GUIDE TO WATER AND WASTE-WATER MANAGEMENT IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

Prepared for the

WATER RESEARCH COMMISSION

By

BINNIE & PARTNERS

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This publication stems from a research project entitled:

An investigation into the water and effluent management problems in the fruit and vegetable processing industry: Inhouse optimisation of water use and effluent treatment in the fruit and vegetable processing

that was carried out by Binnie and Partners.

FOREWORD

The South African Fruit and Vegetable Canners' Association wishes to express its thanks to the Water Research Commission which has done so much to make possible and bring to fruition "The Guide to Water and Waste-water Management in the Fruit and Vegetable Processing Industry".

The industry processing fruit and vegetable products in South Africa has become established in various regions throughout the country, and it is an industry that by the nature of its products requires to use water in the manufacturing process.

It is therefore of importance that methods be tabulated as to the optimum usage of water within a canning factory, and how best waste water should be disposed of by a canning factory.

Not only do methods need to be specified as to the management of water and effluent, but, equally important, it is necessary that there should be a monitoring process established that can be followed by factories, as to their usage of water and the disposal of waste water.

"The Guide to Water and Waste-water Management in the Fruit and Vegetable Processing Industry" endeavours to cover all these aspects of the matter, and it should prove to be a necessary and useful guide to managers, engineers and other senior staff in fruit and vegetable processing factories in South Africa.

Chairman
S.A. Fruit and Vegetable Canners' Association (Pty) Ltd.

PREFACE

This Guide has been compiled from data collected during preliminary surveys of the Industry by Mr W Rose of the NFPA of USA, and Binnie & Partners, during which time each one of the major processing plants was visited to identify the problem areas. Thereafter, detailed investigations were completed within the production plants of Messrs Langeberg Co-op (Ashton, Cape), Gants Foods (Somerset West, Cape), Land Harvest (Port Elizabeth, Cape), and Irvin & Johnson (Springs, Transvaal). The results of these surveys are available in a separate WRC Report No 96/1/86.

The work was initially steered and later co-ordinated by a committee established under the chairmanship of the Water Research Commission, comprising representatives of the South African Fruit & Vegetable Canners Association, the Department of Water Affairs, Department of Health, and senior representatives of the processing plants where the work was conducted; all these parties are thanked for their invaluable assistance.

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Acknowledgements are due to the Co-ordinating Research and Development Committee for the investigations into the water and waste-water management problems of the South African Fruit and Vegetable Processing Industry.

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SUMMARY

This guide identifies the need for improved water and waste-water management in the Fruit and Vegetable Processing Industry, based on the results of a country-wide survey carried out for the Industry.

The form and aim of the survey are summarised. For each sector of the Industry the averaged results of the survey are given, for water usage and for the volume and quality of the waste water discharged. Target figures for the Industry calculated from the averaged survey results are presented.

A technique for carrying out a factory survey to collect data for comparison with the target figures is outlined. The process stages within the industry requiring improved management, as determined by the national survey, are given.

Factors causing excessive water usage and waste-water generation are discussed. The water usage and effluents generated by individual process steps are given. Techniques for saving water and reducing waste-water quantity and pollution strength are given. Methods that can be used to pretreat effluents are described.

The amounts and types of solid wastes generated in the Industry are identified. Current disposal routes are outlined and further opportunities for recycling materials and recovering by-products are described. The need within the industry for a co-operative approach to the problem of solid waste disposal is noted, and a proposed joint venture organisation is outlined. The need for additional research into the recovery of useful products from solid waste is highlighted.

The detailed results of the surveys undertaken are summarised in a companion volume entitled "Water and Waste-water Management in the Fruit and Vegetable Industry", WRC Report No. 96/1/86, which is available on request from the Water Research Commission.

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GLOSSARY

a	annum (year)
COD	Chemical oxygen demand
DAF	Dissolved air flotation
NASEV	National average specific effluent volume
NASWI	National average SWI
N.B.	Nominal bore
RO	Reverse osmosis
SS	Suspended solids
SWC	Specific water consumption
SWI	Specific water intake
t	tonnes
TDS	Total dissolved solids
UF	Ultrafiltration
WC	Water consumed
WE	Water employed
WI	Water intake
WR	Water recycled
WRC	Water Research Commission
WRE	Water recirculated

TERMINOLOGY

WATER INTAKE

All water entering a premises from municipal and/or private sources.

WATER RECYCLED

Water which leaves a process or subprocess and is reused in another process or subprocess with or without treatment.

WATER RECIRCULATED

Water which leaves a process or subprocess and is returned to that process or subprocess for further use.

WATER EMPLOYED

The aggregate of water intake plus water recycled plus water recirculated.

SPECIFIC WATER INTAKE

The water intake for a particular period divided by the raw material used in production for the same period.

SPECIFIC WATER CONSUMPTION

The water consumption for a particular period divided by the raw material used in production for the same period.

WATER MANAGEMENT

The monitoring of water consumption and pollution at each process step and maintaining them at the minimum value compatible with product quality.

EFFLUENT

Liquid outflow from a process.

WASTE WATER

Final factory outflow.

ULTRAFILTRATION

Separation of colloidal or very fine solid materials by filtration throug microporous membranes.

REVERSE OSMOSIS

A technique used in desalination and waste-water treatment; pressure i applied to a saline or waste solution, forcing pure water to pass from th solution through a semi-permeable membrane that will not pass ions or organi molecules.

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CHAPTER 1

INTRODUCTION

1.1 Background

The Fruit and Vegetable Processing Industry of the Republic of South Africa approached the Water Research Commission in 1976, requesting that water and waste-water management techniques and problems within their Industry be investigated.

The subsequent investigations by consulting engineers involved visiting 39 major processing factories, to examine in general terms the water intake and effluent production at each process step.

As many of the factories process a wide range of commodities simultaneously, consuming water for the overall operation and producing a composite mixed effluent whose characteristics vary depending on the commodities being processed, the study investigated each of the major individual commodities in turn to define the parameters relating to each one.

Water intake, waste-water volume and waste-water pollution loads were determined on a specific basis per ton of raw material processed and the aggregates of these were compared with the annual total production values for each factory. A national average value for each major parameter was then derived, against which the performance of the various factories could be compared.

Two "model" factories were then chosen where detailed studies were undertaken with the aim of saving water and of reducing pollution, as well as operating dissolved-air flotation, screening and membrane plants for testing their potential for treating waste water in the Industry.

1.2 The overall situation (1982)

The Fruit and Vegetable Processing Industry in South Africa handles annually about 21 different commodities in quantities greater than 1 000 tons. It is estimated that a total of about 870 000 tons of raw fruit and vegetables, of which about 86% are fruit, are processed annually by the industry to four main product groups including:

(a) canned products;
(b) frozen products;
(c) juiced products;
(d) dehydrated products.

The overall water and waste-water situation (1982) is summarised in Tables 1.1 (a) and (b) below:

Table 1.1

(a) The overall water and waste-water situation

Parameter	Total Quantities	COD	SS
Potable water consumed	$6,2 \times 10^6\ m^3/a$	*	*
Liquid waste discharged	$5,0 \times 10^6\ m^3/a$	13 900 t/a	2 340 t/a
Solid waste discharged	$0,3 \times 10^6$ t/a	*	*

* Not applicable

(b) National averages

National average specific water intake (NASWI)	$7,13\ m^3/t$
National average specific effluent volume (NASEV)	$5,57\ m^3/t$
National average specific COD	16,4 kg/t or 2 780 mg/ℓ
National average specific SS	2,75 kg/t or 468 mg/ℓ

Figure 1.1 shows the NASWI and also the variation in SWI for each major commodity processed. The commodities having the widest variation in SWI are peaches, pears, apricots, berries and the freezing of cabbage, peas and carrots. It should be noted that certain commodities such as peaches, pears, pineapples and citrus produce effluents with high COD's . Treatment methods to reduce COD are discussed in the Guide.

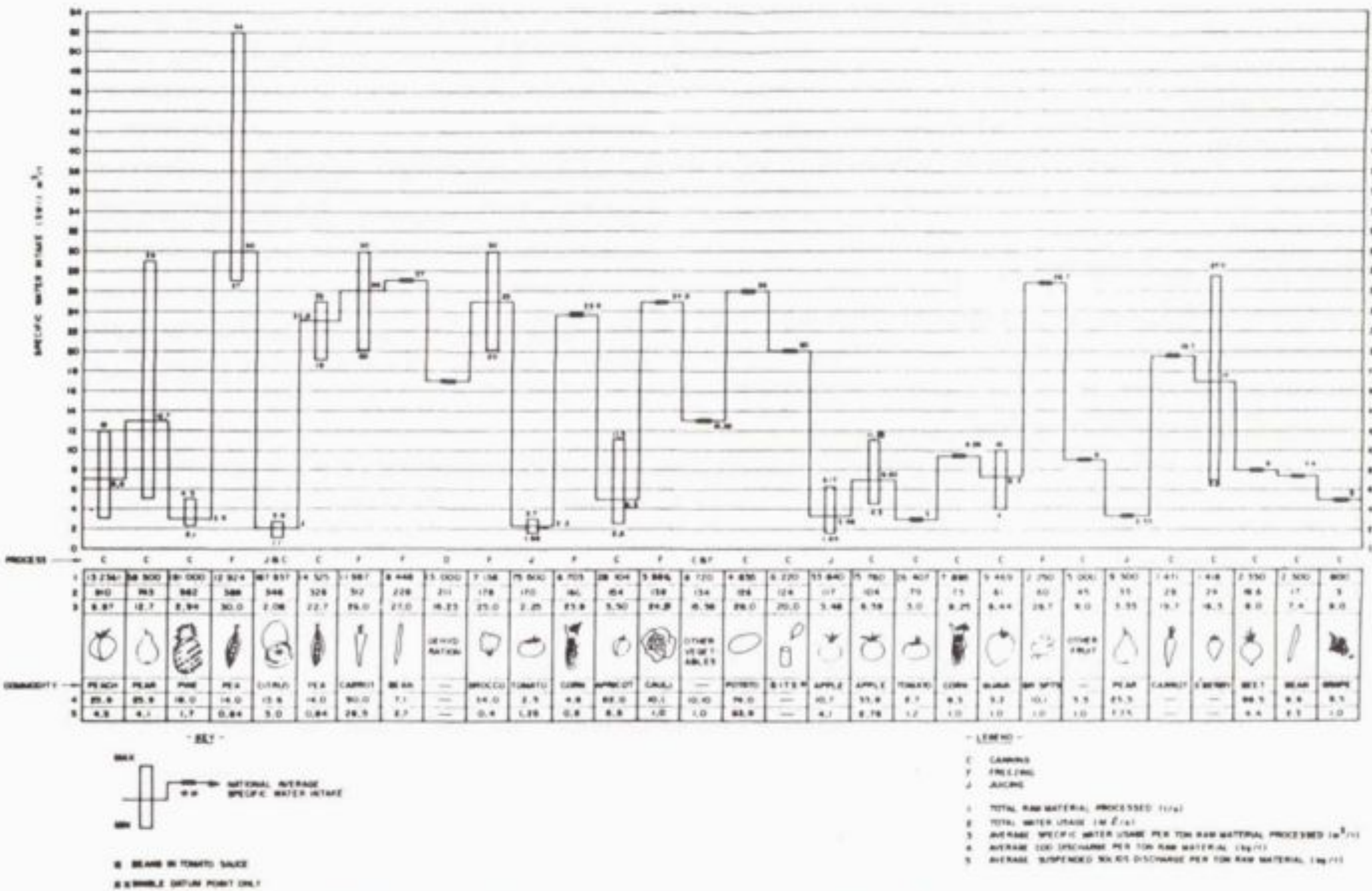


FIG 11 VARIATION IN SPECIFIC WATER INTAKE (SWI) & EFFLUENT LOADING FOR VARIOUS COMMODITIES (1979 to 1984)

1.3 The need for water and waste-water management

Figure 1.1 illustrates the need for reducing to a minimum the variation i water intake between factories processing the same commodities Investigations have shown that water management is not widely practised sinc with little exception, water of potable quality is selected for each majo task, whereas water of lesser quality could be used in many cases.

The following major observations governed the development of this Guide:

(a) The SWI varies widely amongst factories processing the same commodity;

(b) Individual process steps within the overall processing cycle consum different quantities of water at different factories even if simila plant is employed;

(c) Production lines consume water related to the full design capacity an have no facilities for operating at part load;

(d) Large factories processing different products have long commodit transport stages between process steps which result in excess wate intake and spillages that are difficult to limit;

(e) The absence of water meters and flow recorders on each process line a most of the factories, makes record keeping and hence control of wate usage difficult, if not impossible;

(f) Effluent qualities vary widely between factories processing the sam commodity;

(g) Unnecessary contact between water and product and between water an solid waste together with juice and product spillages, cause highe concentrations of COD and SS in the effluents than are necessary;

(h) The seasonal constraints imposed on the industry affect overall wate and waste-water management;

(i) The low cost of water and of waste-water disposal often result in ove usage of water;

(j) There is an absence of information identifying the minimum quantitie of water for each processing step.

This Guide sets out methods for determining or achieving the following:-

- The target water intake for a factory;
- The target water intakes for various stages of processing for variou commodities;
- Managing water intakes to achieve the target values;
- Target values for pollution loads in effluents and waste waters;
- Reduction of effluent organic loads;
- Pretreatment of final effluents.

1.4 The Water Act

The Water Act No 54 of 1956 was amended in 1984 by the Water Amendment Act No. 96 of 1984. This contains important changes which affect all fruit and vegetable processing plants. Factory management should obtain and read a copy of the Act. The more important provisions are as follows:

(a) The definition of industrial use of water has been expanded to include the use of water for feedlots and fish farming.

(b) Section 12, governing the quantity of water used above which a section 12 permit is needed, has been changed so that any plant using more than 150 cubic metres per day of any water including private borehole and sea water, is now required to apply for a permit under this section of the Act.

(c) The Minister may terminate or reduce the supply of water from a Government Water Works or direct any supplier of water to an industry to terminate or reduce such supply until the industry complies with the requirement of the Act.

(d) The revised section 12 of the Act also requires a permit from the Minister to authorise the construction and enlargement of any water or effluent treatment works or process within the works and no person shall be allowed to operate the works unless the works are registered as prescribed by regulations in terms of the Act.

(e) Section 21 requires that any person using for industrial purposes water, including sea water, shall purify or otherwise treat the water so used and any effluent arising therefrom in accordance with such requirements as the Minister may prescribe from time to time, after consultation with the SABS. The person using water for industrial use amongst other provisions, must furnish the Director-General in writing with such particulars regarding such use and the disposal of the purified or treated water, including water recovered from any effluent, as may be prescribed by regulation under section 26.

(f) Section 22 (1) states that any person who has control over land on which any thing was or is done which involved or involves a substance capable of causing water pollution, whether such substance is a solid, liquid, vapour or gas or a combination thereof, shall take such steps as may be prescribed by regulation under section 26 in order to prevent:

   (i) any public or private water on or under that land, including rain water which falls on or flows over or penetrates such land, from being polluted by that substance, or if that water has already been polluted, from being further polluted by that substance; and

(ii) any public or private water on or under any other land, or the sea, from being polluted, or if that water has already been polluted, from being further polluted, by water referred to in paragraph (a) which became polluted in the circumstances described in that paragraph

(g) The Director-General may authorise any person in writing to enter upon any land referred to under section 22 (1) or (b) or on which water is used for industrial purposes or any of the steps referred to in section 21 (1) are carried out, and to conduct on such land such investigation as the Director-General may determine

(h) Section 26 states that the Minister may make regulations relating to:

(i) any matter which under this Chapter is required or permitted to be prescribed by regulation under this section;

(ii) the prevention of wastage or pollution of public water and private water, including underground water, of pollution of sea water, and of damage to the environment caused by water;

(iii) the information to be furnished to the Director-General in connection with the operations of any mine or industrial undertaking in so far as such operations affect a matter to which this Chapter relates, and the persons by whom such information is to be furnished;

(iv) the information to be furnished to the Director-General in connection with water used for industrial purposes and in connection with the purification, treatment or disposal of water so used and effluent produced by or resulting from such use, and the persons by whom such information is to be furnished;

(v) the manner and place of disposal of water used for industrial purposes and effluent, and the requirements to be complied with in connection with such disposal;

(vi) the use or reuse for any purpose of water used for industrial purposes and effluent;

(vii) the registration of sites or portions of sites where water used for industrial purposes or effluent containing poisonous matter is disposed of, and the control over and the disposal of such sites or portions of such sites.

CHAPTER 2

PLANNING AND CONDUCTING A FACTORY SURVEY

2.1 General

Permit applications for either Section 12 or 21 of the Water Act call for a comprehensive understanding of water and waste-water management and require that fully detailed schematic diagrams of manufacturing processes be submitted. To assist with the preparation of these applications and to assess the performance of plant, methods of carrying out a survey are given in this chapter. For continual monitoring, refer to the procedure outlined in Appendix A.

Plant performance should be assessed and compared with the target water consumption flows and pollution loads as given in Table 2.1.

2.2 Preparation for the survey

The steps involved in preparing for a factory survey are as follows:-

Step 1 : Process line block diagram - (Figure 2.1)

(a) Prepare a block diagram indicating each process step as well as common services; the interstage transportation from one process to the next should be treated as a process step.

(b) Mark onto the block diagram all points of water supply to the process line, pipe diameters and how the supply is controlled e.g. B = ball valve, V = valve, VB = valve plus ball valve, N = nozzle spray; mount water meters (M) at each point of the water supply.

(c) Mark onto the block diagram all points of effluent discharge and add the process line raw material throughput; add a block for flow, COD, SS and pH measurements.

Step 2 : Main plant area (Figure 2.2)

- Divide the plant up into areas and make sketches of relative positions of all drainage channels, gratings and plant.

