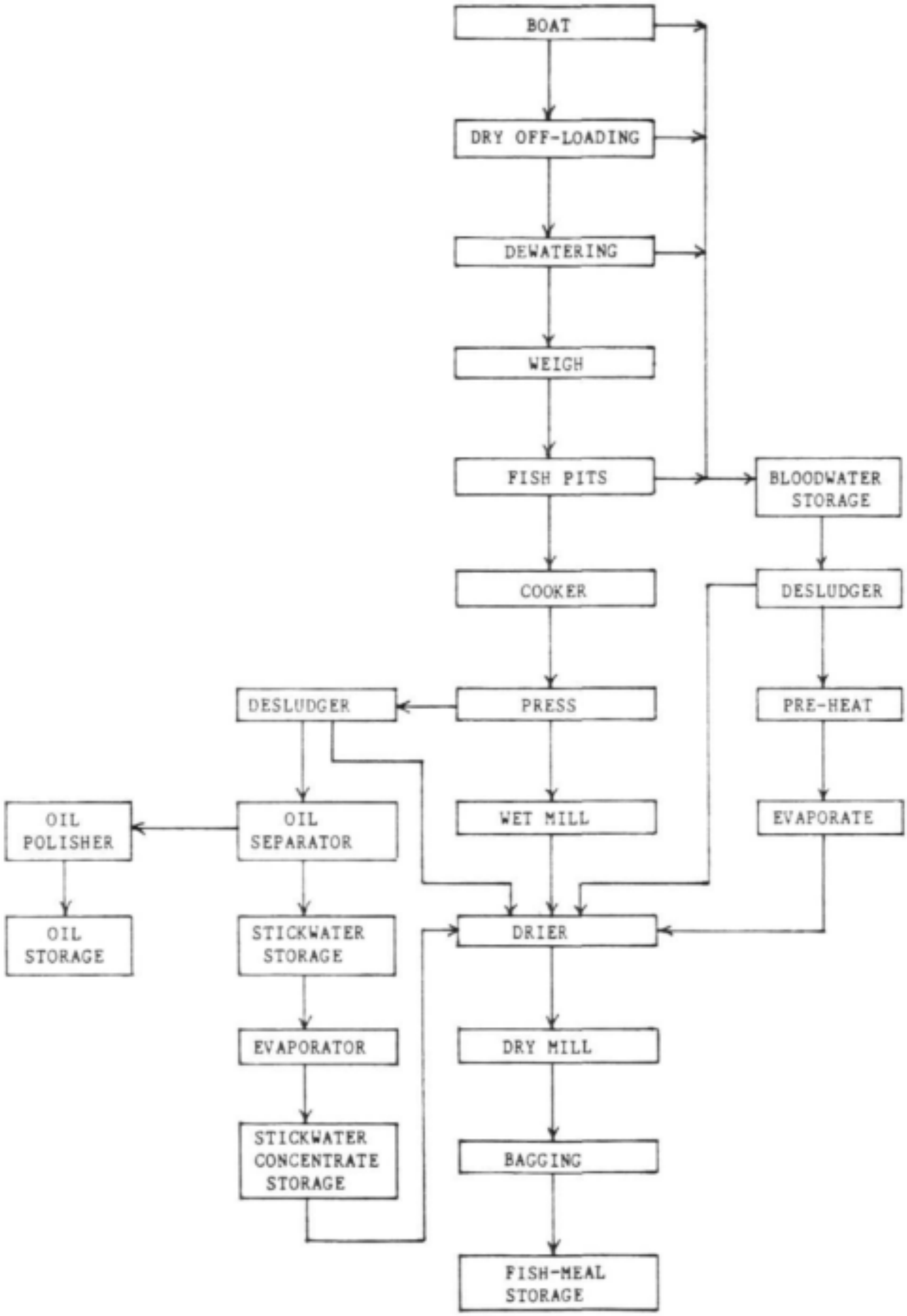


Figure 5. Typical fish-meal process

The major volumetric effluent load arises from condenser cooling (93,6% of the total waste water volume) but this effluent contributes zero nett organic load (Table 7). Conversely, the effluents produced during oil polishing and separation are low in volume but constitute a major proportion of the organic pollutant load generated during fish-meal production. Effective management of these pollutant sources is thus essential.

Stickwater is not usually discharged as an effluent. Raw stickwater is generally evaporated in multiple-effect evaporators to produce a concentrate which is added to the fish-meal entering the drier. Condensate from the first effect of the stickwater evaporators is pure distilled water which is re-used as boiler feed. The condensates from subsequent evaporator effects are contaminated and are discharged along with the condenser cooling water. Table 8 shows the very large pollutant potential of raw and concentrated stickwater, and the consequent need to eliminate entirely any losses of this material into the waste-water flow. With effective housekeeping, stickwater evaporation is a low-pollution process, as demonstrated by the low pollutant concentrations in the second and third effect condensates given in Table 8.

TABLE 8. TYPICAL STICKWATER PLANT ANALYSES

Parameter	Raw stickwater	Stickwater concentrate	2nd & 3rd Effect condensates plus cooling water
COD, kg/m^3	150	450	1,5
TS, % m/m	12	40	3,3
Protein, % m/m	8	26	nearly zero
FOG, % m/m	1	3	nearly zero

Two-stage centrifugation of the press liquor is used firstly to separate solids (desludging) and secondly to separate fish oil (oil separation). The solids are returned to the drier, while the fish oil is polished by the addition of hot water followed by further centrifugation. Oil separation and polishing give rise to low-volume, high-strength effluents, as shown in Table 9.

TABLE 9. POLLUTANT VALUES FROM OIL SEPARATION/POLISHING

Parameter	Units	Value	
		Range	Average
Specific effluent volume	m^3/t	0,5 - 0,10	0,07
COD concentration	mg/ℓ	11 000 - 217 000	69 300
COD specific mass load	kg/t	0,8 - 15,2	4,9
SS concentration	mg/ℓ	3 000 - 58 000	19 600
SS specific mass load	kg/t	0,2 - 4,1	1,4
Protein concentration	mg/ℓ	1 500 - 6 000	4 400
Protein specific mass load	kg/t	0,11 - 0,42	0,31
NH_3-N concentration	mg/ℓ	150 - 400	300
NH_3-N specific mass load	kg/t	0,01 - 0,03	0,02
FOG concentration	mg/ℓ	1 500 - 2 200	1 900
FOG specific mass load	kg/t	0,11 - 0,15	0,13

Other sources of pollution from fish-meal production are plant and equipment washdown and, at some factories, deodorizer discharges. Effluent from plant and equipment washdown vary widely in volume and concentration, depending on the level of housekeeping practised and the use of dry-brushing or vacuum techniques for collection of dry solids. Deodorizer discharges are generally low in terms of organic strength, and not a major waste water pollution problem for the industry but emissions to atmosphere can constitute an odour nuisance.