Step 3 : Water survey (Figure 2.3)

- Install water meters at each point of water usage, including sump make-up, boiler plant, cooling tower make-up, laundry, bottle washing, ablutions etc., and prepare a water survey log sheet.

TABLE 2.1 TARGETS FOR WATER INTAKE AND FINAL EFFLUENT DISCHARGED

COMMODITY	STYLE*	PRESENT						INTERIM TARGET **						ULTIMATE TARGET					
		SWI RANGE	NASWI	COD		SS		Water Intake	Effluent	Filtered COD		SS		Water Intake	Effluent	Filtered COD		SS	
		m^3/t	m^3/t	kg/t	mg/ℓ	kg/t	mg/ℓ	m^3/t	m^3/t	kg/t	mg/ℓ	kg/t	mg/ℓ	m^3/t	m^3/t	kg/t	mg/ℓ	kg/t	mg/ℓ
apples	C	4,3 - 11,2	6,6	33,8	6 800	2,0	430	4,6	4,2	27,7	6 500	1,6	400	3,6	2,9	7,8	2 700	1,1	370
apples	J	1,8	1,8	10,7	3 095	4,1	4 148	0,6	1,1	4,8	4 500	1,0	1 000	0,5	1,0	3,0	3 000	0,5	500
apricots	C	2,5 - 14,5	5,5	52,0	3 646	5,5	390	5,5	4,1	27,5	6 700	2,7	660	5,5	5,1	15,7	3 800	1,1	320
beans in tomato	C	20 - 70	20,0	-	2 000	-	154	-	20,0	-	2 000	-	154	15,0	10,0	-	1 000	-	150
beetroot	B	8 - 16	8,0	98,0	5 940	4,4	270	20,0	16,5 +	57,0	3 500	2,1	130	10,0	8,5	17,0	2 000	2,1	130
citrus	C&J	1,1 - 2,6	2,1	13,6	6 500	3,0	-	1,5	2,1	10,5	5 000	1,0	500	1,5	2,1	7,3	3 500	1,1	500
corn	C	6 - 11	9,8	6,3	2 100	0,9	300	5,0	4,0	6,0	1 500	1,0	250	5,0	4,0	6,0	1 500	1,0	250
green beans	C	7,4	7,4	8,2	1 490	2,2	400	5,1	4,5	6,8	1 500	1,8	390	5,1	4,5	6,8	1 500	1,8	390
guavas	C	4,0 - 10	6,4	3,2	700	0,9	195	6,0	4,6	3,2	700	0,9	195	6,0	4,6	3,20	700	0,9	195
peaches	C	2,5 - 11,5	5,5	26,0	4 544	5,0	880	5,1	4,1	20,7	5 000	2,0	400	5,1	4,1	11,6	2 800	1,0	500
pears	C	4,5 - 12,9	12,7	26,0	2 930	4,1	464	8,0	6,4	16,1	2 500	3,2	500	8,0	6,4	16,1	2 500	3,2	500
pears	J	1,4 - 1,9	1,5	23,5	15 000	7,7	6 900	0,6	1,1	6,4	6 000	1,0	1 500	0,6	1,0	5,1	4 700	0,5	500
peas	C	19 - 25	22,0	14,0	2 000	0,8	120	10,0	8,0	15,0	1 850	2,5	312	10,0	8,0	7,6	1 000	1,6	200
pineapples	C	2,1 - 4,5	2,9	18,0	12 900	1,7	1 390	2,8	1,6	12,4	7 974	2,0	1 290	2,8	1,6	8,0	5 160	1,5	970
strawberries	C	6,8 - 27	17,0	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
tomatoes	C	2 - 3,0	2,4	2,7	1 100	1,2	491	2,0	2,2	2,7	1 100	1,2	493	2,2	2,2	2,7	1 100	1,2	491
broccoli	F	8,1	8,1	34,0	5 930	0,4	50	10,0	8,0	29,0	3 600	1,0	125	10,0	8,0	15,0	1 880	1,0	125
cauliflower	F	25	25,0	-	1 950	-	274	12,5	10,0	15,0	1 500	2,7	274	12,5	10,0	15,0	1 500	2,8	274
carrots	F	6 - 26	6,1	90,0	14 980	28,5	4 717	8,5	6,8	45,0	6 500	5,0	800	8,5	6,8	30,0	4 400	4,0	500
corn	F	4,6	4,6	4,6	1 000	0,5	100	5,6	4,5	4,6	1 022	1,0	222	5,6	4,5	4,6	1 022	1,0	222
green beans	F	10 - 25	25,0	7,1	286	2,7	100	16,0	14,4	6,0	450	1,5	110	16,0	14,4	6,0	450	1,5	110
peas	F	10	30,0	-	1 950	-	274	20,0	16,0	31,2	1 950	4,4	274	20,0	16,0	31,2	1 950	4,4	274
potatoes	F	25,7	25,7	74,0	2 880	81,9	3 266	20,0	16,0	44,0	2 750	8,0	500	1,3	10,0	27,5	2 750	5,0	500

*Style: C = canning; J = juicing; B = bottling; F = freezing.
** Interim is defined as the first stage of solids removal.

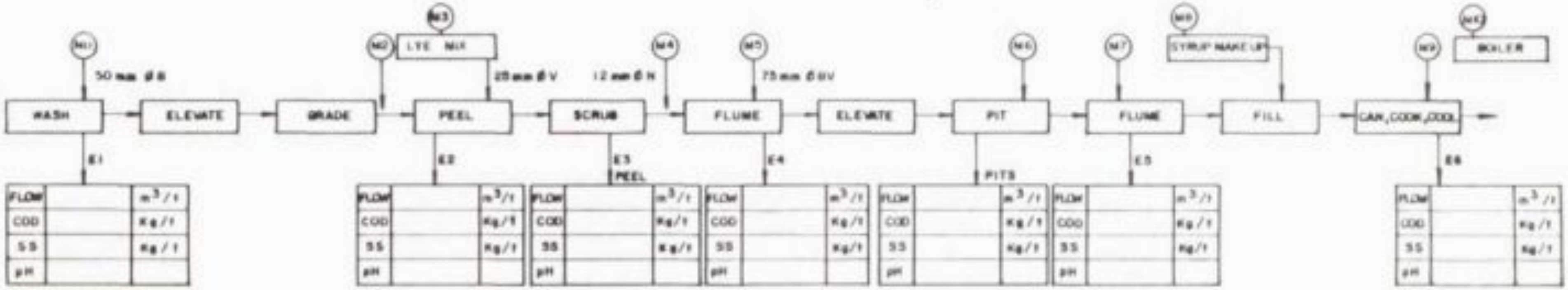


FIGURE 2.1 EXAMPLE OF PROCESS LINE BLOCK DIAGRAM

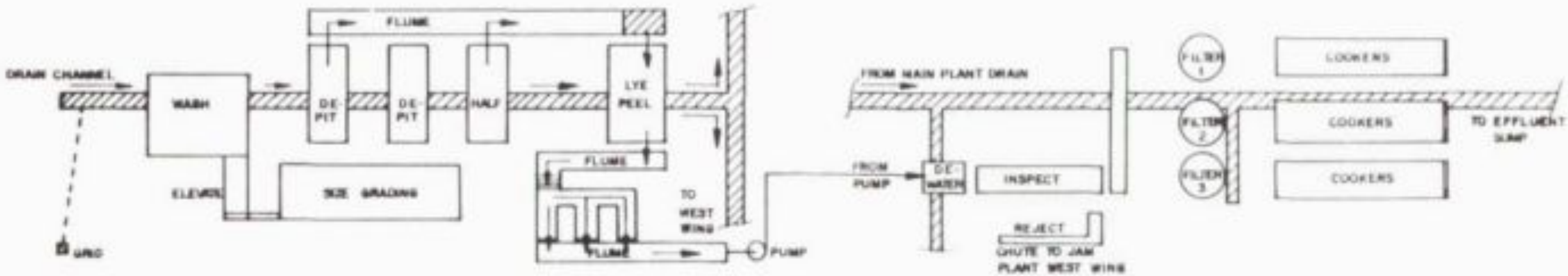


FIGURE 2.2 EXAMPLE OF DRAINAGE DIAGRAM FOR MAIN PLANT AREA

Step 4 : Effluent survey (Figure 2.4)

- Install a final effluent flowmeter (chart recorder type) and prepare an effluent survey log sheet.

2.3 Flow measurement

General

Flow metering is the key to water and waste-water management; without this data true events cannot be identified and malpractice goes undetected. Flows may need to be measured either in open channels or in pipes. Methods of measurements for both situations are given in Appendix A.

Water intake

The main incoming water meters should be fitted with 24 hour recording equipment, enabling management to monitor these events daily and to determine SWI.

Chart recorders can be fitted to most conventional meters and conversion kits are available.

Metering at individual plant items not only assists with determining the water balance but can also provide useful plant data such as evaporation rates in cooling towers of refrigeration plant, giving an early warning of impending mechanical difficulties.

Effluent flows

The flow of effluent must be continuously measured and recorded to determine the overall water balance at a factory.

The metering of effluents is relatively straightforward, however the method and equipment to be used must be suitable for the quality of the effluent, particularly the suspended solid load. See Appendix A for details of flow metering equipment.

2.4 Carrying out the survey

The survey should be conducted for five consecutive days as follows:

(a) Read municipal water meter and all the meters M1, M2 ....Mn hourly (Figure 2.3).

(b) Note starting and stopping of production shifts and washing - down times (Figure 2.3).

FIGURE 2.3 WATER SURVEY LOG SHEET

TITLE	COMMODITY DATE			METER CALIBRATION FACTOR																		LINE NO. COMPANY		THROUGHPUT	t/h. t/d	
TIME	1 MUNICIPAL METER	2 DIFF	3 M1	4 DIFF	5 M2	6 DIFF	7 M3	8 DIFF	9 M4	10 DIFF	11 M5	12 DIFF	13 M6	14 DIFF	15 M7	16 DIFF	17 M8	18 DIFF	19 M9	20 DIFF	21 SUM OF DIFF M1-9	PROD.* RUNNING m³/t	M1 to M6 PREPARATION TOTAL	M7 to M10 PROCESS TOTAL		
06h00																										
07h00																										
08h00																										
09h00																										
10h00																										
etc.																										
TOTALS																										

* PROD = PRODUCTION

FIGURE 2.4 EFFLUENT SURVEY LOG SHEET

TOTAL	COMMODITY DATE		FLOW-RATE CALIBRATION																			LINE NO. COMPANY		THROUGHPUT	t/h. t/d	
TIME	FINAL EFF. FLOW	SAMPLE NO.	DIFF	FLOW E1	DIFF	SAMPLE NO.	FLOW E2	DIFF	SAMPLE NO.	FLOW E3	DIFF	SAMPLE NO.	FLOW E4	DIFF	SAMPLE NO.	FLOW E5	DIFF	SAMPLE NO.	FLOW E6	DIFF	SAMPLE NO.	FLOW E7	DIFF	SAMPLE NO.	FINAL COMPOSITE SAMPLE	
06h00		F1				E 1/1			E 2/1			E 3/1			E 4/1			E 5/1			E 6/1			E 7/1		
07h30		F2				E 1/2			E 2/2			E 3/2			E 4/2			E 5/2			E 6/2			E7/2		
08h00		F3				E 1/3			E 2/3			E 3/3			E 4/3			E 5/3			E 6/3			E7/3		
09h00		F4				E 1/4			E 2/4			E 3/4			E 4/4			E 5/4			E 6/4			E7/4		
10h00		F5				E 1/5			E 2/5			E 3/5			E 4/5			E 5/5			E 6/5			E7/5		
11h00		F6				E 1/6			E 2/6			E 3/6			E 4/6			E 5/6			E 6/6			E7/6		
12h00		F7				E 1/7			E 2/7			E 3/7			E 4/7			E 5/7			E 6/7			E7/7		
13h00		F8				E 1/8			E 2/8			E 3/8			E 4/8			E 5/8			E 6/8			E7/8		
etc.																										
TOTAL																										

(c) Read main effluent meter and measure individual effluent flows (Figure 2.4).

(d) Note raw material throughput t/h and t/d (Figures 2.2 and 2.3).

(e) Collect hourly samples of each effluent; comply with sample storage procedures needed for analysis.

(f) Analyse each effluent for COD (total and filtered) SS, TDS and pH (Figure 2.3).

2.5 Data compilation (Figure 2.5)

The purpose of the survey is to arrive at a water and effluent balance across the plant. The figures obtained must be compared with the target figures as given in Table 2.1.

Inspection of the sample data sheet Figure 2.5 reveals that each process step for the particular commodity has been examined for flow, COD, SS, TDS and pH. The values of the various parameters have been expressed in specific quantities per ton of raw material processed and as a percentage of the total daily load.

The typical data sheet identifies the following:

(a) 70% of the water intake is used in processing and 30% is used in washdown of the plant.

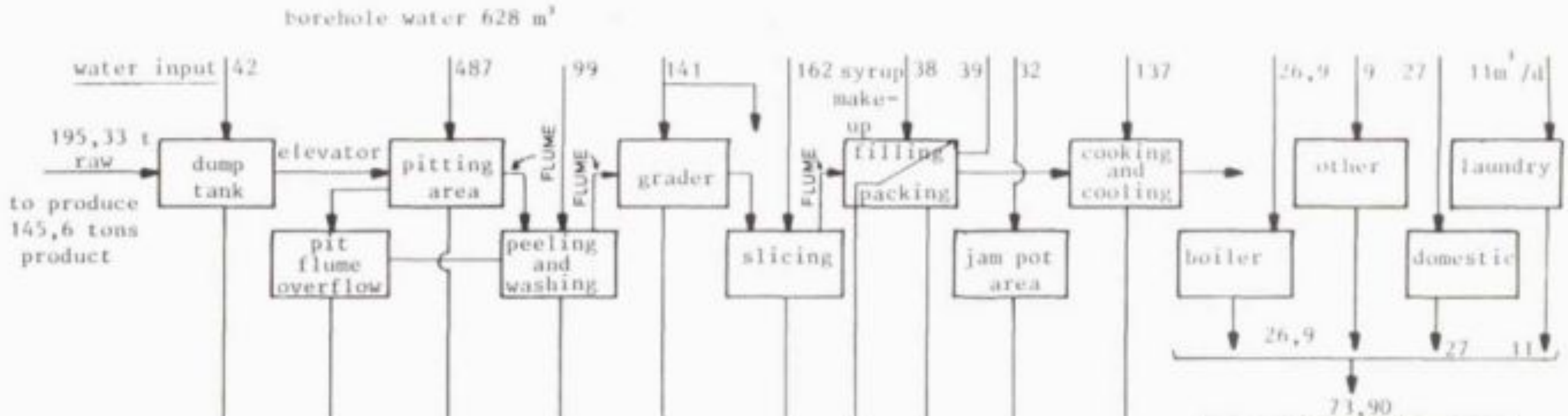
(b) 45% of the COD load occurs in 19,3% of the flow and arises from the peeling/washing stage, which also carried 39% of the suspended solids.

2.6 Comparison of water intake and pollution loads with targets

The targets set in this Guide have been derived from a detailed survey of the industry. All measured quantities have been averaged and these weighted averages have been shown to be generally attainable whether dry conveying or wet fluming or pumping is used for product transportation.

The data collected on water flows and pollution loads, should be assembled into charts to show the distribution of the parameters along each of the process lines. Figure 2.6 is a typical example of data collected during a survey.

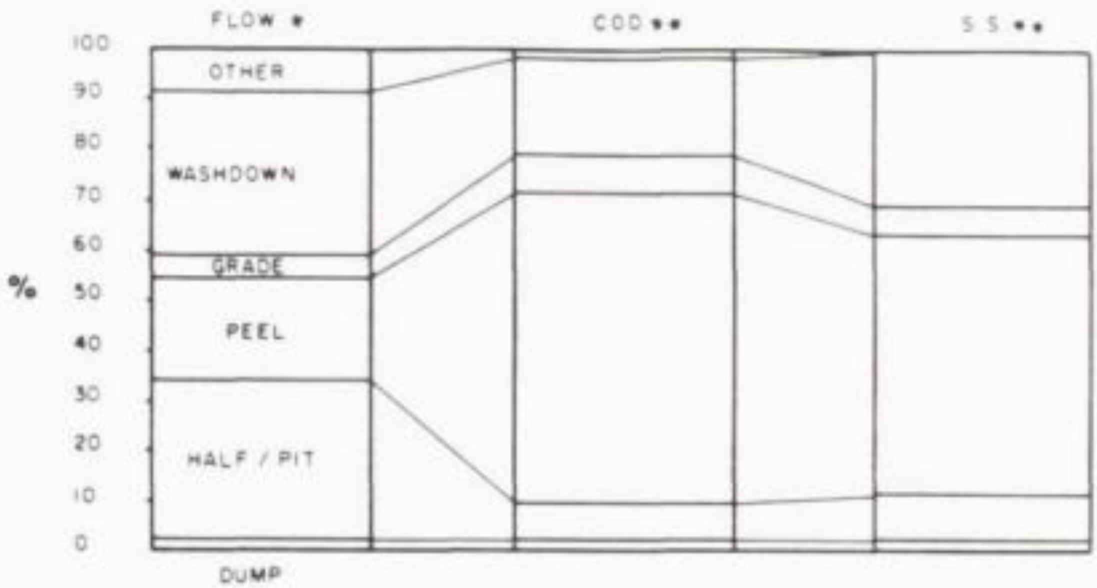
Examination of Figure 2.6 identifies where effort is needed to achieve the maximum improvement. For example apricot processing with dry transportation shows that more than 60% of the COD and 50% of the SS loads discharged occurred at the peeling stage which accounted for 30% of the flow. The next highest generator of pollution from processing was plant washdown which accounted for a further 15% of COD and 30% of the total SS in 30% of the total flow.



												process total	wash-down	Daily total
	flow m³/d	42	94	145	214	51	59	47	10	13	102	777	332	1 109
	m³/t	0,29	0,64	0,99	1,46	0,35	0,40	0,32	0,07	0,09	0,70	5,30	2,27	7,57
	% total	3,8	8,5	13,1	19,30	4,60	5,30	4,2	0,9	1,20	9,2	70,0	30,0	100
	Filt. COD mg/ℓ	1 080	4 713	3 347	10 500	13 767	1 335	9 447	5 940	1 870	546	4 123	1 363	5 486
	kg/t	0,31	3,03	3,32	15,38	4,80	0,54	3,03	0,40	0,16	0,38	31,35	3,09	34,44
	% total	0,70	8,8	9,6	45,0	14,0	1,6	8,8	1	0,5	1	91	9	100
Not obtained in survey	Tot.COD mg/ℓ													
	kg/t													
	% total													
	SS mg/ℓ	1 830	894	962	1 763	989	553	683	412	102	14,36	1 000	526	1 526
	kg/t	0,53	0,57	0,95	2,58	0,34	0,22	0,22	0,03	0,01	0,01	5,46	1,19	6,65
	% total	8,0	8,6	14,3	39,0	5,0	3,3	3,3	0,4	0,1	0,1	82	18	100
	pH	5,0	4,8	4,50	11,7	4,4	4,5	4,4	4,6	4,5	-	6,7	8,90	-
Not obtained in survey	TDS													
	kg/t													
	% total													

Note: tons are per ton of raw material

FIGURE 2.5 EXAMPLE OF SURVEY ANALYSIS SHEET



* m^3/t RAW MATERIAL

** kg/t RAW MATERIAL

FIGURE 2.6 BREAKDOWN OF EFFLUENT GENERATION IN APRICOT PROCESSING (DRY TRANSPORTATION)

The information collected during the country-wide survey was collated a described above and the process stages requiring management are given in Tabl 2.2.