3.2 Fish canning

Figure 6 illustrates a typical sequence for fish canning. The fish are generally wet off-loaded so as to cause a minimum of damage, and then flumed to holding pits where they are kept fluidized with mechanically chilled sea water. From the holding pits, the fish are flumed as required to cutting tables for head, tail and gut removal, followed by further processing as

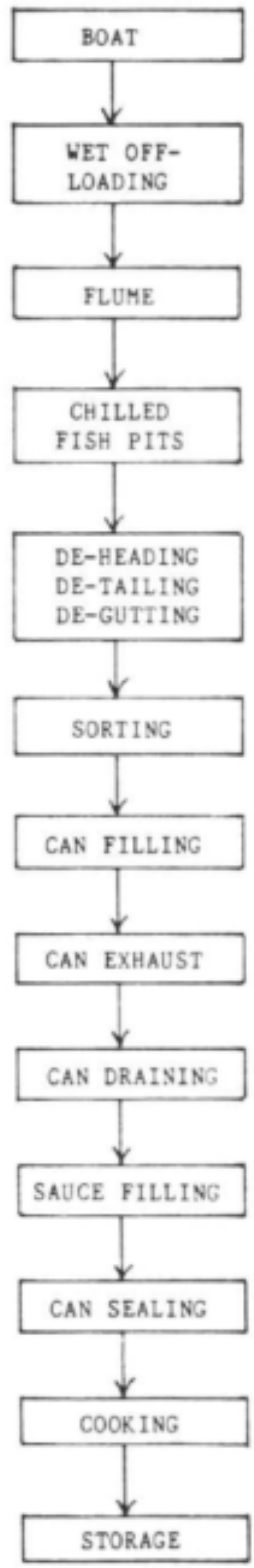


Figure 6. Typical fish-canning process

required for the particular canned product being produced. The offal is flumed to dewatering reels where the solids are recovered and added to the fish-meal plant holding pits.

Most of the sea-water usage in fish canning is for fluming the fish to the various process stages and for plant and floor washing. From surveys carried out at local fish canneries, sea-water usage ranges around 2 to 3 m^3/t and the specific effluent volume generated is of the same order.

The quality of fish-canning effluent is typically much better than that from fish-meal production, firstly because generally only better quality fish is processed (the exception being canning of pet food) and secondly the greater water usage from fluming gives a substantial dilution of the resultant effluent.

During canning of pilchards, the quality of the final effluent measured at a local cannery was found to be as follows (range given in brackets): COD 3 400 (1 400 to 5 100) mg/ℓ; CCOD 1 900 (950 to 2 700) mg/ℓ and SS 700 (300 to 1 200) mg/ℓ. Washdown effluents were found to be somewhat lower in COD, but SS concentrations were similar to those from processing as shown above.

The quantity of fish processed to canned products is small in comparison with fish-meal production. Trials carried out demonstrated also that the effluents produced from typical fish-canning processes are amenable to treatment by the processes discussed in later sections. Overall therefore, the management of cannery waste waters is not a major problem for the industry.

CHAPTER 4

HOUSEKEEPING FOR MINIMIZING EFFLUENT PROBLEMS

4.1 Existing effluent management practices

Processes for reducing pollution commonly used include dewatering of effluents on reels (perforated rotary drum screens) for gross solids capture, the use of scum tanks for settling of suspended solids and flotation of oil, and the evaporation of stickwater. These all contribute to reducing the effluent load discharged to sea. However, zero discharge of waste water (with the exception of cooling water and condensates) can be achieved, as for example at one local fish-processing factory where the effluent volume generated is minimized by good housekeeping, adequate storage capacity is provided and all the effluent collected is evaporated to a concentrate for processing to fish-meal.

Problem areas in existing practice are as follows:

(a) Polluted bilge water and hold washdown discharges occur in harbours;

(b) Water addition during dry off-loading leads to unnecessarily high effluent volumes and consequent hydraulic overloading of effluent treatment facilities;

(c) Excessive water is used during wet off-loading, with the same consequences as in (b);

(d) Inadequate facilities are provided for treating bloodwater;

(e) Inadequate plant capacity is provided for evaporation of stickwater, leading to overloading and loss of stickwater during peak periods;

(f) Oil polisher discharges are inadequately treated;

(g) End-of-line waste-water treatment is inadequate.

4.2 Management targets for reducing pollution

To minimize the hydraulic and organic loads transmitted to effluent treatment processes, the volume and/or strength of the effluents should be reduced to the minimum at source by good management and housekeeping. Steps which management should take include the following:

(a) Fleet management should be such that delays between catching and processing are minimized;

(b) Discharge of bilge waters and washing of holds in harbours is not permitted in terms of the Sea Fisheries Act and such effluents should therefore be collected in shore-based tanks for treatment;

(c) All fresh water and sea water used for industrial purposes must be metered as required by permits issued in terms of Section 12 of the Water Act and all fresh water and sea water reticulated to service connections at jetties and all water supplied to boat holds for off-loading or washdown should therefore be metered and recorded, with a view to reducing consumption to the minimum practicable, rather than using the volume that is convenient;

(d) All bloodwater should be collected for treatment;

(e) Stickwater evaporation plants should be sized so as to have 20% spare capacity for peak loads to avoid evaporator overload which results in excessive contamination of the evaporator condensate/cooling water streams and temperature recorders should in addition be installed at all marine discharge points where stickwater losses can occur - because of the very high pollutant potential of stickwater, reduction of stickwater losses to a minimum is desirable;

(f) Treatment facilities for waste waters from factories should be designed so as to have adequate capacity and performance for the maximum effluent loads that can occur at any time;

(g) To properly quantify the size of effluent handling and treatment facilities required, and to enable patterns of improvement to be monitored, each factory should carry out a detailed survey of all effluent flows, volumes and strengths.

4.3 Major pollutant sources

Assuming zero discharge of stickwater at all times, the largest contribution to the typical pollutant load discharged from fish-processing factories arises from off-loading and fish pit bloodwaters. Around 45% of the overall COD load and 40% of the overall SS load occur in these effluents, which constitute typically 8% of the total waste-water volume. These effluents must receive proper treatment as a necessary first step in effluent management in the industry, and the benefit to the industry is the economic recovery of revenue-earning material in the form of increased product yields.

In fish canning the organic load (COD and SS) in the cannery waste water arises in approximately equal proportions from wet off-loading /fluming and the cannery operations. These effluents have been found to be amenable to flotation treatment, particularly if chemical dosing is used to coagulate the solid material for recovery.

Because of the very high organic strength of raw or concentrated stickwater, all losses of such material must be eliminated entirely. In view of the high value of stickwater when processed to fish-meal, good factory management would imply careful control of stickwater handling for maximized product yield.