TABLE 2.2 PROCESS STAGES REQUIRING IMPROVED MANAGEMENT

COMMODITY		PROCESS	FLOW CONTROL	COD CONTROL	SS CONTROL	REMARKS
Apricots	(c)	peeling	-	x	x	segregation
		washdown	x	x	x	treat
Apples	(c)	peeling	-	x	x	segregation
		de-airing	x	x	x	
Green beans	(f)	1st wash	-	-	x	
		snippers	-	-	x	
		blanch	-	x	-	
		cooling flume	x	-	-	close circuit
Beetroot	(c)	peeling	-	-	x	
		retort	-	x	-	
Broccoli	(f)	cooling flume	x	x	x	close circuit
Carrot	(f)	1st wash	x	x	-	
		peeling	-	x	x	segregation
Peach	(c)	peeling	-	x	x	segregation
		pitting	x	x	x	segregation
		washdown	x	-	x	treat
Pear	(c)	peeling	x	x	x	segregation
Potato	(f)	peeling	x	x	x	

c - canning; f - freezing; x - management needed.

CHAPTER 3

WATER AND WASTE-WATER MANAGEMENT STRATEGY

3.1 Steps to water/waste-water management

The steps to water and waste-water management are as follows:

PRELIMINARY

- Meter all incoming water including private supply.
- Fit water meters at every process step.
- Fit effluent flow meters.
- Read all meters daily and plot graphs.
- Conduct detailed effluent survey for each commodity.
- Compare water usage with targets.
- Supply hosepipes from separate metered main.
- Improve washdown procedure.

SEGREGATION

- Segregate effluents from the following process steps and remove solids:

  (a) washing;
  (b) pitting;
  (c) peeling;
  (d) scrubbing.

- Fit juice trays beneath slicing, coring, dicing and filling machines.

TRANSPORTATION

- Convert flumes to dry belt systems wherever practical.
- Fit constant head and overflow tanks to all flumes and pump circuits.

CLOSE RECYCLE LOOPS

- Apply counter-current reuse along process lines where practical.
- All post blanch waters to be recycled after purification.
- Treat flume waters for solids removal and reuse.

REVISED WASHDOWN SEQUENCE

- Dry brushing/squeegee
- Air
- Secondary water
- Chemically assisted cleaning
- Potable water

WATER/EFFLUENT BALANCE

Draw up water/effluent balance and compare with targets as given in Table 2.1.

3.2 Factors contributing to excessive water usage and effluent generation

Factors causing excess water usage or pollution generation are as follows:

Water source and location of plant

Excessive water usage and effluent generation is often related to water availability and cost. Concern about the effects of pollution by effluents is more widely found at remotely-sited plants who operate their own irrigation schemes.

Layout of the plant

Many plants are old and have steadily been extended and the range of products processed expanded in attempts to operate for longer periods each year. This causes long distances between different process areas and it is common practice to use particular items of process plant on different lines to process other products when the main process lines are out of season. This leads to long inter-stage transportation systems with inherent spillage and excessive water use if wet systems are employed.

Standards of housekeeping

Whereas management at all the factories maintain housekeeping standards aimed at promoting a high degree of product quality and hygiene, additional housekeeping measures aimed at reducing pollution or water intake are often overlooked probably because of a lack of awareness. For instance peach halves falling to the floor upstream of can fillers are generally hosed into the drain to avoid them being trodden under foot resulting in unsanitary and slippery conditions. The use of water to dispose of the useless produce to make the process area look clean is understandable. However,these practices result in excess water use and increase the water to product contact. This in turn leads to further fruit-based substances being leached into the effluent, thereby creating additional pollution.

Throughout the processing shift all spilt solids should be collected by brush and spade and placed in a container for disposal as solid waste.

Water monitoring

Raw material intake is monitored at every processing plant to ensure that target amounts of product are recovered from the raw materials employed. As examples of this, fruit is weighed, product yield checked, sugar/syrup weighed, caustic soda use monitored and coal and electricity consumption are closely watched.

In spite of this careful monitoring of raw material the same skills do not seem to be applied to the use of water, which is in fact a raw material as vital to production as the fruit or vegetable itself. As an example of poor control over water usage Figure 3.1 shows the variation of water intake per ton of a product over a 70 -day period, during which time the specific water intake varied from 5 to 25,2 kℓ/t.

The reasons for these variations are associated with leakages, spillages, indiscriminate use of hosepipes, badly maintained cooling towers and excessively long periods of plant washdown. Furthermore process plants consume a base load of water whether or not produce is passing through the line.

It is essential that all management install water meters so that the amount of water used at each process step at all times can be monitored.

Water reticulation should be designed (See Figure 3.2) to allow each line to be controlled by a solenoid valve which closes when the plant is stopped.

Water meter readings must be recorded at least once per shift. This permits management to identify a particular area or process step which is consuming excess water. It also allows monitoring of the performance of common equipment.

Hosepipe management

Strict control over the use of hosepipes is essential in all processing plants in order to minimise water wastage resulting from indiscriminate usage.

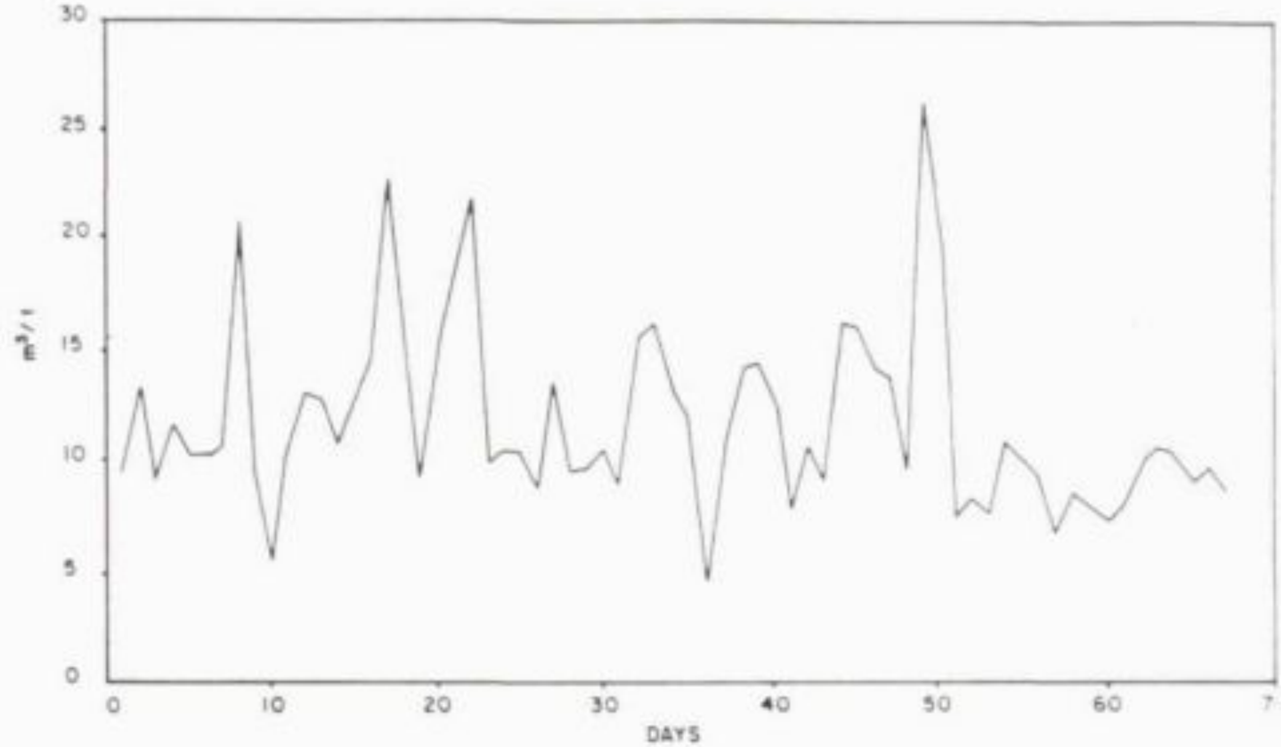
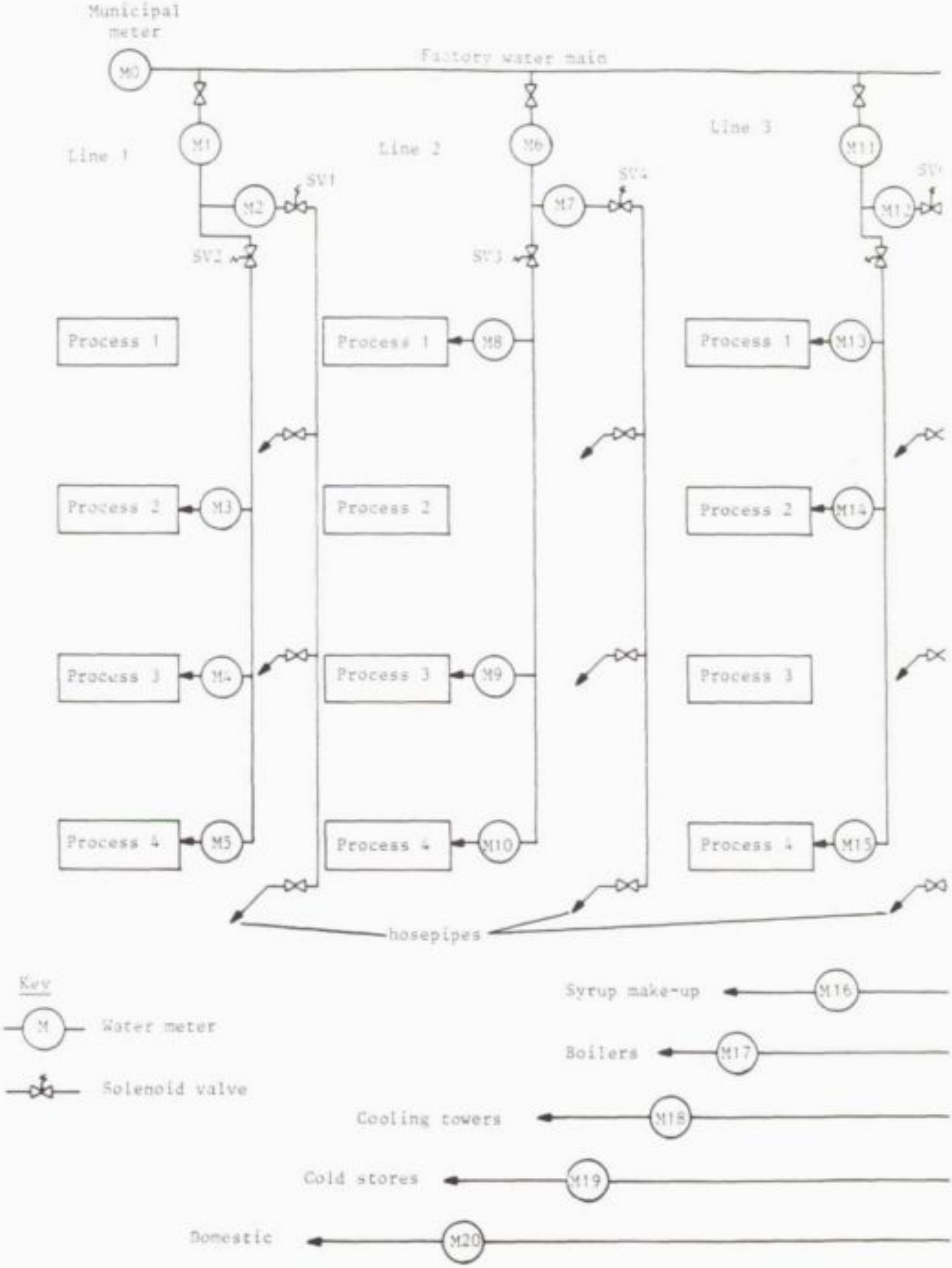


FIGURE 3.1 EXAMPLE SHOWING VARIATION IN SPECIFIC WATER INTAKE


Municipal meter
M0
Factory water main
Line 1
Line 2
Line 3
M1
M2
SV1
SV2
M6
M7
SV4
SV3
M11
M12
Process 1
Process 2
Process 3
Process 4
M3
M4
M5
M8
M9
M10
M13
M14
M15
hosepipes
Key
M
Water meter
Solenoid valve
Syrup make-up
M16
Boilers
M17
Cooling towers
M18
Cold stores
M19
Domestic
M20

Flow from hosepipes of different dimensions plotted against water supply pressure is given in Figure 3.3. This shows that using hosepipes of small diameter at high pressures delivers less water than large diameter hoses at low pressure.

All hosepipes should be connected to a discrete ring main system activated only during times allowed by factory management. It is recommended that hosepipes should be limited to 12,5 mm diameter, operated at a pressure of at least 350 kPa.

Product to water contact

In general terms, once the protective barrier on a commodity is punctured, fruit sugars, organic acids and carbohydrates will be leached into the water. The greater the surface area of product exposed to the water the greater the leaching rate.

The leaching rate reaches a maximum when the difference in concentration of the leached product and process water is greatest, eg. zero in the water and a maximum in the exposed product. The rate steadily reduces until an equilibrium is established. The presence of fruit sugars and other leachates in the process water gives rise to organic and bacterial pollution. These effects are graphically illustrated in Figures 3.4 (a), (b) and (c); the bacteria in flumes can be effectively controlled provided the correct pH level is maintained.

Boiler and steam plant

Boiler and steam plant can consume large volumes of water and produce large quantities of effluent. To minimise water intake and effluent production, they must be efficiently operated and maintained.

The main areas of unnecessary water loss in a steam system are as follows:

(a) Excessive boiler blowdown;

(b) No condensate return;

(c) Live steam injection;

(d) Steam leaks;

(e) Inadequate lagging;

(f) Poor steam reticulation.

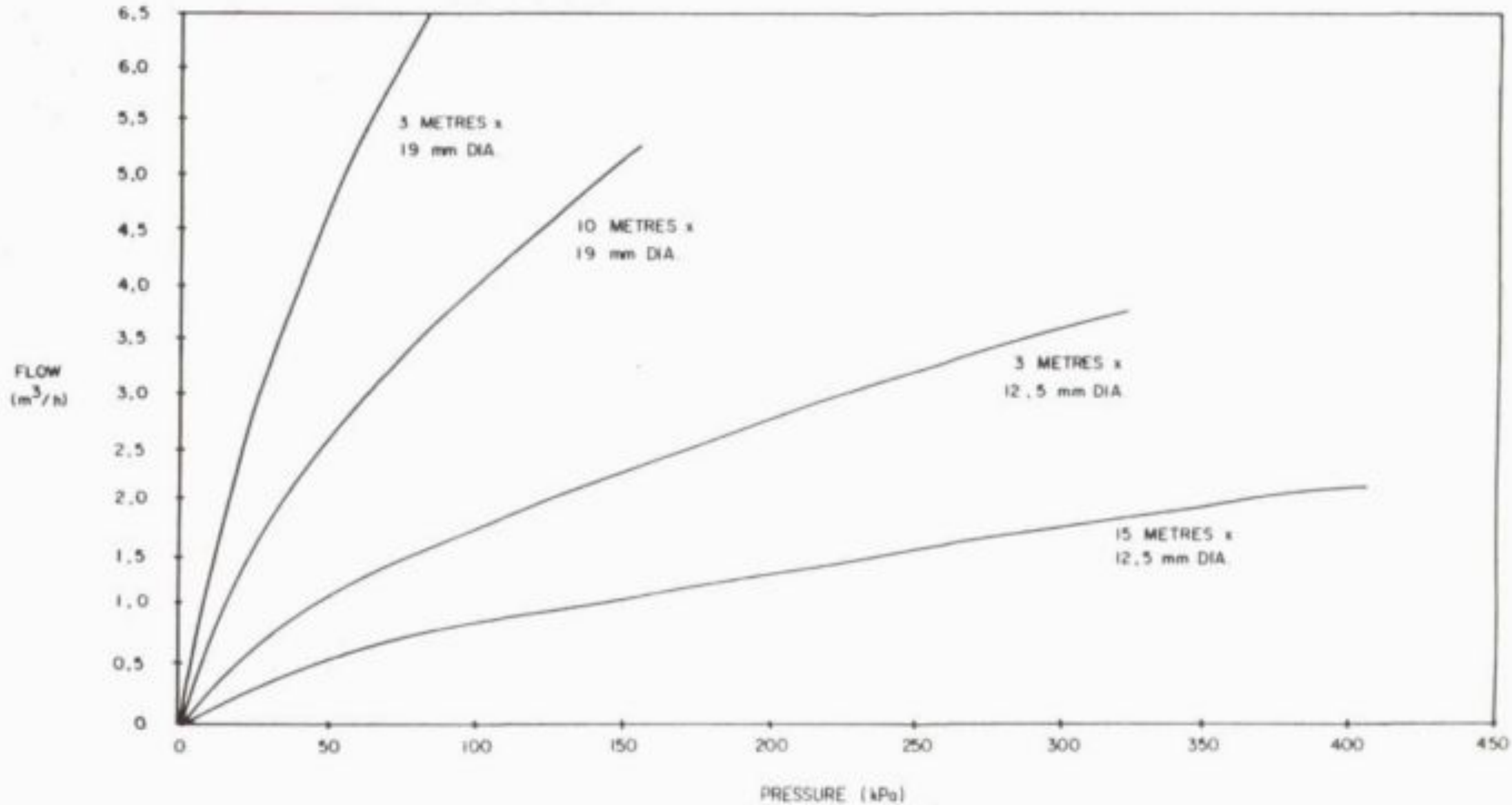


FIGURE 3.3 WATER FLOW FROM HOSEPIPES

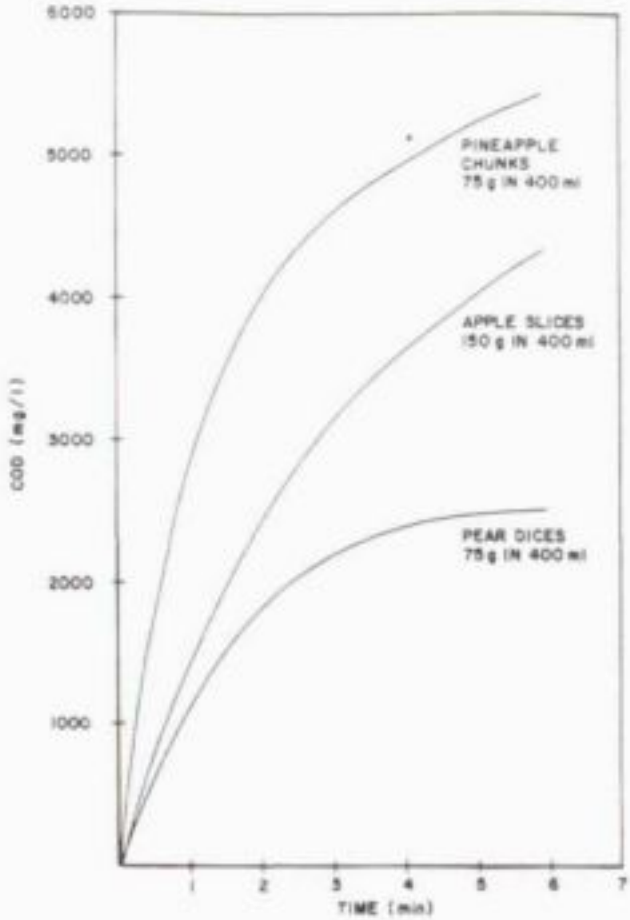


FIGURE 3.4(a) LEACHING RATE FOR WATER/PRODUCT CONTACT

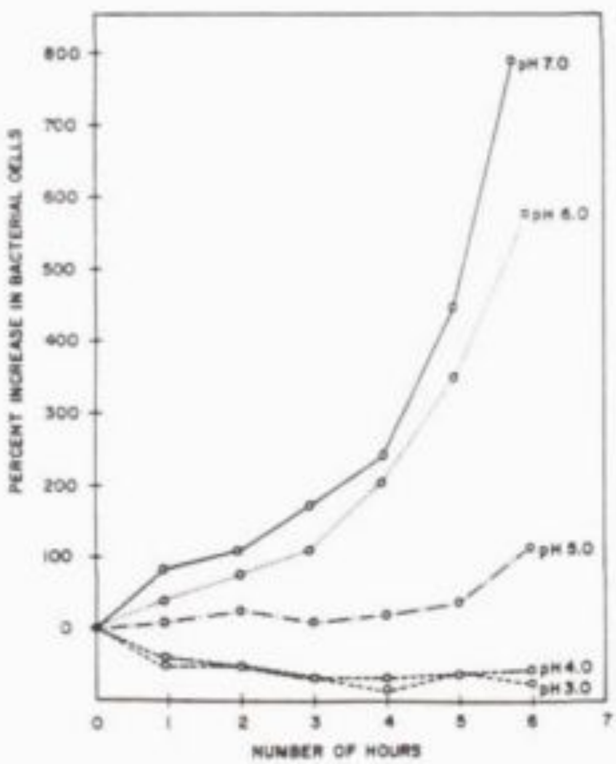


FIGURE 3.4(b) EFFECT OF pH ON THE GROWTH RATE OF

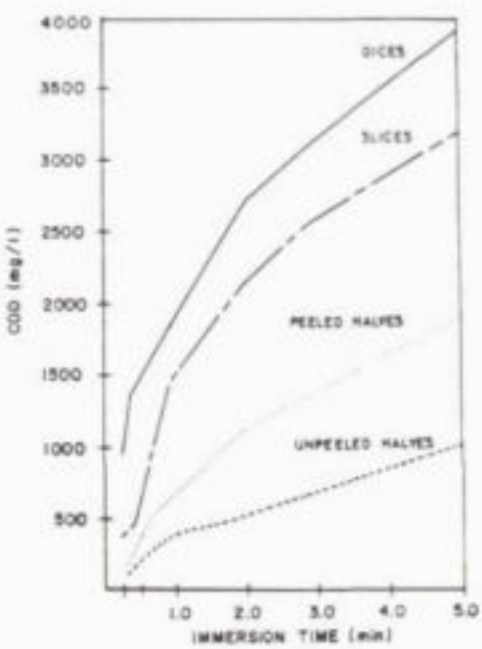


FIGURE 3.4(c) EFFECT OF IMMERSION AND

Water cooling systems

Cooling systems must be designed, operated and maintained so as to ensure optimum performance and minimum water usage and effluent production.

Water cooling systems dispose of waste heat from plant items such as steam or water vapour condensers, refrigeration condensers, compressor and stationary diesel engine cooling jackets, post-blanch cooling systems, and coolers for containers.

The main factors leading to unnecessarily high water usage in cooling systems are as follows:

(a) Blocked spray nozzles;

(b) Damaged fans and blocked air inlet grilles;

(c) Clogged tower packing and demister;

(d) Blocked water strainers;

(e) Dirty water sumps;

(f) Leaking water sump make-up float valve;

(g) Poor chemical treatment;

(h) Undersized tower.

3.3 Effluent segregation

It is shown in Figure 3.5 and Table 3.1 that segregation of effluents into streams with high and low suspended solids concentrations, high COD concentrations and high concentrations of dissolved salts, enables the optimum effluent management strategy to be applied.

This would include the separate collection and disposal of solid waste , the drainage from all first washing, peeling, cutting and snipping operations into a highly contaminated stream and the remainder to a separate stream.

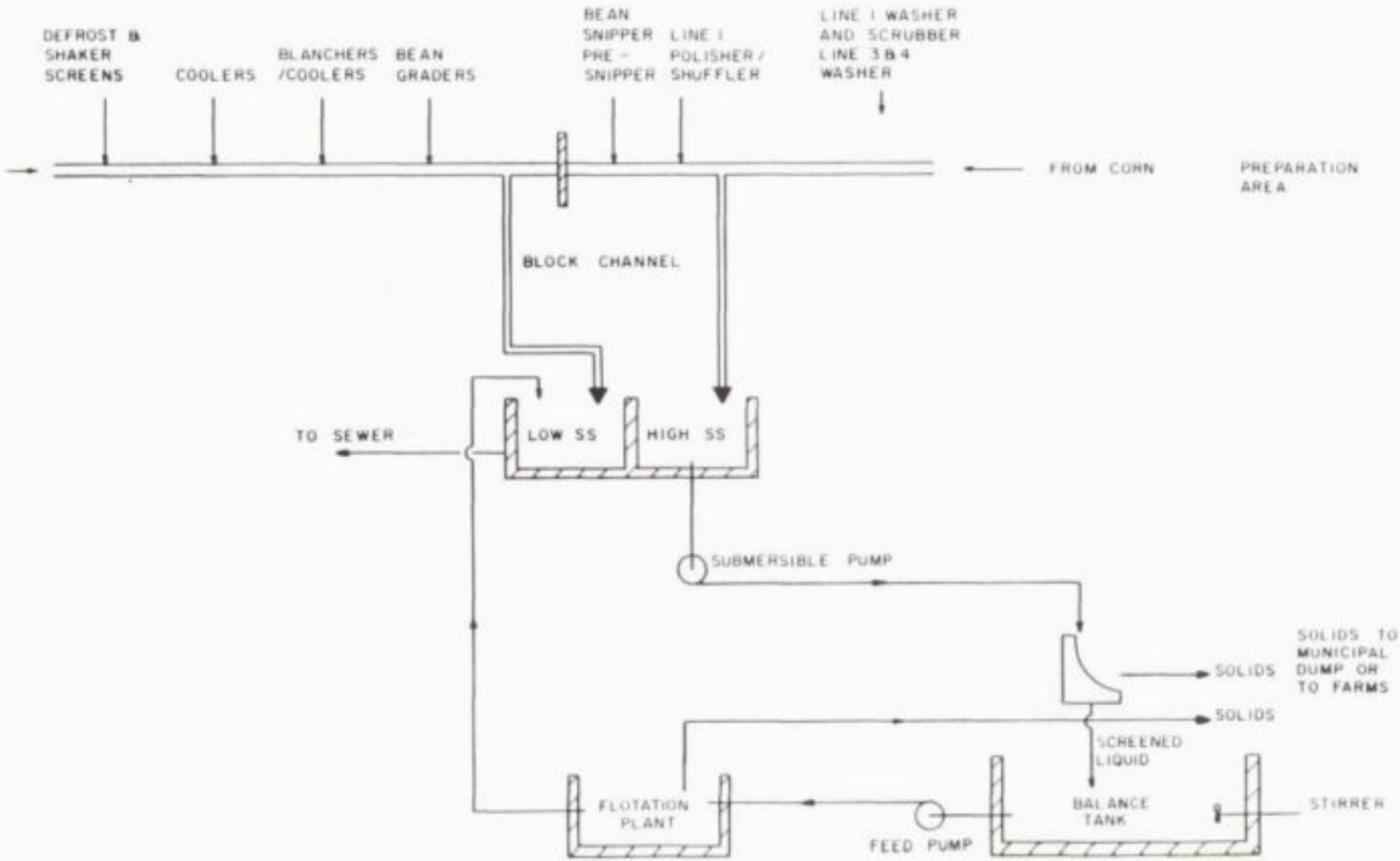


FIGURE 3.5 SCHEMATIC OF TYPICAL EFFLUENT SEGREGATION SYSTEM

TABLE 3.1 SEGREGATION OF EFFLUENTS

Commodity		High SS	High COD	High Salts
apples	C	coring	blancher effluents	-
apple & pear	J	press wash	centrifuge blowdown	-
apricots	C	peeling	peeling	caustic lye
beetroot	C	peeling retort	peeling retort	- -
corn	C	reception area	blancher flow	-
green beans	C	wet transport flumes	blancher flows	-
guavas	C	peeler waste	-	-
peaches	C	peeling	peeling & flumes	caustic lye
pears	C	flume (halves) washdown	peeling	caustic lye
pineapples	C&J		centrifuges juice spilling	
peas	C	1st flumes	blancher	
totatoes	C	peeling	-	
broccoli	F	first wash post blanch cooling	post blanch cooling	
cauliflower	F	first wash post blanch cooling	post blanch cooling	
carrots	F	peeling/ scrubber	first wash & scrubber	
corn	F	reception &	blancher dehusking	
green beans	F	snipping	snipping, cutting & blanching	
peas	F			
potatoes	F	peeling & scrubbing	post blanch cooling	

Legend: C - canning; J - juicing; F - freezing.

The foregoing segregation was undertaken at one factory processing frozen vegetables, after having implemented the in-house measures for water renovation including recycling of post-blanch cooling water and counter-current reuse along all process lines.

3.4 Characterisation of effluents

Preparation areas - canning and freezing

Preparation areas are those in which the commodities are prepared for processing. These include dump tanks containing water, drum or spray-washers, drum-screen or roller-graders, both mechanical and chemical peelers and depitting and cutting equipment.

Dump tanks

The approach to water management in dump tanks depends on the category of the product. Category 1 and 2 cover those root and non-root commodities which are to be peeled at some stage of their processing and Category 3 covers the remainder.

Products in Category 1 will generally have adhering soil to be removed in the first stage washing, whereas Categories 2 and 3 will have fertiliser and insecticidal residues in addition to any leaching of sugars and other product-based substances through being damaged or overripe.

Make-up water derived from downstream process or preparation steps can be used in the dump tank for Category 1 products.

To avoid a continual rise in the concentration of sand/soil in the dump tank, water should be recycled through side settlers and returned to the dump tank as shown in Figure 3.6.

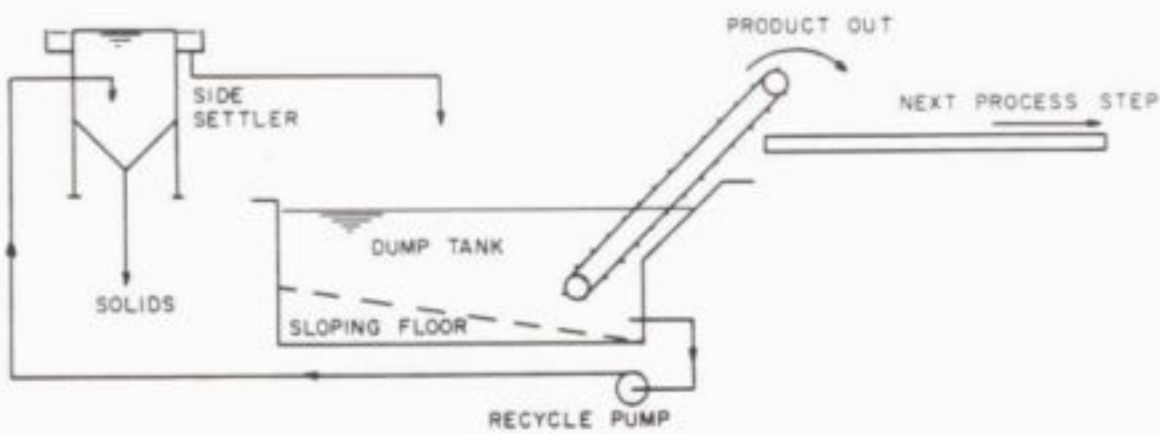


FIGURE 3.6 SIDE SETTLER WITH DUMP TANK

Size-grading equipment

Various products need size grading either prior to or after preparation. Water intake to graders is generally limited to spray nozzles for lubrication. Spray nozzle selection to provide the correct degree of mechanical action and the appropriate spray pattern is critical for minimum water use. As would be expected the fine sprays leach sugars readily and thus the COD from graders could be high. However, the flows are small and thus the total organic load from these areas is generally low.

Pitting and coring

During this process water is used for lubrication. Typically, peach pitting and fluming account for 21% of the total water flow in the process line and the effluent carries 18% of the COD and 23% of the SS.

All pits should be transported by dry systems such as conveyor belts.

Peeling

Peeling is achieved by means of mechanical (manual or automatic), chemical or steam systems.

This stage of processing accounts for the following flows and overall pollution loads expressed as a percentage of total flow and load, as given below:

Parameter	apricots	beetroot	carrots	peach	pear	potatoes
% Flow	28	14	18	19	28	48
% COD	33	28	44	10	42	53
% SS	55	49	84	14	28	86

Improved management in this area will result in a major reduction in pollution. For example the caustic overflows must be segregated from all other effluents for disposal or regeneration.

The peel sludges must not be permitted to come into contact with water and must be handled dry directly to the point of disposal. Peel originating from mechanical peelers should be disposed of as solid waste.

Slicing

The final stage of preparation involves some form of cutting prior to commencing the processing. The water consumption at this stage is confined to sprays and lubrication only, and the effluent becomes rich in commodity-based substances.

Fluming

The transportation of products by water flumes has two drawbacks:-

(a) Water consumption is increased;

(b) The water in contact with the product leaches product-based substances into the water.

Substitution of flumes by conveyor belts or other methods of "dry" transportation should be implemented wherever possible.

In flume systems water make-up is provided to ensure adequate water for conveyance of the product. The major cause of water usage in a fluming system is overflow. This is caused by variations in the rate at which the product is introduced into the circuit, resulting in make-up water being added to the circuit.

Since limited control can be exercised over the rate of product addition because of variations in the upstream processing plant, facilities to collect, store and provide the balancing volume of water without using make-up are required.

Blanchers

The effluents arising from blanching have a high organic strength. Typical qualities of some blancher effluents are shown in Table 3.2.

TABLE 3.2 QUALITY OF SELECTED BLANCHER EFFLUENTS

Commodity	pH	SS	COD	Volume	% of Total	
		mg/ℓ	mg/ℓ	m^3/t	Flow	COD
Apple	N.A.	379	13 382	1,78	34	50
Broccoli	5,6	86	31 216	0,05	1	3
Carrots	8,8	4 270	40 000	0,26	4	12
G/beans	5,3	47	369	0,33	4	N.A.
Corn	6,8	N.A.	N.A.	0,63	14	N.A.
Peas	N.A.	524	9 095	0,85	13	60
Potato chips	N.A.	3 280	9 570	2,93	11	38

Note: N.A. = Not available

Post blanch cooling flumes

After blanching vegetables must be cooled prior to freezing. This is done either by a cooling flume or water sprays in order to reduce the product temperature.