4.4 Effluent segregation/combination

When effluents of widely differing concentrations occur, it is good practice to treat these by suitable means at source rather than after combining the low-volume, high-strength discharges with the high-volume, low-strength discharges. Mixing of such effluents usually results in a large volume of medium-strength effluent which entails expensive treatment.

The effluents generated in fish processing range from virtually clean sea water to highly contaminated organic effluents. Effective ways of segregating/combining these effluents are outlined in Section 6.1.

CHAPTER 5

EFFLUENT TREATMENT PROCESSES

5.1 First principles

The effluents arising during fish off-loading and processing have been quantified and are potentially very strong and of high volume. Good housekeeping, to minimize both the strength and volume of the resultant effluent, is the essential first step in implementing an effective effluent management policy. The resultant, minimal effluent which is generated must then be treated by appropriate unit processes, organized into a suitable waste water treatment scheme, to achieve the desired final discharge quality. To establish effective effluent treatment routes, various effluent treatment unit processes were studied on pilot scale, and some on full scale. The results of these studies have been reported in "Water and Effluent Management in the Fishing Industry", op.cit.

Although general conclusions can be drawn in many cases as to the effectiveness of a particular effluent treatment process, two factors stand out in assessing the particular application of any such process, namely that any effluent treatment system will only be as effective as the degree of supervision and maintenance which it receives, and secondly that the choice of treatment process must be selected to match local factors. These principles must be put into practice for effective application of the effluent treatment unit processes discussed hereafter.

5.2 Screening

Screening is widely employed in the fishing industry to recover particulate fish solids from off-loading and transport water and from cannery effluents. The fish solids so recovered are generally added to the fish-meal pits for processing to fish-meal. The type of screen most frequently found is the perforated rotary drum type, generally referred to as dewatering reels. These are primarily used to separate fish solids from transport water. Typical dimensions and operating characteristics are drum diameters around 1 m, drum lengths ranging from 2 to 3 m, rotational speeds around 60 rpm and drum perforations around 3 mm. Relatively large drum perforation sizes are employed, to prevent excessive blinding of the screen surface, and therefore only gross solids are recovered. This gross solids recovery is a valuable contribution to reducing the solids load in the factory waste water, but this treatment does not in itself produce an effluent quality which is acceptable for marine discharge.

The effluent from dewatering reels contains considerable quantities of solids which can be removed by screens of smaller aperture. One suitable type is the tangential wedgewire screen. Trials conducted on fish factory effluents using static tangential wedgewire screens showed that these screens could produce a substantial further reduction in the suspended solids concentration of effluents which had already passed through dewatering reels. The results obtained are summarized in Table 10. On anchovy effluents, suspended solids (SS) removal ranged from around 50% removal at a weir loading of 3,3 $m^3/m.h$ (m^3/h of effluent fed per m of screen width) down to 27% removal at an increased weir loading of 4,7 $m^3/m.h$. At comparable weir loadings, 60% SS removal can be obtained on effluents from processing of pilchards or other firmer fish.

TABLE 10. EFFICIENCY OF STATIC TANGENTIAL WEDGEWIRE SCREENING

Screen aperture (mm)	Weir loading ($m^3/m.h$)	Type of effluent	COD, mg/ℓ			SS, mg/ℓ		
			In	Out	% Removal	In	Out	% Removal
0,5	3,3	Anchovy	54 393	41 004	25	4 812	2 375	51
0,5	4,0	Anchovy	71 548	52 301	27	2 373	1 600	33
0,5	4,2	Anchovy	67 364	58 159	14	2 108	1 375	35
0,5	4,7	Anchovy	78 243	65 272	17	3 702	2 710	27
0,5	4,7	Pilchard	8 362	6 323	24	5 040	2 010	60

Note: Floating oil in the ancnovy samples is not included as "suspended solids" in the analyses, although some of this material was retained by the screen as a surface film.

Maximum weir loadings for static tangential wedgewire screens were found to be approximately 3 $m^3/m.h$ for anchovy or other oily effluents and 4 $m^3/m.h$ for pilchard or less oily effluents. Such weir loadings should give SS removal figures of around 50% at the concentrations typically experienced with these effluents, provided effective cleaning systems, such as arrays of automated high pressure hot water sprays and/or traversing mechanical brushes, are fitted. Such cleaning systems are particularly necessary if effluents from processing of soft or otherwise unfavourable fish are being screened. Rotary versions of these screens are also available.

5.3 Settling

Most local fish factories have installed a scum/settling tank for oil and/or solids recovery from the factory waste water and to provide a degree of treatment for the final discharge to sea. Surface loading rates ranging from 0,4 to 7,6 $m^3/m^2.h$, with corresponding hydraulic retention times of 1,67 to 0,1 h, have been observed. The efficiency of oil and solids removal is generally found to be better at the lower surface loading rates/higher hydraulic retention times.

In a radial flow pilot scale clarifier, not equipped with either top or bottom mechanical scrapers, it was found that for effective solids removal the surface loading rate should not exceed 0,5 $m^3/m^2.h$. Table 11 compares the performance of different clarifier configurations at various surface loading rates. Figure 7 illustrates the effect of surface loading rate on % SS removal

The efficiency of oil removal by clarifiers is also improved at lower surface loading rates, and a loading rate of 0,5 $m^3/m^2.h$ has been found to give better than 60% oil recovery. The high value of this recovered material (around R700/t in 1985) emphasizes the requirement to provide adequate surface area in settling tanks.

TABLE 11. EFFICIENCY OF CLARIFIERS

Type of clarifier	Type of effluent	Surface loading rate $m^3/m^2.h$	Retention time h	COD		SS	
				Feed g/ℓ	% Removal	Feed g/ℓ	% Removal
Rectangular, horizontal flow (full scale)	Combined final	0,46	1,0	26,8	22	3,5	74
Circular, radial flow (pilot scale)	Anchovy	0,71	1,0	10 - 96	10 - 13	2 - 5	4 - 12
Circular, radial flow, mechanically scraped (full scale)	Combined final	2,77	1,0	9,5	5	3,1	1,6