Recycling of cooling water has been succesfully carried out using heat exchangers to dump the heat removed from the primary circuit (including the post blanch cooler) to a secondary circuit served by an evaporative cooling tower. Such a system is shown schematically in Figure 3.7.

Cooking and cooling

The quality of effluent from the cooking stage warrants little attention; close control is however needed over the discharges of water from retort cookers.

The cooking/cooling stage, where practical should be converted to closed circuit whereby the cooling water from the retorts is recycled over a cooling tower. The circuit should be identical to that shown for post blanch cooling in Figure 3.7.

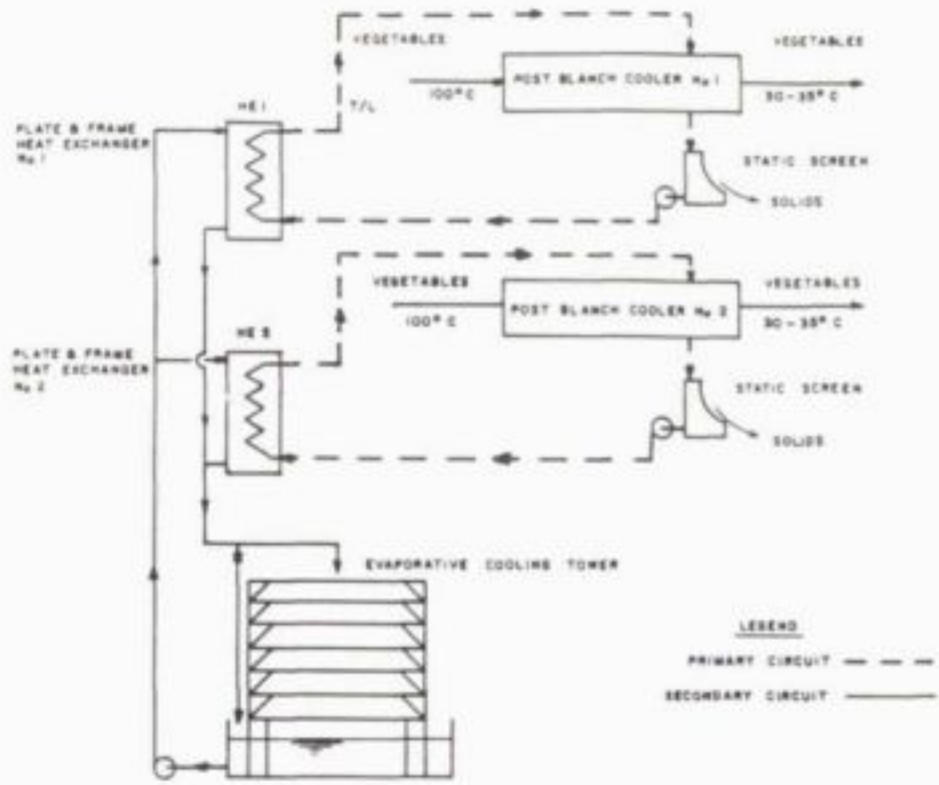


FIGURE 3.7 POST BLANCHER WATER RECYCLE

Juicing presses, vacuum pumps and evaporators

Plant washdown water accounts for 20% to 31% of the total water intake.

About 30% of the COD and the SS load originates from the washing of the presses and this proportion should be segregated for further treatment. Similarly the overall plant washdown produces 45% of the overall COD and 34% of the SS.

The removal of the gross pomace from the press area by dry methods is preferable. Vacuum pump sealing water and evaporator condensates should be collected and reused.

Washing down

Washing down of production lines is a most important part of production and is carried out to remove unwanted accumulated liquids and solids.

Invariably large quantities of water are wasted in the first stage of washing-down to dislodge solids from crevices in plant. As shown in Figure 3.3, hosepipes operating at pressures high enough to dislodge solids consume large quantities of water. Table 3.3 shows a breakdown of the quantity of water employed during washdown for some commodities:-

TABLE 3.3 WATER EMPLOYED DURING WASHDOWN AND POLLUTANTS GENERATED FOR SOME COMMODITIES

Commodity	Style	Processing (% volume)	Washdown		
			% Volume	% COD	% SS
Apples	C	75	24	9,5	16,5
Apples	J	20	76	51,0	45,5
Apricots	C	67	23	18,0	30,0
Beetroot	B	-	30		
G/beans	C	85	15		
Guavas	C	78	14		
Peaches	C	70	30	9,0	18,0
Peas	C	84	16		
Pears	J	20	70		
Pears	C	84	16	20,0	17,0
Pineapples	C	75	14		

Note: (1) The balance of water used is accounted for by boiler feed and domestic usage.

(2) C = Canning; J = Juicing; B = Bottling

Washing down of process plant should be divided into three distinct stages:-

(a) Preliminary removal of solids from machinery using air hoses, and mopping up of solids from floor: NO WATER SHOULD BE USED;

(b) Preliminary washing of all machinery using secondary quality water e.g. water from flumes treated by dissolved air flotation or ultra-filtration, followed by addition of foaming antiseptic detergent;

(c) Final wash-down with high pressure potable water.

Proper washdown procedures (refer 3.1) can reduce water intake substantially and will reduce the suspended solids and COD loads in the effluent.

At plants using vacuum pumps, evaporator condensates and vacuum pump seal water should be used for washing-down purposes.

Final effluents

Table 3.4 shows the quality of some of the final effluents which are generated by the Industry. Implementation of the various measures recommended in this Guide should reduce the strength and the quantity of the various effluents.

TABLE 3.4 FINAL EFFLUENTS

COMMODITY	STYLE	SS mg/ℓ	COD mg/ℓ
Apples	C	430	6 800
Apples	J	4 148	3 095
Apricots	C	390	3 646
Beans in tomato	C	154	2 000
Beetroot	B	270	5 940
Citrus	C&J	-	6 500
Corn	C	300	2 100
Green beans	C	400	1 490
Guavas	C	195	700
Peaches	C	880	4 544
Pears	C	464	2 930
Pears	J	4 900	15 000
Peas	C	120	2 000
Pineapples	C	1 190	12 900
Strawberries	C	-	-
Tomatoes	C	493	1 100
Broccoli	F	50	5 930
Cauliflower	F	274	1 950
Carrots	F	4 717	14 980
Corn	F	100	1 000
Green beans	F	100	286
Peas	F	274	1 950
Potatoes	F	3 266	2 880

Legend C = Canning; F = Freezing; J = Juicing;
B = Bottling.

CHAPTER 4

WASTE-WATER TREATMENT

4.1 The options for disposal of waste water

The options for discharging factory waste water are as follows:

Route

R1 : Land application;
R2 : Land application or disposal to sea after on-site pretreatment;
R3 : Discharge to municipal sewer after on-site pretreatment;
R4 : Discharge to municipal sewer after partial treatment on site;
R5 : Discharge to receiving water after full on-site industrial treatment.

Disposal route R1

The simplest form of waste water disposal is that of irrigation. This form of treatment is likely to be the cheapest to implement in areas where land is relatively plentiful and cheap. The irrigation scheme must be designed in accordance with Information Bulletin B1/1 entitled "Guidelines for the disposal of effluent on land in South Africa" published by the Department of Agriculture (Appendix B.). In some climatic areas, a storage dam is required to store the factory waste water for the duration of inclement weather. Waste waters from this Industry readily ferment, and it is therefore necessary to provide aeration to maintain aerobic conditions and thereby avoid unpleasant odours.

Disposal route R2

This involves disposal by irrigation or to sea with varying degrees of pretreatment. In all cases effluents should be screened to remove gross solids prior to irrigation or disposal to sea.

Disposal route R3

Disposal to sewer requires a permit from the local authority. The permit conditions specify acceptance limits for various pollution parameters. To meet these limits an appropriate degree of on-site treatment will usually be required.

Disposal route R4

To reduce municipal charges for disposal of waste waters to sewer, the strength of the waste water may be reduced by additional on-site treatment. Processes used could include air flotation, sedimentation, filtration, chemical treatment or membrane process.

Disposal route R5

This involves the construction on the industrial premises of a custom-designed treatment plant to treat the effluent to the appropriate standard for discharge to the environment, for example direct to receiving waters, in which case the General Standard or the Special Standard will apply, or via land application. In both cases, a permit is required from the Department of Water Affairs.

4.2 Balancing of effluent

Balancing is the storage and mixing of effluent over a chosen period to smooth out the volumetric discharge rate and the pollutant strength. The provision of balancing facilities allows an effluent treatment plant to be designed for the average flow rather than for instantaneous peaks, thereby reducing the size of the treatment plant.

The sizing of balancing facilities can be calculated using a graphical technique consisting of plotting cumulative flow versus time for one complete cycle, e.g. 24 hours.

Figure 4.1 illustrates the method. Cumulative effluent volume is plotted against time, i.e. line 1 is drawn from the origin to the 24 - hour point. Line 3 is drawn parallel to the average line 2 through the point of maximum accumulative volume as shown. The vertical scaled distance represents the volume of the balance tank required for hydraulic balancing. A further 25% capacity should be allowed as a contingency for future expansion.

4.3 Solids removal

Definitions

Suspended material in fruit and vegetable effluents can be classified according to their size and type:

Large solids - Objects greater than 25 mm in any dimension, comprising pieces of whole fruit or vegetable, their stalks, pips, leaves or fibres;

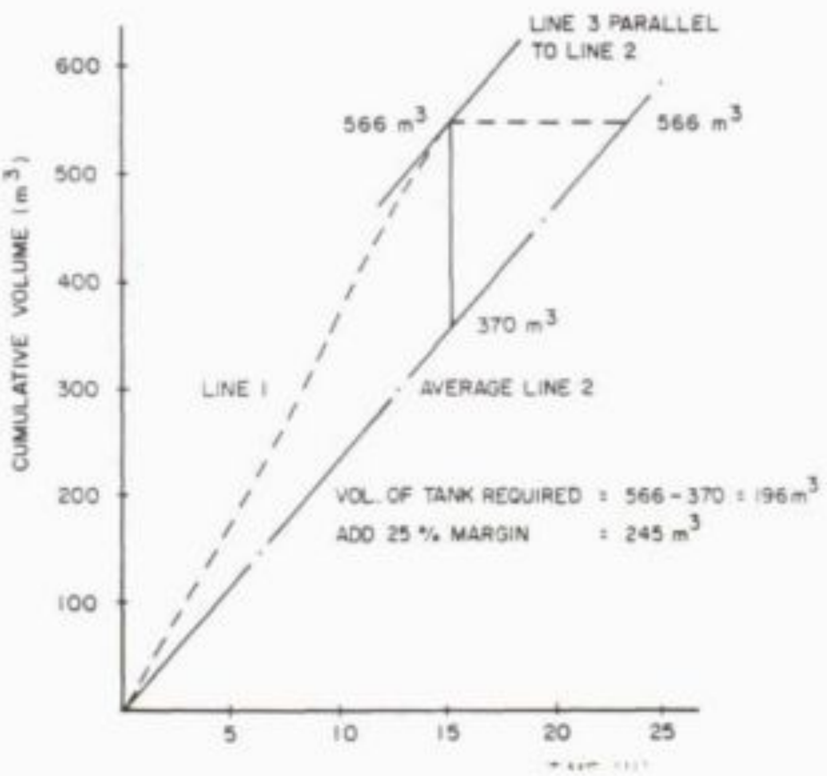
Grit - Suspended matter with a settling velocity substantially greater than small organic particles, including sand, soil and gravel;

Settleable solids - Suspended material measured by settling;

Colloids - Substances that will not settle unaided as the particles have surface charges that must be neutralised before particle coagulation, flocculation and settling will occur.

FIGURE 4.1 GRAPHICAL METHOD FOR DETERMINING BALANCE VOLUME

Time	Flow m^3/h	Accumulative volume m^3	Time	Flow m^3/h	Accumulative volume m^3
07h00	28	28	16h00	47	357
08h00	33	61	17h00	35	392
09h00	34	95	18h00	42	434
10h00	28	123	19h00	37	471
11h00	40	163	20h00	34	505
12h00	32	195	21h00	26	531
13h00	34	229	22h00	35	566
14h00	37	266	22-01h00	0	566
15h00	44	310			



Total suspended solids - Total amount of solids that either float on the surface of, or are in suspension in water, waste water, or other liquids.

Screens

Solids should be removed sequentially from the coarsest to the finest. The coarsest solids should be removed by bar screens which can be provided with suitable cleaning systems. Fine screens are available in rotary, vibrating and static versions. Static wedgewire screens are effective on all fruit and vegetable effluents. However, they must be cleaned regularly to maintain efficient operation.

Coagulation and flocculation

Coagulation and flocculation are often used in conjunction with sedimentation to enhance the process of settlement. The chemicals used are water soluble electrolytes and polymers.

The coagulation/flocculation process should be carried out in specially designed basins or tanks to promote floc growth and settlement.

Sedimentation

Sedimentation occurs when the effluent is held in a quiescent state or at a velocity low enough for the solid particles to settle. The design parameters include surface area, detention time, tank depth and overflow rate. Sedimentation tanks may be circular or rectangular vertical flow, radial flow or horizontal flow types. Sedimentation is generally necessary prior to filtration when turbidities of feed to the filters exceed 10 mg/ℓ.

Dissolved air flotation (DAF)

As an alternative to sedimentation for the removal of solids, dissolved air flotation can be used. Commercial flotation plants are available in rectangular or circular format. Either type may be successfully used, but the design parameters must be correctly selected and this depends on the commodity being processed.

DAF treatment has been tested and found successful on effluents arising from processing of various vegetables and fruits, including effluent from freezing plants. Generally, at least 50% of the COD and SS loads can be removed from these effluents without any chemical dosing. In many instances the SS removal will be as high as 80%. The addition of polymers in small doses e.g. 0,5 mg/ℓ should improve the removal of organic matter.

Inside the factory, flume waters can be renovated by using DAF, thereby extending the run time between dumps.

4.4 pH Control

The control of pH within certain limits is necessary irrespective of whether the effluent is discharged into the municipal system, treated on site or disposed of to land. Municipal limits are generally from pH 5 to pH 9. In on-site chemical treatment the efficiency of coagulation and flocculation is also pH dependent. For biological treatment, the optimum pH lies between 6,5 and 7,5. With respect to pH control for land disposal, see Appendix B.

4.5 Membrane processes

Introduction

Membrane separation processes offer the following advantages in the fruit and vegetable processing industry:

(a) Valuable food substances can be recovered from effluent;

(b) Large volumes of clean water can be recovered for reuse in a factory instead of being discharged to drain;

(c) Sugar solutions and fruit juices can be pre-concentrated.

Cross-flow microfiltration

Cross-flow microfiltration is a pressure - driven filtration process (100 to 600 kPa) for the removal of suspended and colloidal particles from a water, waste-water, or sludge stream.

Ultrafiltration

In ultrafiltration (UF), membranes are used to mechanically separate suspended solids from a liquid. This is similar in principle to filtration through screens or beds of porous media. A major difference is that, whereas conventional filtration processes are not capable of removing suspended particles finer than about 0,001 mm, e.g. colloids, UF can be used to separate large organic molecules from liquid suspensions of solutions.

Nanofiltration

Nanofiltration is membrane separation which falls between ultrafiltration and reverse osmosis. The membrane does not reject monovalent ions or organic molecules with a molecular weight less than 500 daltons.

Reverse osmosis

Reverse osmosis (RO) plants are physically similar to UF plants but the mechanism of separation relies upon the diffusion of water molecules through a semi-permeable osmotic membrane.

CHAPTER 5

SOLID WASTE HANDLING

5.1 Solid waste generation by the Industry

Solid wastes arising from the Industry can be classified into two main categories, viz.

(a) In-plant residues which comprise reject raw material, product pieces, soil and other debris removed from the raw product, peels and skins etc.

(b) End-of-process residues which comprise solids removed from the final effluent discharge by screening, sedimentation or flotation or from secondary processes.

Table 5.1 gives a product-by-product breakdown of the solid wastes generated. The total quantity of solid waste generated by the Industry on an annual basis is estimated at 340 000 tonnes (1979-1980 base) which is approximately 38% of the total raw materials intake. This indicates the magnitude of the problem faced by the Industry.

5.2 Current disposal methods

An estimated breakdown of the solid waste disposed of by the different disposal routes in current use is as follows:-

(a) 64% is utilised directly or after storage as a low-grade feedstuff (approx. 21 800 tons);

(b) 20% is dried and sold as a high-grade animal feedstuff (approx. 68 000 tons);

(c) 10% is dumped to land (approx. 34 000 tons);

(d) 4% is recovered to produce a high-value by-product (approx. 1 360 tons);

(e) 2% is applied to land as a fertilizer either during or after composting (approx. 6 800 tons).