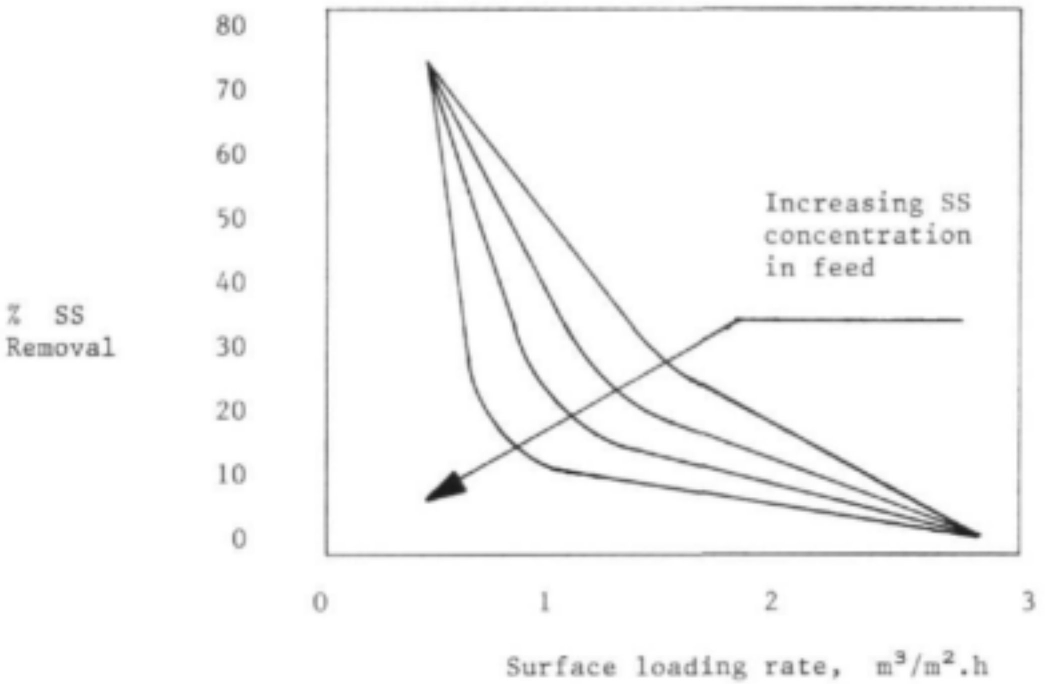


Figure 7. Effect of surface loading rate on clarifier efficiency

5.4 Chemical dosing

Chemical dosing trials on various fish processing effluents confirmed that acidic coagulants such as sulphuric acid and ferric chloride are suitable for precipitating colloidal materials into a suspended floc form which can be removed by settling or air flotation. Protein-specific coagulants such as lignosulphonic acid and sodium hexametaphosphate were also found to be effective coagulants, provided the pH of the effluent is lowered to around pH 3 to pH 5. The results of chemical dosing trials carried out are summarized in Table 12. The chemical that gave the largest reduction in the centrifuged COD (CCOD) concentration of anchovy and pilchard effluents was ferric chloride, in the pH range 3 to 4.

Chemical dosing does not generally reduce the total COD of the effluent, but merely converts materials from the soluble or colloidal form to the suspended form. This is reflected by a decrease in the CCOD concentration of the effluent, with a proportional increase in the suspended solids (SS) concentration. To purify the effluent, the precipitated SS must be physically removed. Depending on the physical nature of the precipitated floc, typically either settling or flotation may be used to separate these recovered solids, which may then be added to the fish-meal product to enhance the yield.

TABLE 12. EFFICIENCY OF CHEMICAL DOSING								
Effluent source	Initial conditions		pH Level giving max. CCOD reduction	Chemical dosing		% CCOD reduction	Chemical efficiency	
	CCOD mg/ℓ	SS mg/ℓ		Chem	Dosage giving CCOD reduction g/ℓ		g CCOD reduced per g chemical	g SS precipitated per g chemical
DOL A	20 800	1 200	3,0	H	6,5	51	1,6	0,3
DOL A	49 700	3 600	4,7	F	2,4	81	16,5	12,4
DOL A	29 200	3 900	3,0	H+L	2,7+0,5	51	4,7	4,7
DOL A	12 100	1 000	3,0	H+S	4,0+0,20	55	1,6	0,5
DOL A	59 200	10 200	3,5	H+S	4,5+4,50	40	2,6	2,6
CAN A	8 500	900	5,0	H+S	0,5+0,15	56	7,3	5,5
CAN P	3 300	800	4,0	F	0,90	72	2,6	3,6

Legend:

DOL = Dry off-loading
CAN = Cannery
A = Anchovy
P = Pilchard

H = Sulphuric acid
L = Lignosulphonic acid
F = Ferric chloride
S = Sodium hexametaphosphate

Notes: Centrifuged COD (CCOD) reduction is used as a measure of the efficiency of precipitation from soluble/colloidal to suspended form.

5.5 Flotation

Flotation processes operate on the principle of lighter fractions separating upwards from the bulk liquid. The fractions separated may either be naturally buoyant, as in oil separation in scum tanks, or may be made buoyant artificially by the formation of air-containing conglomerates. The air addition is generally either induced, by the action of venturi or orifice devices or pumps, or, alternatively, may be by the release of air dissolved under pressure. These air flotation methods are referred to respectively as induced air flotation (IAF) and dissolved air (pressure) flotation (DAF).

A full-scale scum tank was operated in the conventional settling mode and then modified to induced air flotation by pumping the feed flow through an orifice plate to which factory air at 5 bar was supplied. Table 13 shows the performance of the tank before and after this modification to induced air operation.

TABLE 13. COMPARISON OF GRAVITY AND INDUCED AIR FLOTATION

Type of operation	COD			SS		
	Feed g/ℓ	Effluent g/ℓ	% Reduction	Feed g/ℓ	Effluent g/ℓ	% Reduction
Conventional	9,5 - 23	9 - 20	5 - 13	3 - 3,2	2,8 - 3,1	2 - 6
Average	16,3	14,5	11	3,1	2,9	4
Induced air	6,8 - 21	3,8 - 15,8	19 - 44	0,8 - 2,0	0,4 - 1,2	18 - 71
Average	16,0	10,8	33	1,5	0,7	51

Modification to induced air flotation resulted in a marked improvement in COD and SS removal at comparable feed concentrations. The quantity of suitably fine air bubbles that can be introduced by induction in this way is however limited, and subsequent experience showed that dissolved air flotation was more efficient at higher feed concentrations (greater than 30 000 mg/ℓ COD). Because of the simplicity of the modification required, and the low operating and maintenance costs, it is nevertheless worthwhile converting suitable existing tanks to induced air flotation.

Circular and rectangular DAF plants were operated on various fish-processing effluents over a range of operating conditions (feed flow rate, saturated sea water flow rate and saturator pressure) and chemical dosing regimes (type of chemical dosage). The results obtained are summarized in Table 14. The large variation in feed concentrations (generally very dependent on the quality of fish being processed) and the range of chemical dosing regimes investigated results in a fairly wide spread in the overall treatment efficiency obtained in terms of percentage removal of COD, and SS.

TABLE 14. EFFICIENCY OF DISSOLVED AIR FLOTATION

Effluent	Chemical dosage	Average percentage reduction (range %)			Float solids	
		COD	CCOD	SS	Yield m^3/m^3 feed	% TS
DOL A	Nil	56 (41-90)	45 (10-65)	69 (29-74)	0,029	22
DOL A	H	66 (28-80)	50 (10-62)	65 (31-76)	0,048	14
DOL A	H+S	76 (60-80)	64 (53-76)	63 (59-68)	-	12
DOL A	H+L	48 (42-54)	44 (29-58)	-	0,038	12
DOL A	F	80 (-)	64 (-)	93 (-)	-	8
DOL A	F+H	78 (-)	61 (-)	94 (-)	-	8
DOL A + CAN A	Nil	35 (9-67)	48 (22-62)	35 (14-62)	0,022	14
DOL A + CAN A	H	48 (38-78)	36 (9-58)	40 (20-75)	0,043	12
DOL A + CAN A	H+S	55 (-)	24 (-)	12 (-)	0,050	5
CAN P	Nil	35 (7-63)	19 (11-26)	66 (64-69)	0,014	8
CAN P	H	69 (64-73)	66 (65-67)	75 (71-79)	0,087	7
DOL A + CAN P	Nil	67 (63-68)	39 (9-65)	49 (36-70)	-	20
				Average	0,046	12

Legend:

DOL = Dry off-loading
CAN = Cannery
A = Anchovy
P = Pilchard

H = Sulphuric acid
L = Lignosulphonic acid
S = Sodium hexametaphosphate
F = Ferric chloride

The efficiency of DAF treatment is reduced at feed concentrations greater than 38 g COD/ℓ and/or 2,1 g SS/ℓ. At greater concentrations, it was found that a dilution of the feed with sea water to these levels gave improved overall performance, despite the corresponding increase in hydraulic loading rate at the same pollutant mass loading rate.

Two-stage DAF was also investigated with seawater dilution in the first stage and chemical dosage in the second stage only. Better than 80% overall purification efficiency was achieved by this process at a hydraulic loading rate of 2,6 m^3/m^2.h. The results obtained are summarized in Table 15.

TABLE 15. EFFICIENCY OF TWO-STAGE DISSOLVED AIR FLOTATION

Parameter	STAGE 1			STAGE 2			Specific removal efficiency, kg per kg chemical
	Feed (g/ℓ)	Effluent (g/ℓ)	% Removal	Feed (g/ℓ)	Effluent (g/ℓ)	% Removal	
TCOD	237	158	33	134	52	61	8,2
CCOD	132	86	35	71	32	55	3,9
SS	14	9	36	8	2,3	71	0,61
FeCl dosage	Nil	-	-	10	-	-	-

DAF processes can be readily applied to effluents from the fishing industry as sea water is always available (under permit) for use as the dissolved air carrier water. If oily effluents are chemically dosed with acidic coagulants, the resultant float quality is runny and a suitable float removable mechanism must be provided.

5.6 Membrane processes

Two types of membrane processes, viz. ultrafiltration (UF) and reverse osmosis (RO) were tested on selected fish-processing effluents. The essential features of these processes are as follows:

(a) UF is the separation of colloidal or suspended materials by filtration through microporous membranes. A concentrate and a filtrate stream are produced, the latter being the fraction which has passed through the membrane; in the context of effluent treatment, the permeate is the treated effluent stream. Typical pressures used range from 0,5 to 1,0 MPa.

(b) RO is also a physical separation process but in this case the pressure driving force is used to overcome the osmotic pressure of the feed to enable water and some other molecules to pass through a semi-permeable membrane; the pressures exerted employed are typically greater than 3 MPa. The high osmotic pressure exerted by the dissolved inorganic salts in sea water makes RO treatment uneconomical for most fish-processing effluents.

(c) If the recovered concentrate streams from membrane processes are of suitable quality for processing to fish-meal, the enhanced fish-meal yield significantly improves the economics of the membrane process and may in some cases give a nett profit. A heat treatment stage must be included in the processing of the concentrates.

In UF trials conducted at a fish-meal factory, bloodwater from dry off-loading was treated in a tubular UF plant and stickwater was concentrated in a plate-and-frame UF plant as an alternative to evaporation.

From a limited number of tubular UF trials carried out for bloodwater treatment, the permeate fluxes (i.e. treated effluent flow per unit area of membrane) were found to be within the economically viable range provided that the permeate flux could be maintained over an acceptable membrane operating life. At operating pressures of 1,0 to 1,6 MPa and temperatures of 19 to 22°C, an average permeate flux of 20 $\ell/m^2.h$ was obtained when concentrating bloodwater by UF to 16% TS; 70 to 80 % COD rejection was achieved. The concentrate quality obtained was acceptable for processing the concentrate to fish-meal using existing production methods; a heat treatment stage would be required.

In the plate-and-frame UF trials carried out on stickwater, concentrates up to 35% TS, suitable for return to the drier along with the presscake, were produced but at diminishing flux rates as shown in Figure 8. Stickwater concentration by ultrafiltration will only give a cost advantage over evaporation including mechanical vapour recompression, if permeate fluxes around 30 $\ell/m^2.h$ can be maintained. Typical results of stickwater concentration by ultrafiltration are given in Table 16.

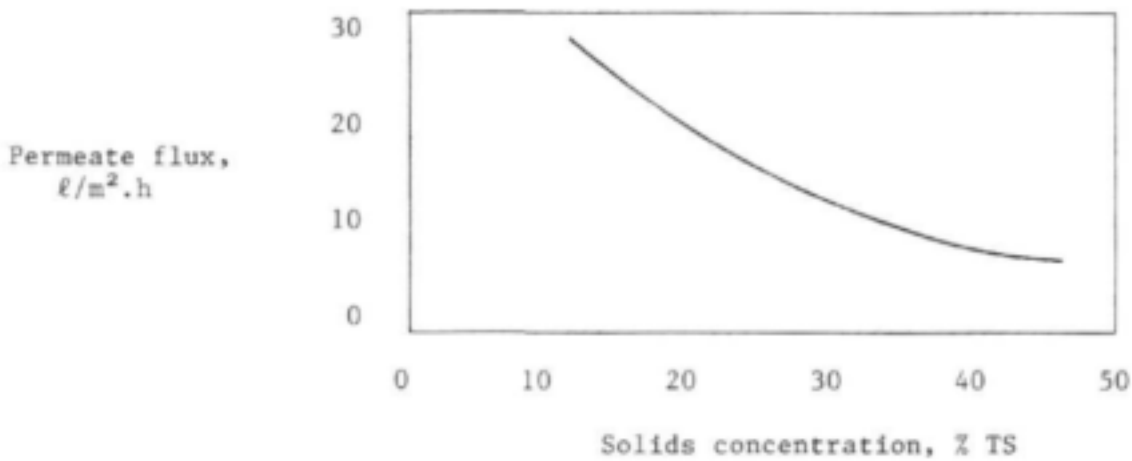


Figure 8. <u>Permeate flux versus solids concentration in plate-and-frame UF of stickwater</u>

TABLE 16. STICKWATER CONCENTRATION BY PLATE-AND-FRAME UF			
Phase	% TS	% Protein	% FOG
Raw stickwater	12	8	1
Stickwater concentrate	40	26	3,5
UF permeate	8	3	0

Reverse osmosis trials for concentration of stickwater were carried out with a tubular plant. Concentrating raw stickwater from 10% to 18% TS resulted in the flux declining from 12 to 3 ℓ/m^2.h.b. The permeate had an average COD of 1 800 mg/ℓ and a total solids content of less than 1 000 mg/ℓ. The membranes used have a upper temperature limit of around 60°C, and this is a disadvantage in stickwater processing.