TABLE 5.1 ANNUAL SOLID WASTE GENERATION IN THE FRUIT AND VEGETABLE INDUSTRY (1979/80 STATISTICS)

Process	Total raw material (t/a)	Solid waste (t/a)	Specific solid waste load (t/t of raw material)	Type of solid waste
Canning of peaches	132 000	31 800	0,241	Pips (9 180 t/a) Balance: Peels, sludge, rejects
Canning of apricots	28 100	6 990	0,248	Pips (1 760 t/a) Balance: Peels, sludge, rejects
Canning of pears	58 500	23 000	0,393	Peels, cores, spillage, rejects
Canning of apples	15 760	5 300	0,336	Peels, cores, spillage, rejects
Juicing of apples and pears	Apples 33 640 + Pears 9 300 = 42 940	Apples 9 900 + Pears 2 740 = 12 640	0,294 0,295	Pomace from presses, filter cake discharges, settling tank sludges
Canning and juicing of citrus fruit	Oranges 136 000 + Lemons 8 500 + Grapefruit 16 000 = 160 500	Oranges * 61 200 + Lemons * 4 250 + Grapefruit 9 600 = 75 050	* 0,45 * 0,50 * 0,60	*Reduce by 20% if peel utilised. Skin, albide and pips

Table 5.1 (Continued)

Process	Total raw material (t/a)	Solid waste (t/a)	Specific solid waste load (t/t of raw material)	Type of solid waste
Canning and juicing of pineapples	186 800	85 000	0,455	Peel, cores, spillage, rejects
Canning of guavas	9 500	2 367	0,249	Lye, peel, rejects
Tomato concentrate, juice and canning	26 400 (whole tomatoes) and 75 500 (concentrate and sauce) 101 900	10 190	0,10	Skins and pips
Canning of other fruits	1 525	638 (est)	0,40	1 420 t/a Strawberries, youngberries and loganberries: 175 t/a grapes, mangoes, pawpaws. Rejects used for jam
Canning of green beans	2 300	398	0,173	Pips, snippings, spillage
Canning of beans in tomato sauce	1 200 (est)	960 (est)	0,80	Spillage and rejects
Canning of beetroot	2 330	932	0,40	Skins, tops, tails, rejects and spillage

Table 5.1 (Continued)

Process	Total raw material (t/a)	Solid waste (t/a)	Specific solid waste load (t/t of raw material)	Type of solid waste
Canning of peas	14 300 t/a peas excluding vines, pods, etc. 17 500 t/a including vines, pods etc.	57 200	*0,80	* Includes vines, pods, etc. Assumes a 10% loss of berry during process
Canning of sweetcorn	7 895	3 158	0,40	Cobs, greens, spillage
Canning of mixed vegetables	2 600 (est)	1 170 (est)	0,45	Pea vines, potatoes & carrot peel, sludge & spillage
Canning of other vegetables	Not available (small quantities)	Not available (very small quantities)	0,45	Cuttings, peelings, spillage, rejects
Freezing of vegetables	58 800	24 100 (est)	0,45	Cutting, peelings, spillage, rejects
TOTAL/ AVERAGES	884 220	340 893	0,38	

The majority of solid waste is disposed of by direct feed to animals, land application and landfill. A small proportion of the solid waste is converted to high-value by-product e.g. dried citrus pulp is successfully recycled as a high-grade animal feedstuff, marzipan is manufactured from apricot pips, and peach pips are converted to activated carbon.

5.3 Potential disposal methods

Potential disposal methods are as follows:

(a) reuse as animal feed;

(b) disposal to land as fertilizer;

(c) disposal to landfill;

(d) conversion to a fuel;

(e) incineration.

Whilst there are various possibilities for the conversion of solid waste into valuable by-products, it may prove more economical to have waste removed by e.g. municipalities, contractors or farmers "as is".

In evaluating the alternatives for recovery of solid wastes, the factors unique to each factory must be assessed. One factor which must always be taken into account is that transport costs must be kept to a minimum to achieve economic viability. The opportunity may exist for a regional venture approach, by establishing a processing plant central to a number of factories.

Use of solid wastes in animal feed

Proposed methods for upgrading solid wastes to animal feeds which are theoretically viable include the following:

(a) drying to 10% moisture using either external fuels or methane gas generated by anaerobic digestion; it is estimated that digestion of two tons of solid waste material will provide sufficient methane fuel gas to dry one ton of waste material;

(b) extracting starch and/or protein from citrus pulps, pomaces a
fibrous green plant material;

(c) combining caustic lye peel residues with acidic wastes.

Disposal to land as fertilizer

Solid wastes which are not converted to animal feed or a by-product present major disposal problem and are often relegated to land applicatio Acceptable application rates vary depending inter alia on the type of was material, the nature of the soil, the type of cover crop, the rainfall patte for the area, subsoil drainage, etc. Acceptable limits for application rat have not been well established locally, but in the USA application rat ranging from 7 to 25 tons of dry solids per hectare per annum have be successfully used.

Surface application of organic wastes will generally give odour and pe control problems and can give a high strength leachate during periods rain. Consequently, solids applied to land should be ploughed in to ensu that they are covered at all times. Similar problems can be experienced wi leaching and percolations as associated with irrigation of organic effluen onto land as discussed in Appendix B and due cognisance should be taken of t provisions of the Water Act in this regard.

Landfill

Solid wastes from the Industry can be disposed of to conventional sanita landfill sites at loading rates ranging from 12 to 120 tonnes per hectare (p annum). Pretreatment of the wastes is advisable if their pH falls outsi the range pH 6 to pH 8.

The Institute of Solid Waste Management is a useful source of information the management of landfill operations.

Conversion to fuels

Solid wastes from the Industry can be fermented to produce alcohol or metha gas or can be processed to a good quality of charcoal.

In carbonisation (conversion to charcoal), a yield of about 30% mass/mass is probable if the materials are supplied at around 10% moisture content.

Incineration

Experience with the incineration of municipal refuse and other wastes has shown that in most instances such processes are uneconomical since there is a nett energy demand. This method of disposal should thus only be considered as a last resort.

5.4 Regional joint venture approach

The joint regional venture approach has the following major advantages:

(a) Economies of scale are achieved.

(b) Transportation distances and the associated costs are kept at an economically viable level.

(c) Downtime on the solid waste processing plant due to the seasonal nature of the Industry can be reduced by taking advantage of the overlap between different products at different factories.

(d) Opportunities are created for achieving a more balanced recovered product by blending wastes of varying composition.

(e) The economic viability of such ventures can be enhanced by the inclusion of solid wastes arising from other industries such as wine making.

(f) Facilities available in other industries could also possibly be utilised, for example rendering plants for abattoir wastes or alcohol distillation plants for organic wastes.

In reviewing the possibilities of a regional approach to by-product recovery, possible centres for processing sites have been identified on a geographical basis. An example of a possible joint venture regional approach is given in Table 5.2.

TABLE 5.2 POSSIBLE REGIONAL JOINT VENTURE APPROACH TO SOLID WASTE BY-PRODUCT RECOVERY FROM FRUIT AND VEGETABLE PROCESSING

CENTRE	JOINT VENTURE COMPANIES
Ashton	Langeberg Ashton Canning
Ceres	Ceres Fruit Growers Ceres Fruit Juices S A Preserving Ceres Fruit Industries
East London	Langeberg Western Province Preserving Co Deep Freezing & Preserving Collondale Cannery
Strand	Deep Freezing & Preserving Gants' Foods
George	Table Top Langeberg (Mossel Bay)
Boksburg	Langeberg Irvin & Johnson (Springs)
Nelspruit	Barvale Patoma (Kaapmuiden) Langeberg (Hoedspruit)
Paarl	Langeberg RFF (Groot Drakenstein)
Port Elizabeth	Land Harvest Val Orange

APPENDIX A

FLOW METERING EQUIPMENT

Introduction

To assist the Industry in assessing the effectiveness of its water and waste-water management programme, the questionnaire given in Appendix D should be completed from the monthly records at the factory and returned to the Water Research Commission, P O Box 824, Pretoria 0001 by 31 August each year. The data, which will be treated as strictly confidential, will be used to update the water usage and waste-water disposal norms for the Industry. The revised norms will be published in the S A Waterbulletin.

General

This section describes the various types of equipment used for flow measurement.

Flume meters

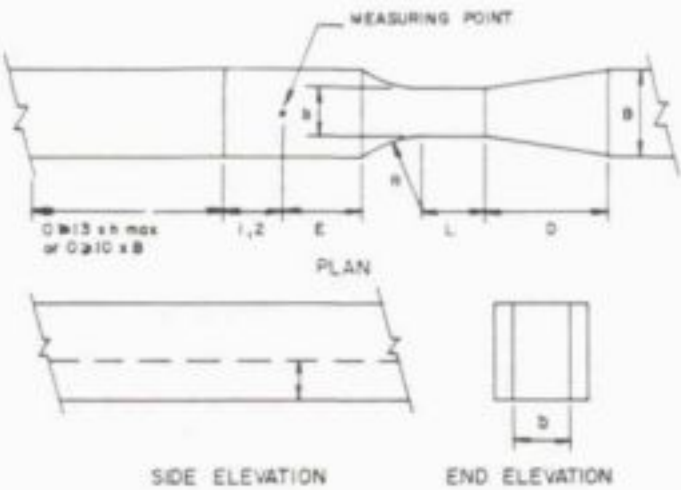
The classical method of effluent flow monitoring is the flume and/or venturi. Various types of venturi flume exist for fitting into open channels. Figure A.1 provides the design of a flume suitable for widely varying flow rates. Having installed a flume, only measurement of water depth is needed to calculate the flow.

The value of Cv is found from the Table A.1.

TABLE A.1 VELOCITY FACTORS FOR DIFFERENT b/B RATIOS

b/B	Cv	b/B	Cv	b/B	Cv	b/B	Cv
0,10	1,0022	0,30	1,0209	0,44	1,0476	0,58	1,0901
0,10	1,0051	0,32	1,0240	0,46	1,0526	0,60	1,0980
0,20	1,0091	0,34	1,0272	0,48	1,0579	0,62	1,1065
0,22	1,0110	0,36	1,0308	0,50	1,0635	0,64	1,1154
0,24	1,0132	0,38	1,0346	0,52	1,0695	0,66	1,1253
0,26	1,0155	0,40	1,0386	0,54	1,0760	0,68	1,1354
0,28	1,0181	0,42	1,0430	0,56	1,0829	0,70	1,1469

FIGURE A.1 Flume meter



Notes:

(i) h max $\leqslant$ 3 x b
(ii) 5 cms $>$ h $\leqslant$ 180 cm
(iii) length of inlet section $\geqslant$ 120 cm + E
(iv) b/B $\leqslant$ 0,70
(v) h/b $\leqslant$ 3
(vi) E = 3 to 4 times h max.
(vii) max gradient at inlet section is 1:100

Where Q = flow in m^3/s
b = restriction width in m
B = downstream channel width in m
E = distance of measuring point upstream of commencement of restriction
Cv = velocity factor from table or by calculation
Ce = outlet coefficient depending on friction losses
h = backup water height in m.

$$Q = \frac{2 \times (2)^{0,5}}{9} \times Cv \times Ce \times (g)^{0,5} \times b \times (h)^{1,5} \quad (m^3/s)$$

$$\text{The value of Ce} = \left[\frac{b}{b + 0{,}004L}\right]^{1,5} \times \left[\frac{h - 0{,}003L}{L}\right]^{1,5}$$

Weirs

Among other methods of measuring effluent flows are weirs and the use of empirical equations. Weirs must however only be used where they will not become blocked with gross solids.

(a) V-notch weirs

Figure A.2 shows the general arrangement and formulae for calculating the flow over a weir. The general arrangement should be designed in accordance with the notes. The flow is calculated from the height of water above the weir apex when measured at the correct point. The V-shape results in a major change of level for a small increase in the rate of flow and it is therefore particularly suitable for varying rates of flows. The weirs can be made of sharp-edged metal plates.

An arrangement is provided in Figure A.3 for a measuring box which can be inserted at a suitable place within the effluent pipeline.

(b) Rectangular weirs

The general arrangement of a rectangular weir is provided in Figure A.4. This type of weir is best suited to relatively constant flows.

Empirical methods

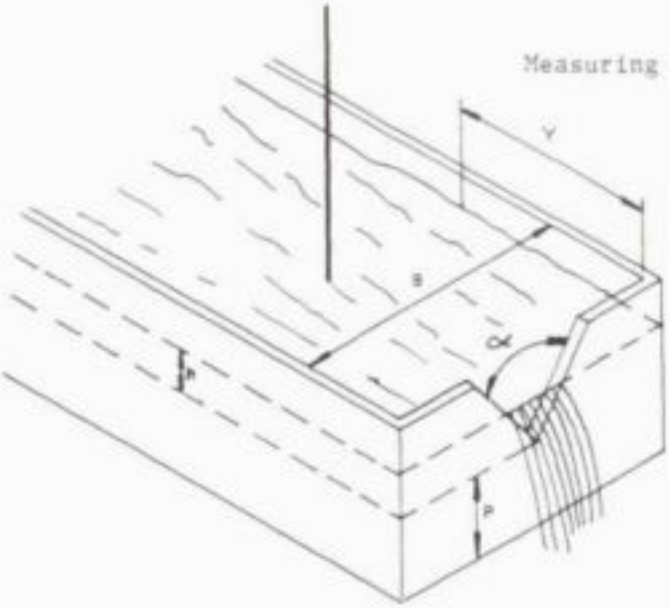
In many installations open-ended pipes have a free discharge into air in which case there are two methods of measuring flow, which, although not as accurate as weir measurements, are sufficient for many purposes.

(a) The co-ordinate method

This method requires the measurement of the horizontal and vertical co-ordinates of the discharge flume - see Figures A.5 (a) and (b) and Table A.2.

(b) The California pipe method is another method of estimating the flow in partially-filled pipes. The pipe must be horizontal for the method to work. If not then a connection with an open-ended stand pipe is needed to a horizontal section of pipe (see Figures A.6 (a) and (b)). Tables A.3 (a) and (b) give calculated values for T and W to enable the flows to be calculated.

FIGURE A.2 V-notch weir



Notes:
minimum h = 5 cm
maximum h = 30 cm
opening angle α = 30 to 90°
measurement range = 0,75 to 240 m^3/h
notches to be sharp edged

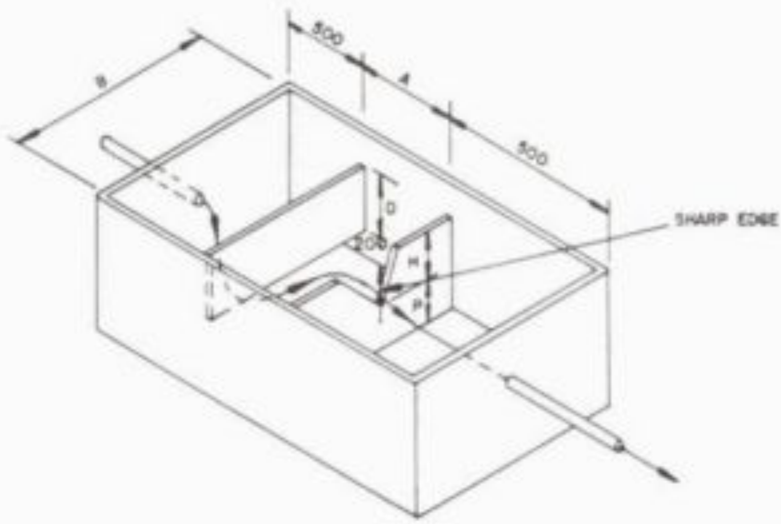
Inlet length before weir
Y $\geq$ 1,5 m
B $\geq$ 80 cm
P $\geq$ 45 cm
h/p $\leq$ 0,4
hB $\leq$ 0,30

$$Q = \frac{8}{15} \, Ce \, (2g)^{0,5} \times \tan \frac{\alpha}{2} \, (h)^{2,5}$$

if α = 30°	α = 45°	α = 90°
$Q = 0,63 \, Ce \, h^{2,5}$	$Q = 0,98 \, Ce \, h^{2,5}$	$Q = 2,36 \, Ce \, h^{2,5}$

Ce = $0,565 + 0,0087 \, (h)^{-0,5}$
Q = flow m^3/s
g = 9,81 m/s^2
h = metres

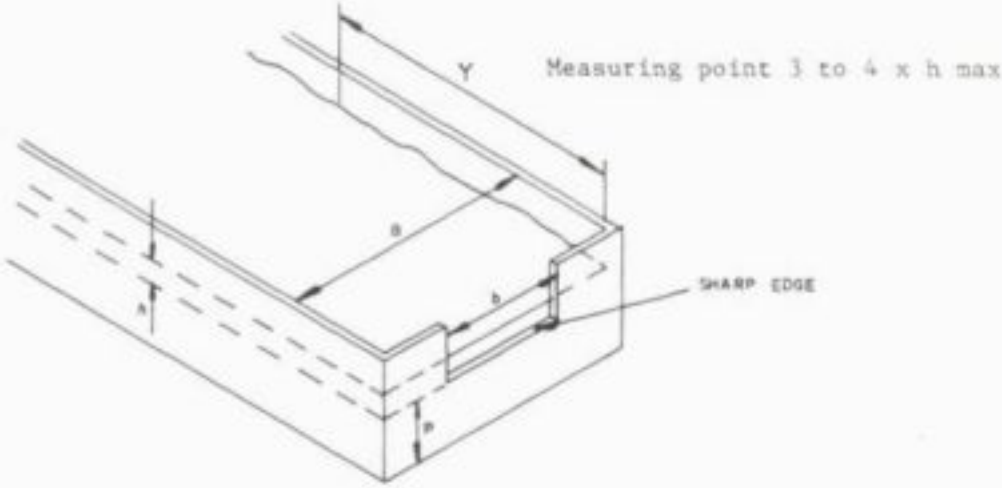
FIGURE A.3 V-notch weir measuring box



Notes on design:

Dimensions:	A	$\geq$ 1,5 m
	B	$\geq$ 80 cm
	P	$\geq$ 45 cm
	H/B	$\leq$ 0,3

FIGURE A.4 Rectangular weirs



$$Q = \frac{2}{3} (2g)^{0,5} \times Ce \times b \times (h)^{1,5}$$

or

$$Q = 2,09 \times Ce \times b \times h^{1,5} \quad m^3/s$$

where $C = 0.616\ (1-0,1\ h/b)$
flow $Q = m^3/s$
$g = 0,81\ m/s^2$
both b and h in metres

Notes:

Suitable for relatively constant flow
overall height between 7,5 cm and 60 cm
base width $b \geqslant 2$ h max $\geqslant 30$ cm
inlet length $\geqslant$ 10 to 13 x h max