CHAPTER 6

DESIGN OPTIONS FOR EFFLUENT TREATMENT

6.1 Effluent segregation/combination

Typical mass pollution loads from combined fish-meal/fish-canning plants are shown in Table 17.

TABLE 17. TYPICAL POLLUTION LOADS IN FISH-MEAL/FISH-CANNING PLANTS

Parameter	Units	Fish-meal			Cannery		Total
		DOL + fish-meal processing	Stickwater evaporator cooler	Hose usage and plant washdown	WOL + fluming	Cannery processing	
Flow	m^3/d % total	403 8,5	$\boxed{2\ 172}$ $\boxed{45,5}$	294 6	$\boxed{1\ 240}$ $\boxed{26}$	664 14	4 773 100
COD	kg/t % total	$\boxed{41}$ $\boxed{45}$	8,1 9	very low	$\boxed{18,6}$ $\boxed{20}$	$\boxed{23,5}$ $\boxed{26}$	91,2 100
CCOD	kg/t % total	$\boxed{20,7}$ $\boxed{42}$	5,8 11	very low	$\boxed{10,3}$ $\boxed{21}$	$\boxed{12,8}$ $\boxed{26}$	49,6 100
SS	kg/t % total	$\boxed{7,6}$ $\boxed{39}$	1,8 9	very low	$\boxed{5,0}$ $\boxed{26}$	$\boxed{5,0}$ $\boxed{26}$	19,4 100

Notes

1. $\boxed{}$ indicates high volume and/or high strength effluent.

2. Processing rates used are 75 t/h for fish-meal processing and 25 to 30 t/h for canning.

From Table 17, the various effluents may be combined into strong (high strength/low volume) and weak (low strength/high volume) groups for cost effective treatment. A proposed grouping of effluents is shown in Table 18.

TABLE 18. SEGREGATION/COMBINATION OF EFFLUENTS
<u>Strong effluent No. 1</u> Bloodwaters from dry off-loading, including effluents from belts and elevators, fish pits, and RSW boats.
<u>Strong effluent No. 2</u> Oil polisher effluents. Initial washdown of stickwater evaporator plant.
<u>Weak effluent</u> Wet off-loading effluents. Cannery fluming effluents. Plant washdown effluents.

6.2 Effluent treatment options

The unit processes that give effective treatment of various fish-processing effluents are screening, gravity settling, flotation, evaporation and possibly membrane processes. Typical efficiencies of these unit processes when applied to the effluent groupings given in Table 18 are given in Figure 9. It is emphasized that in all cases stickwater is concentrated by evaporation and added to the presscake.

The choice for an effluent treatment scheme will depend on whether there is a cannery attached to the fish-meal plant. As a general guide, the design examples in the following sections have been selected to represent effective treatment combinations. Because of the variability inherent in the quality of fish effluents, due in many cases primarily to the variability in the fish quality at the time of off-loading, the treatment scheme must make provision for fish of the worst quality.

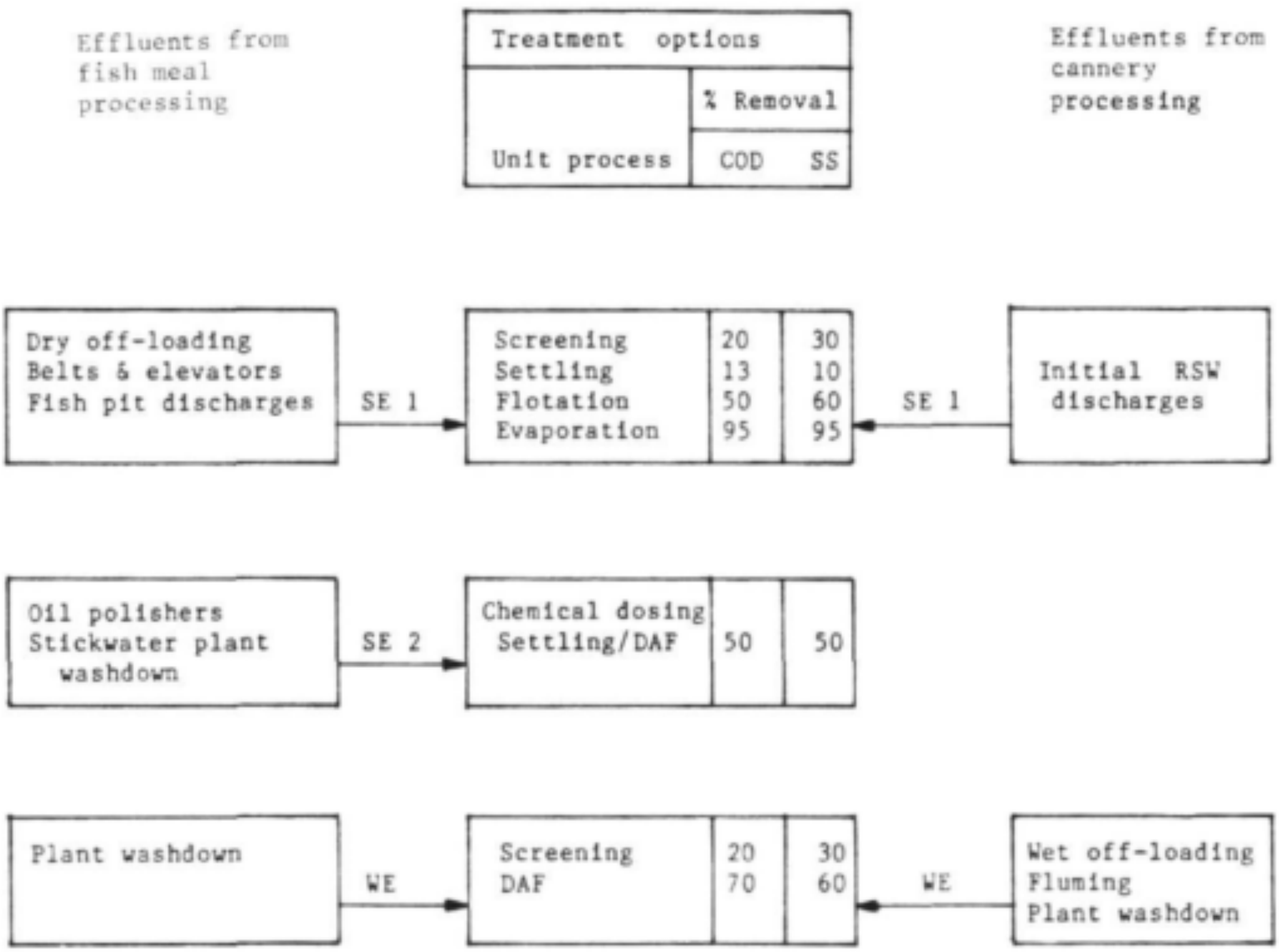
Unit processes such as screening and settling provide relatively inexpensive, simple and effective pretreatment and are recommended as a first stage. The resultant smoothing of the effluent quality fed to subsequent treatment stages is beneficial to the performance of these stages.

A number of options, incorporating selected combinations of the unit processes discussed, have been evaluated in terms of treatment efficiency, costs and by-product recovery. In all cases, a plant processing 600 t/d to fish-meal and 200 t/d to canned products is assumed. Typical analyses of the effluents to be treated are given in Table 19. It is assumed that all stickwater is concentrated and returned to the presscake. The salient features of each option are summarized in Table 20 and details of the various treatment schemes are shown in Figures 10 to 13. Costing of each option is based on 1986 values as shown in Table 21.

TABLE 19. EFFLUENT VALUES ASSUMED FOR EFFLUENT TREATMENT OPTIONS

Source	Volume m^3/t		COD, mg/ℓ		CCOD, mg/ℓ		SS, mg/ℓ	
	A	P	A	P	A	P	A	P
Fish-meal	4,7	-	10 360	-	5 585	-	-	1 980
Cannery	7,4	10,0	10 280	4 195	5 737	2 303	740	1 000
Combined	12,1	10,0	11 600	7 924	5 600	4 290	1 595	1 564

Note: A = Anchovy; P = Pilchard.



Key:
SE 1 = Strong effluent no. 1

SE 2 = Strong effluent no. 2

WE = Weak effluent

DAF = Dissolved air flotation

RSW = Refrigerated sea water boat

Figure 9. Efficiency of treatment options for segregated/combined fish-processing effluents

The effluent treatment schemes proposed can reduce pollution loads by up to 60%. The importance of good management in achieving this efficiency of treatment, cannot be overemphasized. Good management in this context consists firstly of good housekeeping to minimize the pollutant loads generated and secondly of ensuring that effluent treatment plants are correctly operated and well maintained in and out of season.

TABLE 20. SUMMARY OF EFFLUENT TREATMENT OPTIONS EVALUATED

Scheme	Description
1	Wet off-loading flume waters screened; dry off-loading effluents and cannery effluents screened and settled.
2	As Scheme 1, except air flotation substituted for gravity settling of dry off-loading and cannery effluents.
3	Wet off-loading flume water screened; fish-meal effluents and cannery effluents treated in separate dissolved air flotation units; dissolved air flotation effluents combined, balanced and treated in chemically dosed dissolved air flotation plants.
4	Wet off-loading effluents screened; fish-meal effluents treated by evaporation; oil polisher effluent settled, combined with cannery effluent and treated by dissolved air flotation.

TABLE 21. COSTING PARAMETERS FOR EFFLUENT TREATMENT OPTIONS

Recurrent operating costs		Valuation of by-products	
Operating parameter	Cost	By-product	Value
Electricity	6,7c/kW.h	Fish-meal	R700/t
Coal	R75/t	Fish-oil	R450/t
Semi-skilled labour	R1000/man-month	Recovered solids	R200/t

WET OFF-LOADING	
Volume	6,2 m^3/t
COD	18,6 kg/t
SS	5,0 kg/t

CANNERY + FISH-MEAL	
Volume	2,0 m^3/t
COD	64,4 kg/t
SS	12,6 kg/t

COOLING WATER & CONDENSATES	
Volume	3,6 m^3/t
COD	8,1 kg/t
SS	1,8 kg/t

STATIC TANGENTIAL WEDGEWIRE SCREENING	
Weir loading	4 $m^3/m.h$
% COD rem.	20%
% SS rem.	30%

STATIC TANGENTIAL WEDGEWIRE SCREENING	
Weir loading	3 $m^3/m.h$
% COD rem.	20%
% SS rem.	30%

FLOW BALANCING	
Retention	4 h

SETTLING	
Surface loading	0,5 $m^3/m^2.h$
Retention	4 h
% COD rem.	13%
% SS rem.	10%

Key:

rem. = removal

SEA DISCHARGE	
Volume	11,8 m^3/t
COD	67,8 kg/t
SS	13,2 kg/t

Figure 10. Scheme 1 - Pretreatment for effluents from fish-meal and cannery plants

WET OFF-LOADING	
Volume	6,2 m^3/t
COD	18,6 kg/t
SS	5,0 kg/t

CANNERY + FISH-MEAL	
Volume	2,0 m^3/t
COD	64,4 kg/t
SS	12,6 kg/t

COOLING WATERS & CONDENSATES	
Volume	3,6 m^3/t
COD	8,1 kg/t
SS	1,8 kg/t

STATIC TANGENTIAL WEDGEWIRE SCREENING	
Weir loading	4 $m^3/m.h$
% COD rem.	20%
% SS rem.	30%

STATIC TANGENTIAL WEDGEWIRE SCREENING	
Weir loading	3 $m^3/m.h$
% COD rem.	20%
% SS rem.	30%

FLOW BALANCING	
Retention	4 h

CHEMICAL DOSING	
Coagulant	2,5 g/ℓ

AIR FLOTATION	
Loading	5 $m^3/m^2.h$
% COD rem.	50%
% SS rem.	50%

Key:

rem. = removal

SEA DISCHARGE	
Volume	11,8 m^3/t
COD	48,8 kg/t
SS	9,7 kg/t

Figure 11. Scheme 2 - Treatment of fish-meal and cannery effluents including air flotation stage