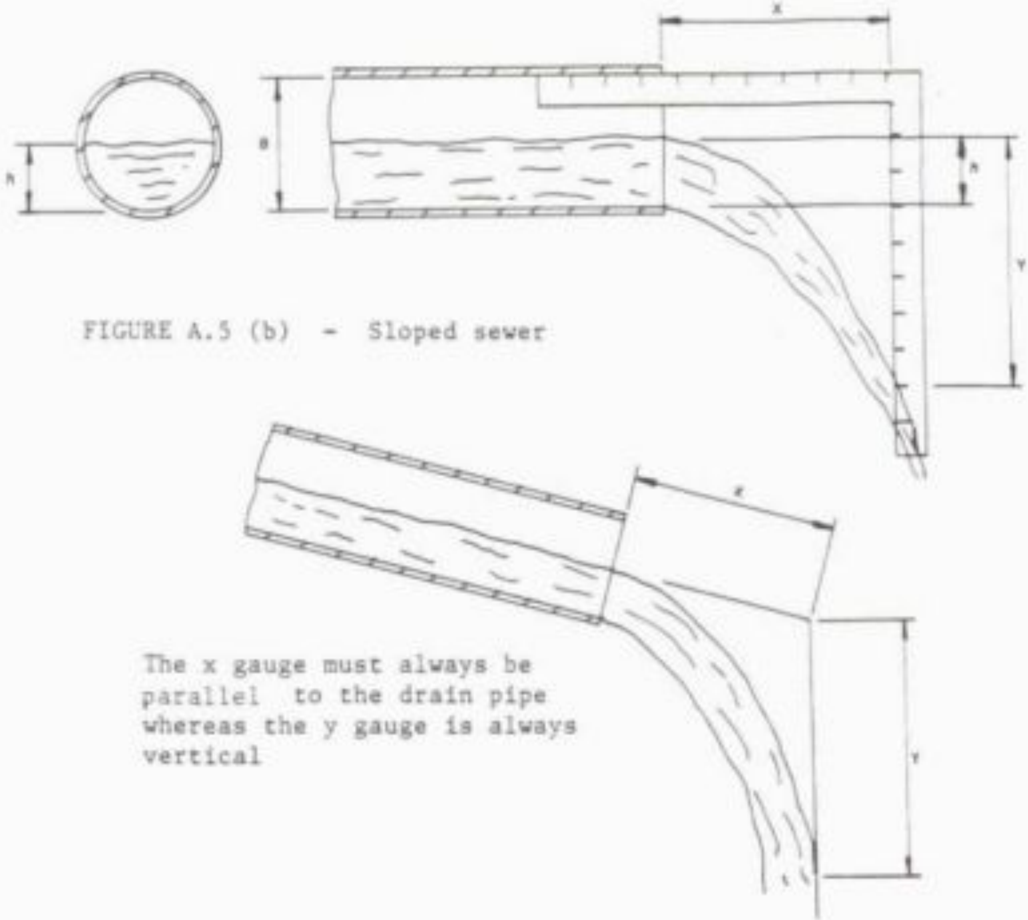
width $B \geqslant 3b$ (at least 90 cu): $\dfrac{B - b}{2} \geqslant 2$ h max

ratio $h/p \leqslant 0,50$

FIGURE A.5 Co-ordinate method for determining end-of-pipe flows

FIGURE A.5 (a) - Horizontal sewer

FIGURE A.5 (b) - Sloped sewer



The x gauge must always be parallel to the drain pipe whereas the y gauge is always vertical

The flow can be calculated with sufficient accuracy by $Q\ m^3/d = \frac{6{,}05.Ax}{y}$ where x and y is in mm.

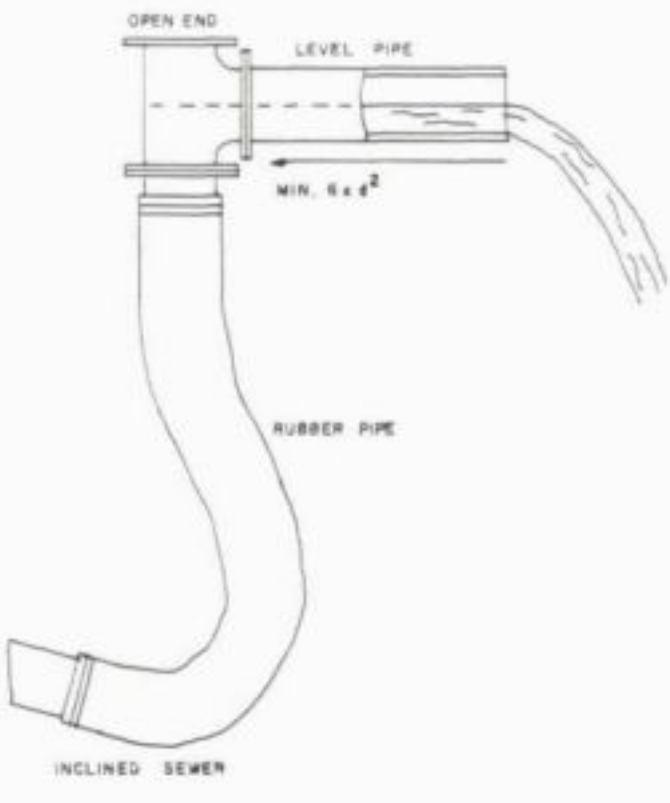
A in mm^2 from Table A.2

FIGURE A.6 California pipe method for determining end-of-pipe flows.

FIGURE A.6 (a) - Horizontal pipe

The flow is proportional to d, the pipe diameter and a, the distance of the water from the top of the pipe, all measured in mm.

FIGURE A.6 (b) - Vertical pipe



The flow = T x W m³/d

$$\text{where } T = 1{,}469 \left(1 - \frac{a}{d}\right)^{1{,}88}$$

$$\text{and } W = d^{2{,}48} \times 10^{-2}$$

T and W given in Tables A.3 (a) and (b)

TABLE A.2 FLOW FROM OPEN-ENDED PIPES

Cross section area of pipe filled with liquid

with A: cross sectional area ($mm^2 \times 10^{-3}$)
h: flow depth in mm
b: pipe diameter in mm

DEPTH OF FLOW (A) IN mm	AREA FILLED WITH LIQUID IN $mm^2 \times 10^{-3}$						
	DIAMETER OF PIPE (b) IN mm (INCHES)						
	150(6")	200(8")	250(10")	310(12")	380(15")	460(18")	610(24")
10	0,5	0,6	0,7	0,7	0,8	0,9	1,0
20	1,4	1,6	1,8	2,1	2,3	2,5	2,9
30	2,5	3,0	3,3	3,7	4,2	4,6	5,3
40	3,8	4,5	5,1	5,7	6,4	7,0	8,2
50	5,2	6,1	7,0	7,9	8,8	9,8	11,4
60	6,6	7,9	9,1	10,3	11,5	12,8	14,8
70	8,1	9,8	11,3	12,8	14,4	16,0	18,6
80	9,6	11,7	13,5	15,4	17,4	19,4	22,6
90	11,1	13,7	15,9	18,2	20,5	22,9	26,8
100	12,5	15,7	18,3	21,1	23,8	26,7	31,3
110	13,9	17,7	20,8	24,0	27,2	30,5	35,9
120	15,2	19,7	23,3	27,0	30,7	34,5	40,6
130	16,3	21,6	25,8	30,0	34,3	38,6	45,6
140	17,2	23,5	28,3	33,1	37,9	42,8	50,6
150	17,7	25,3	30,8	36,2	41,6	47,1	55,8
160	-	26,9	33,2	39,3	45,4	51,4	61,1
170	-	28,5	35,5	42,4	49,1	55,8	66,5
180	-	29,8	37,8	45,5	52,9	60,3	72,1
190	-	30,8	40,0	48,5	56,7	64,8	77,7
200	-	31,4	42,1	51,5	60,5	69,3	83,4
210	-	-	44,0	54,4	64,3	73,9	89,1
220	-	-	45,8	57,3	68,1	78,5	95,0
230	-	-	47,2	60,0	71,8	83,1	100,8
240	-	-	48,4	62,7	75,5	87,7	106,8
250	-	-	49,1	65,2	79,1	92,3	112,8
260	-	-	-	67,6	82,7	96,9	118,8
270	-	-	-	69,8	86,2	101,4	124,8
280	-	-	-	71,7	89,6	105,9	130,9
290	-	-	-	73,4	92,9	110,4	137,0
300	-	-	-	74,7	96,0	114,8	143,1
310	-	-	-	75,5	99,1	119,1	149,2
320	-	-	-	-	101,9	123,4	155,3
330	-	-	-	-	104,6	127,6	161,4
340	-	-	-	-	107,8	131,7	167,0
350	-	-	-	-	109,2	135,7	173,5
360	-	-	-	-	111,1	139,5	179,5
370	-	-	-	-	126,6	143,3	186,5
380	-	-	-	-	113,4	146,8	191,4
390	-	-	-	-	-	150,2	197,3
400	-	-	-	-	-	153,4	203,1
410	-	-	-	-	-	156,4	208,9
420	-	-	-	-	-	159,1	214,6
430	-	-	-	-	-	161,6	220,2
440	-	-	-	-	-	163,7	225,7
450	-	-	-	-	-	165,3	231,1
460	-	-	-	-	-	166,2	236,4
470	-	-	-	-	-	-	241,6
480	-	-	-	-	-	-	246,7
490	-	-	-	-	-	-	251,6
500	-	-	-	-	-	-	256,4
510	-	-	-	-	-	-	261,0
520	-	-	-	-	-	-	265,4
530	-	-	-	-	-	-	269,6
540	-	-	-	-	-	-	273,6
550	-	-	-	-	-	-	277,4
560	-	-	-	-	-	-	280,9
570	-	-	-	-	-	-	284,1
580	-	-	-	-	-	-	289,9
590	-	-	-	-	-	-	289,3
600	-	-	-	-	-		291,2
610	-	-	-	-	-		292,2

* [illegible] Technical Guide K49, 1979.

TABLE A.3 (a) Values of T for different ratios of $\frac{a}{d}$ for use in California pipe flow formula

$\frac{a}{d}$	0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09
0,0	1,47	1,44	1,41	1,39	1,36	1,33	1,31	1,28	1,26	1,23
0,1	1,21	1,18	1,16	1,13	1,11	1,08	1,06	1,03	1,01	0,99
0,2	0,97	0,94	0,92	0,90	0,88	0,86	0,83	0,81	0,79	0,77
0,3	0,75	0,73	0,71	0,69	0,67	0,65	0,63	0,62	0,60	0,58
0,4	0,56	0,54	0,53	0,51	0,49	0,48	0,46	0,45	0,43	0,41
0,5	0,40	0,38	0,37	0,36	0,34	0,33	0,31	0,30	0,29	0,27
0,6	0,26	0,25	0,24	0,23	0,22	0,20	0,19	0,18	0,17	0,16
0,7	0,15	0,14	0,13	0,13	0,12	0,11	0,10	0,09	0,09	0,08
0,8	0,07	0,06	0,06	0,05	0,05	0,04	0,04	0,03	0,03	0,02
0,9	0,02	0,02	0,01	0,01	0,01	0,01	0,00	0,00	0,00	0,00

TABLE A.3(b) Values of W for California pipe flow formula

d	W	d	W	d	W	d	W	d	W
25	29	225	6 814	425	32 992	625	85 858	825	170 925
50	163	250	8 849	450	38 016	650	94 629	850	184 060
75	447	275	11 208	475	43 471	675	103 914	875	197 779
100	912	300	13 908	500	49 368	700	113 722	900	212 091
125	1 586	325	16 962	525	55 718	725	124 062	925	227 003
150	2 493	350	20 384	550	62 532	750	134 943	950	242 524
175	3 654	375	24 188	575	69 819	775	146 375	975	258 661
200	5 088	400	28 386	600	77 592	800	158 366	1 000	275 423

taken from: CSIR Technical Guide K49, 1979

Electronic meters

If no space is available for a flume, or a weir, then consideration may be given to the use of electromagnetic or ultrasonic meters.

Average flow in any conduit is equal to the cross-sectional area of the flow multiplied by its average velocity. Two measurements are needed· the liquid depth (width known by channel geometry) and the velocity.

Electromagnetic meters

A typical unit consists of an electromagnetic sensor head clipped to a pipe ring for insertion into the open end of a pipe, or to the base of a channel. This sensor head measures the velocity and is also equipped with a pipe conveying air to the sensor.

The air is allowed to bubble out at about 2 bubbles per second; the back pressure measured on a suitable gauge provides the depth data for the calculation. Portable units can be mounted in any desirable location within a factory or in the final effluent pipe or channel.

Ultrasonic meters

This type of meter is attached to two sensors mounted opposite each other on the outside of a pipe.

The meter measures the instantaneous linear flow velocity. The internal cross-sectional area of the pipe must be measured or estimated. The volumetric flow can then be calculated.

Ultrasonic meters are simple to use but are expensive and are restricted to certain pipe materials and pipes in full flow.

APPENDIX B

GUIDELINES FOR THE DISPOSAL OF EFFLUENT ON LAND IN SOUTH AFRICA

By J.G. Thompson

Reprinted from Information Bulletin No. B1/1 (February 1985) of the Soil and Irrigation Research Institute, Private Bag X79, Pretoria 0001, South Africa

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GUIDELINES FOR THE DISPOSAL OF EFFLUENT ON LAND
IN SOUTH AFRICA

ERRATA

Page 62, Column 1, Line 1: "ration" should be "ratio"

Page 62, Column 1: definition of sodium adsorption ratio "absorption" should be "adsorption" and "(Ca Mg)" should be "(Ca+Mg)"

NB Page 66, Column 1, Line 8: "In fact, the soils listed below in" should be "In fact, the soils listed below (e) in"

SUMMARY

The purpose of this publication is to offer guidelines for the disposal of effluents on land. Although there is a great diversity of effluents, more than 95% of them can be accommodated within four main categories in so far as their effects on soil are concerned. These are sewage effluent, ammonium rich effluents, high organic matter, low sodium adsorption ratio (SAR) effluents and alkaline high SAR effluents. The most common sources of these effluents are listed. It is further indicated that certain kinds of soils are more suitable than others for the disposal of specific types of effluent and, thus, that there are definite desired soil/effluent combinations. Recommendations for the disposal of the various effluents on land are given. Sewage effluent is virtually harmless and can be disposed of on almost all soils without having to apply soil amendments. At the other end of the scale are the alkaline high SAR ones in which the use of soil amendments such as gypsum is essential, and few soils, mainly red clays, are suitable for this purpose. Finally, it is stated that availability of suitable effluent disposal sites be taken into account when choosing a location for an industry that produces effluent requiring disposal on land.

SAMEVATTING

Die doel van hierdie publikasie is om riglyne daar te stel vir die wegdoening van afvalwater op grond. Hoewel daar 'n groot verskeidenheid van afvalwater is, kan meer as 95% daarvan in vier kategorieë gegroepeer word volgens hul effek op grond. Hierdie kategorieë is riool-afvalwater, ammoniumryke afvalwater, afvalwater met 'n hoë organiesestof, maar lae natrium-adsorpsie-verhouding (NAV) en afvalwater met 'n alkaliese, hoë NAV. Die hoof bronne van hierdie afvalwater word aangedui. Sekere gronde is meer geskik as ander vir die wegdoening van spesifieke kategorieë afvalwater en hierdie wenslike grond-/afvalwaterkombinasies word aangedui. Rioolwater is meestal onskadelik en kan op enige grond weggedoen word sonder om aanpassings te maak. Afvalwater met 'n hoë NAV daarenteen, kan slegs op sekere gronde, hoofsaaklik rooi kleigronde, suksesvol weggedoen word. Dit is verder noodsaaklik om gips toe te dien op gronde alvorens hoë NAV afvalwater daarop weggedoen word. Die beskikbaarheid van geskikte wegdoeningspersele is dus 'n belangrike faktor in die beplanning van industrieë waar voorsiening gemaak moet word vir die wegdoening van afvalwater op grond.

INTRODUCTION

The principle of riparianism, whereby a riparian landowner is entitled to a share of the normal flow of a river, is woven into the Water Act (No. 54 of 1956). This act thus ideally requires that waste or surplus unconsumed water be returned to the streams from which they were originally abstracted without causing any material deterioration in water quality downstream. Waste waters and effluents must therefore comply with certain quality standards before they can be discharged to streams. Frequently these quality constraints cannot, for various practical reasons, be met, in which case there are generally only two alternatives. Either a temporary exemption can be granted, which means an inevitable lowering of stream water quality, or disposal on land with whatever other disadvantages this may entail, becomes the unavoidable second choice.

At the outset it must be stated that rarely can pollution be eliminated entirely. Most mineral dissolved salts not taken up by plants and later removed from the land, will merely be transferred to soil or drainage water. The aim of effluent disposal on land is therefore to minimise the effects of pollution usually by retaining, at least in the short term, the undesirable salts in the soil in a way that they eventually reach ground water and/or streams at a reduced rate, thereby minimising their influence on water quality. At the same time every effort should be made to prevent serious soil damage not only to enable the disposal of effluent on land to be on as sustained a basis as possible, but also, in the event of disposal being terminated, to enable the land to be re-used for other purposes including agriculture.

The purpose of this publication is to offer guidelines in regard to which soils are best suited, on a sustained basis, to the disposal of specific kinds of effluent when disposal on land has to be implemented. Since pollution from industrial effluents in some form can never be entirely eliminated, means of minimising their effects are also suggested in some instances. The information presented is based on accepted soil science/water chemistry principles and, to an appreciable extent, on observations and analytical investigations made over a number of years on sites where land disposal of various effluents on one or more soil types has been practised for varying periods of time. Since it is not possible in a project of this nature to cover all aspects for every soil/effluent combination forthwith or within a reasonably short time span, this publication must be regarded as an interim or provisional one that will probably require modification or updating from time to time.