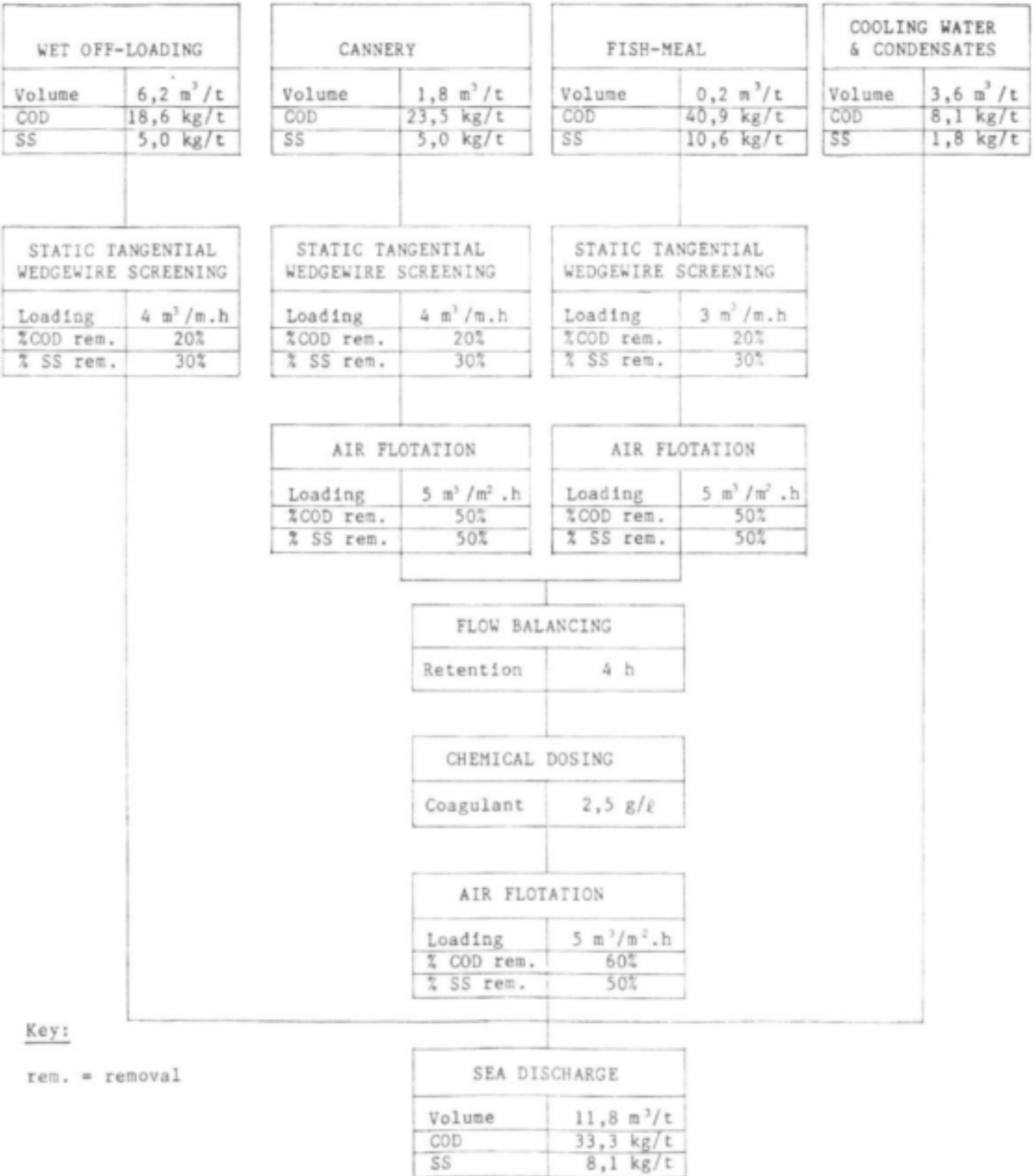


Figure 12. Scheme 3 - Treatment of fish-meal and cannery effluents including multi-stage air flotation

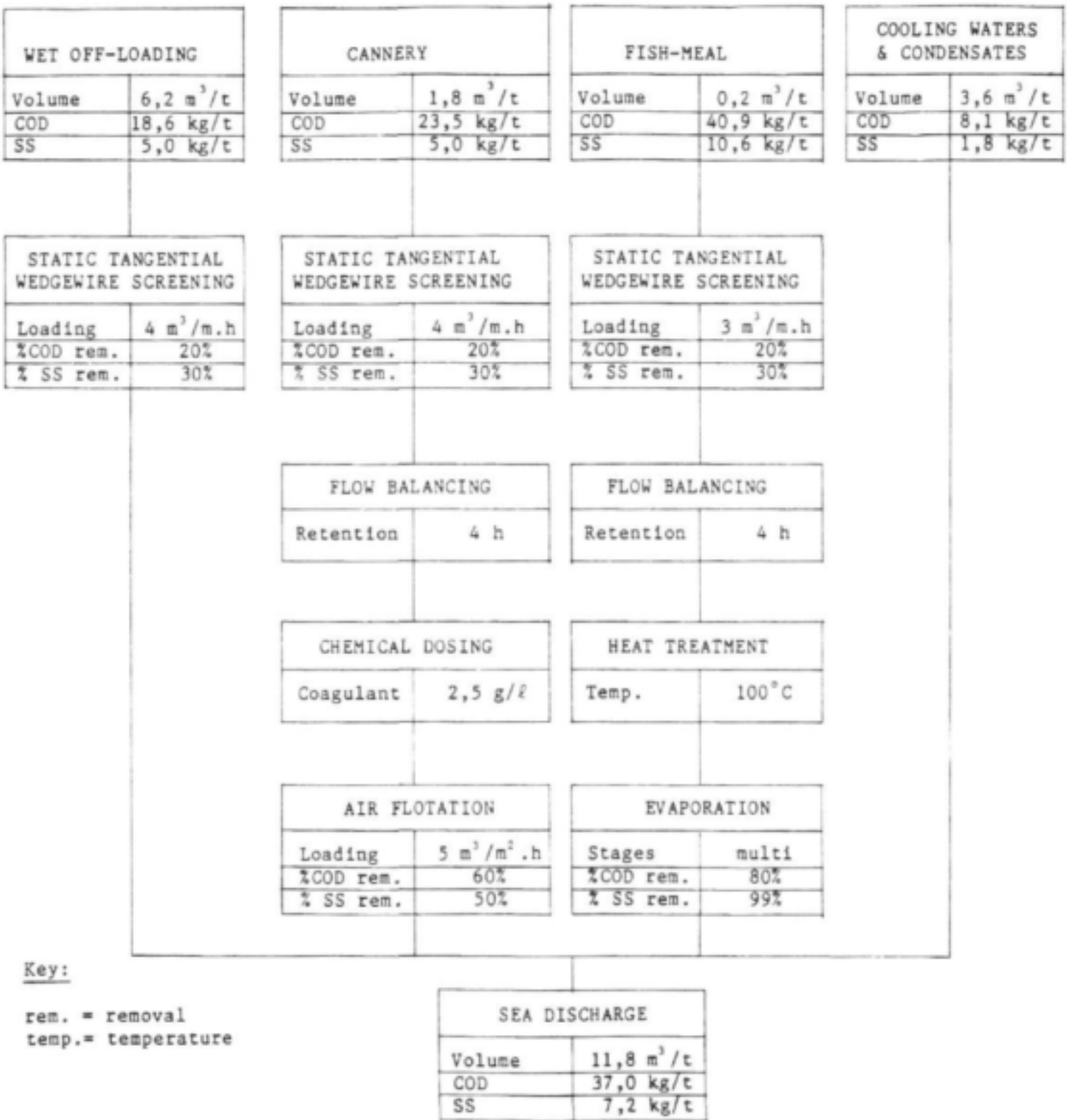


Figure 13. Scheme 4 - Treatment of fish-meal and cannery effluents by evaporation and air flotation