RANGE OF WASTE WATERS AND INDUSTRIAL EFFLUENTS

In terms of volume the two most important effluents in South Africa are sewage effluents (Fuls and du Plessis, 1977[1]) and acid sulphate waters from the mining industry. Until neutralised, the latter are toxic to almost all plants. The most effective treatment for minimising the adverse effects of acid mine waters is removal of the water from the underground, sulphidic, acid-generating zones as early as possible followed by neutralisation with calcium hydroxide, an industrial by-product. This can often achieve a large reduction in total dissolved salt content (Thompson, 1980). On account of the generally large flows involved, most treated acid mine waters have to be discharged to perennial streams in which the quality of water is affected to varying degrees, depending on the relative flows and salinities of the original stream water and the added mine water. The water quality in streams thereafter can then be evaluated for the various purposes on the same basis as any other river water and for this reason acid mine waters are not considered in any further detail in this publication. Sewage effluents, on the other hand, are in the main, relatively innocuous, and appropriately treated, must be regarded as being more of an asset than a liability in a water-short country such as South Africa.

A further large contribution to the salinisation of rivers is return flow of irrigation drainage water from the major irrigation schemes. Since this is the subject of a great deal of current research on its own, it is also not discussed in this publication.

Although produced individually in relatively much smaller quantities, the wide diversity and number of other industrial effluents collectively, and often individually, pose serious problems with respect to pollution control and stream salinisation. Most of them have a much higher total dissolved salt content (TDS) than sewage effluents and their compositions vary very widely. There are varying kinds and degrees of difficulties involved in the effective disposal of effluents on land. Some have a marked tendency to render the soils impermeable or otherwise damage them, while others penetrate the soils with relative ease but still give rise to pollution, mainly of underground water. Upwards of 95%, in fact probably more than 97% of them in terms of volume, can be accommodated within four broad categories. There is inevitably some overlapping i.e. similar effluents may belong either to one category or to another depending on the concentration of a particular constituent, e.g. sodium, that may markedly influence the behaviour of the effluent when applied to land. These categories are:

1. Sewage effluents, processed and upgraded to different levels, usually little contaminated with toxic industrial wastes.

2. Ammoniacal and ammonium salt rich effluents with or without appreciable amounts of other salts and/or organic matter.

3. Effluents with high organic matter content but

[1]FULS, P.F. & DU PLESSIS, H.M., 1977. Effluent disposal in South Africa by means of irrigation. Group discussion on water re-use. Teheran. Nov. 1977.

relatively low sodium adsorption ratio (SAR)*. Total dissovled salts (TDS) due to the presence of mineral salts are not usually very high but salinity due to soluble organic compounds may be.

4. Alkaline effluents with a high SAR, often with large amounts of dissolved organic matter and/or high TDS due to mineral salts.

SOURCES OF EFFLUENTS

The very diverse nature of effluents produced by industry makes a fuller separation other than into four broad categories impractical at present.

Similarly in a publication of this nature, it is not possible at this stage and indeed not essential to indicate all of the industries that produce a particular effluent that does fall within any one of the categories described. However, in Table I most of the more common sources of the four categories of effluent are given.

SOIL AND LAND FACTORS

Apart from depth, soils vary widely in their permeability, aeration and water retaining properties. This is due not only to their texture, i.e. relative proportions of sand, silt and clay, but also to their clay mineralogy and the composition of the bases or cations on the exchange complex. In general, soils of low rainfall regions have a high base saturation and active, often expansive silicate clay fractions whereas soils in the high rainfall areas are leached (low base saturation) and have relatively inert clay fractions rich in sesquioxides of iron or aluminium. Thus, for a given clay content, the former have a greater adsorptive capacity (and hence greater susceptibility to be affected) than the latter and they are also less permeable and generally less well aerated when moist than the latter.

The nature of the cations on the exchange complex also has a profound influence on the soils. A relatively small proportion of sodium relative to calcium and magnesium causes dispersion or deflocculation and hence mobilisation of the clay fraction which in turn leads to a breakdown of soil structure, and the soil becomes impermeable. The actual proportions of sodium required to produce soil deterioration vary from soil to soil but the sesquioxic soils (iron, aluminium and manganese rich) of the high rainfall areas are the most resistant to the dispersive effects of sodium on the exchange complex. Many of these highly weathered soils are also able to adsorb anions, such as chlorides and sulphates, to some extent.

Land factors and site conditions are also important for the disposal of effluent on land. From a stream pollution point of view the site selected should not be low-lying or too close to watercourses and in fact should be as far away as practically possible. Except in the most extreme cases, any disposal of effluent on land must involve plant cover both to maximise water consumption (and thus increase the rate at which effluent can be applied) and to protect the soil from run-off and erosion. Grass pasture is generally the most effective, particularly in preventing erosion. High-lying land with some slope has many advantages such as reducing the risk of localised ponding of effluent and thus undue percolation to ground water, and allowing cold air drainage to take place in winter thereby prolonging the growing period of frost-susceptible pastures. On the other hand, the steeper the slope, the greater the risk of direct pollution of streams from run-off.

*Sodium absorption ratio $= \dfrac{Na}{\sqrt{\frac{1}{2}(Ca + Mg)}}$

when Na, Ca and Mg are expressed as milligram equivalents per litre.

TABLE 1 - Most common sources of the four main effluents

1. Sewage effluents	2. Ammonium effluents	3. High organic matter, low SAR effluents	4. Alkaline, high SAR effluents
Practically all municipalities, town management boards, etc.	Explosives and blasting supply industries.	Cattle feedlots and piggeries.	Paper pulp mills and paper processors.
Most large industrial organisations, mines etc, outside municipal boundaries	Industries involving coke ovens e.g. steel etc.	Cattle abattoirs (hide treatment excluded).	Textile factories.
	Certain chemical industries e.g. vanadium recovery.	Chicken batteries and abattoirs.	Tanneries and hide processors.
	Nitrogen fertiliser plants.	Meat processing factories.	Most chip-board and related wood processing factories.
		Most dairies and cheese factories.	Wool washeries and processors.
		Breweries and yeast industries.	Most canned fruit, canned meat and fish producers.
		Sugar industry effluents.	Some distilleries and breweries.
		Most wineries and distilleries.	Some starch and glucose factories.
		Most canned vegetable factories.	
		Dyers and some textile industries.	
		Some starch-producing factories	

DESIRED SOIL PROPERTIES FOR THE FOUR CATEGORIES OF EFFLUENT

Although most soils can to some extent be used to ameliorate effluent disposal problems, it is clearly evident from the foregoing that certain soils are more suitable than others for the disposal of specific categories of effluent. In other words, there are certain definite desired soil/effluent combinations when effluents have to be disposed of on land. The desirable soil properties for each of the four categories of effluent are as follows:

Sewage effluent

When it is necessary to dispose of sewage effluent on land, the primary purpose will be to minimise eutrophication of streams and dams. Since disposal on land cannot remove all plant nutrients completely, the aim should be to make at least one of them limiting to plant growth, and under Southern African conditions the emphasis to date has been on as complete removal of phosphorus as possible. The disposal area selected should be considered with this objective in mind and, obviously, soils that have a high phosphate-fixing capacity, such as many red soils, would be an additional advantage if they occur within a reasonable distance of the purification works.

The ammonium effluents

When disposed of on land in the normal way, the nitrogen in these effluents can only be removed from the soil by plants, mainly after nitrification to nitrates has been effected by aerobic soil bacteria. The soils should therefore be reasonably well aerated. There is, however, a further difficulty with these effluents. Most of them infiltrate the soils readily but in their passage through the soil, they remove the exchangeable bases, calcium, magnesium, potassium etc. This in conjunction with rainfall, leads to strong, rapid acidification of the soil, even although the effluent itself may often be moderately alkaline. Thus, unleached soils that have an initial high base status, especially calcareous soils, are more suitable than leached, highly weathered soils.

The organic matter rich, low SAR effluents

One of the main soil requirements for the disposal of these effluents is good aeration which in turn implies good permeability. Highly weathered soils with their crumbly surface and very porous subsoil micro-structure are well aerated. Soils that are predominantly sandy and also well aerated, are thus also suitable for the disposal of these effluents provided that they have sufficient clay (i.e. sandy loams to sandy clay loams), to retain temporarily some of the plant nutrients released as a result of the oxidation of organic matter. Sloping land has an advantage in that it is easier to prevent or rectify any localised ponding since this will always adversely affect the soils.

The alkaline high SAR effluents

This group of effluents is the one most likely to damage the soil seriously or even irrecoverably unless appropriate ameliorants and good management practices are carefully followed. The high SAR of these effluents lead to dispersion of the clay fraction and this renders the soil impermeable, as mentioned earlier, and the red highly weathered sesquioxic soils are thus the most suitable for the disposal of these effluents because of their resistance to the adverse effects of adsorbed sodium. Very sandy soils are also not easily rendered impermeable by these effluents on account of their low clay content and they are in some instances used for the disposal of such effluents. However, in such cases, the character of the effluent after passing through the soil may often not be much changed or improved. Mainly on account of reduced volume compared with that of the effluent applied, the salinity of all drainage waters is appreciably increased.

RECOMMENDATIONS FOR THE DISPOSAL OF THE VARIOUS EFFLUENTS ON LAND

The first three categories of effluent have one major facet in common, namely their nitrogen content either in plant available form, or potentially so, that can readily lead to stream eutrofication. Therefore, before considering individually their disposal on land by normal means and their respective desired soil/land conditions, mention must be made here of denitrification. The disposal on land of all three of these effluent groups can, under certain circumstances, be specifically designed for nitrogen removal in gaseous form in this process.

The requirements for this process include:

(a) a carefully controlled water table and a controlled feed rate,

(b) most of the nitrogen having been previously converted to the nitrate form, and

(c) an adequate supply of readily oxidisable organic matter.

In South Africa it is only in sewage disposal works and possibly other rare instances that removal of nitrogen by denitrification has been found to be practical. Some loss of nitrogen by this means undoubtedly occurs from land that has unintentionally been waterlogged by such effluents but any advantage is usually far outweighed by all the disadvantages associated with waterlogged land.

The soils that are involved in normal or straightforward disposal of effluents on land can be rated according to their suitability for a particular kind of effluent. In Table 2-5 lists of soil/land conditions arranged more or less in descending order of suitability is given for each of the four categories of effluent. It is not practical or possible to list all soils in Tables of this nature but it is hoped that a sufficient variety has been included to provide an indication of the main properties that make soils either more suitable or less suitable for a particular category of effluents.

Disposal of sewage effluents

On account of its innocuous nature, treated sewage effluent can be applied to almost any soil without causing any serious damage to the soil itself. However, the extent to which phosphorus is removed from the effluent, will depend mainly on soil and site conditions. Removal of nitrogen, on the other hand, is almost entirely dependent on plant growth, i.e. the more vigorous the pasture, the better the removal of nitrogen. Initially, pasture growth may not be vigorous due to an imbalance of too much nitrogen relative to phosphorus, but since nitrogen, in contrast to phosphorus, is not taken up by the soil the imbalance is rectified usually within 1-2 years. After a number of years the main result is a very great enrichment of the soil with phosphorus (Thompson, 1968). Because not all of the nitrogen is taken up, there is an inevitable increase in the nitrate content in the groundwater. The pastures grown must, of course, be harvested, preferably by mowing and complete removal from the land. A second, less efficient alternative is to have them grazed by cattle as intensively as practically possible.

Many municipal sewage effluents contain small but varying amounts of toxic metal cations. However, these are unlikely to be absorbed by plants and hence into the food-chain unless the soil becomes acid. The pH of the soils of disposal areas should therefore be monitored and if necessary lime applied to maintain pH (1:2,5 water suspension) above 6,0 and preferably above 6,5.

In general, sewage effluents are harmless and virtually all soils can safely be irrigated with them, as mentioned earlier. However, from the point of view of minimising eutrophication of streams and groundwaters, site and soil conditions become important considerations. Possibly one of the most favourable of these that is frequently available, are shallow soils that are underlain by relatively impermeable rock formations on relatively steep slopes. A good pasture grass cover (Kikuyu in warm areas or summer; Rye grass in cold areas or winter) retards surface run-off, promotes infiltration and prevents erosion while the underlying impermeable strata in conjunction with the slope of the land leads to lateral seepage through the soil towards the lower end of the disposal area and a minimum of pollution of underground water. A system of interceptor ditches and a catchment dam at a convenient low point will enable this irrigation drainage water which, with correct management, should contain only minimal amounts of phosphates and a much reduced nitrogen content, to be led away towards watercourses. In the event of over-irrigation during rainy periods and the occurrence of some direct run-off of effluent into the dam, at least some of the collected water can be recirculated to the upper end of the disposal area.

As shown in Table 2, the suitability of soils for disposal of sewage effluent can be arranged in descending order of merit based mainly on their capacity for removing phosphate. On this basis the next most suitable land/soil units include the red, high clay content soils, the highly weathered sesquioxide-rich ones being the best of these, while at the bottom of the list are soils with a naturally high water table which in any event most commonly occur in low-lying positions, usually near watercourses.

TABLE 2 - Descending order of suitability of land/soils for disposal of sewage effluent

(a)	Moderately shallow soils other than sands underlain by relatively impermeable rock on relatively steep slopes only if drains and catchment dam at lower end.
(b)	Moderately deep to deep, red, highly weathered soils on gentle to moderate slopes.
(c)	Reddish brown medium-textured soils not highly weathered and leached, deeper than 50 cm, on gentle to moderate slopes.
(d)	Brown, grey and dark grey medium-textured soils, deeper than 50 cm, on gentle to moderate slopes.
(e)	Calcareous soils, deeper than 50 cm, that are moderately permeable, on gentle to moderate slopes.
(f)	Dark grey to black clays (vertisols or black cotton soils), deeper than 50 cm, on gentle to moderate slopes.
(g)	Sands and loamy sands, deeper than 50 cm, on gentle to moderate slopes.
(h)	Soil with impermeable, alkaline sodic horizons commencing between 20 cm and 50 cm on gentle to moderate slopes.
(i)	Soils with a naturally-occurring water table at depths less than 1 m.

Note

1. Moderately shallow to moderately deep denotes *effective depth* between about 40 and 80 cm while moderately deep to deep means soils with effective depth greater than about 80 cm.
2. Gentle to moderate slopes denotes slopes up to about 4%, and relatively steep slopes from about 4% up to about 8%.

Disposal of ammonium-rich effluents

In order to achieve reasonably effective removal of nitrogen from these effluents by plants, it is necessary that vigorous vegetative growth be promoted. This requires, *inter alia*, that the soil has a balanced supply of plant nutrients which, in turn, means that other plant nutrients, particularly phosphorus and in most instances potassium, will almost certainly need to be applied fairly regularly. Kikuyu and rye grass pastures are more suitable than fruit-bearing (in the botanical sense) and tuber producing crops such as wheat, potatoes etc., which not only have a higher phosphorus and potassium requirement but, through continued application of nitrogen, ripening and proper maturing of these crops are also adversely affected. As in the case of disposal of sewage effluents, the grass needs to be removed either mechanically or by intensive cattle grazing, not only to take off the plant nutrients, but also to assist in maintaining vigorous growth.

Although grass pastures are the most effective in removing nitrogen from effluents there are limitations in the amount of nitrogen that can be taken up by the pastures. Consequently, there are limits to the concentration of nitrogen that can be tolerated in ammoniacal effluents if removal of N is to be reasonably efficient. These limits will depend on the desirable maximum irrigation intensity in a given climatic region on the basis of minimising deep percolation to ground water. For instance, in a region where, say, the maximum desirable rate is 1 000 mm/ann and it is assumed that the maximum amount of nitrogen that can be taken up by the pasture is, say, 700 kg N/ha/ann, then the concentration of N in the effluent should not be more than 70 mg/*l*. Efficient disposal of effluent with higher concentrations would then in theory involve measures such as dilution by one means or another with fresh water together with a commensurately enlarged disposal area, but this would largely defeat the objective of conserving and protecting water resources.

The application of ammoniacal and ammonium rich effluents in conjunction with rainfall, leads, as already indicated, to rapid acidification of the soil to the extent that frequent liming of the soil is usually required. It is for this reason that in Table 3 calcareous soils that are reasonably permeable, are rated at the top for this type of effluent. In addition some of the nitrogen will be lost by volatilisation. These are followed by the shallow soils underlain by impermeable rock strata on relatively steep slopes as described in the section on the disposal of sewage effluents. Again, low-lying soils with a naturally occurring high water table are considered to be among the least suitable soils.

TABLE 3 - Descending order of suitability of land/soils for disposal of ammonium-rich effluents

(a)	Calcareous soils deeper than 50 cm that are moderately permeable, on gentle to moderate slopes.
(b)	Moderately shallow soils other than sands underlain by relatively impermeable rock on relatively steep slopes only if drains and catchment dam at lower end.
(c)	Dark grey to black clays (vertisols or black cotton soils), deeper than 50 cm, on gentle to moderate slopes.
(d)	Brown, grey and dark grey medium-textured soils, deeper than 50 cm, on gentle to moderate slopes.
(e)	Reddish brown medium textured soils not highly weathered and leached, deeper than 50 cm, on gentle to moderate slopes.
(f)	Soils with impermeable, alkaline sodic horizons commencing between 20 cm and 50 cm on gentle to moderate slopes.
(g)	Moderately deep to deep, red, highly weathered soils on gentle to moderate slopes.
(h)	Sands and loamy sands, deeper than 50 cm, on gentle to moderate slopes.
(i)	Soils with a naturally-occurring water table at depths less than 1 m.

Disposal of high organic matter, low SAR effluents

It is the readily oxidisable organic matter content rather than the total organic matter content that most often limits the rate at which these effluents can successfully be disposed of on land. Soils that are naturally well aerated, are desirable for the disposal of these effluents. It is also desirable that they are moderately base saturated and have an appreciable clay content, i.e. soils that are fairly well buffered, since the break-down products of the organic constituents, particularly nitrogen in the ammonium form, tend to acidify the soils as indicated earlier. This will tend to occur at high organic loadings. If at any stage the organic loading becomes too great, anaerobic soil conditions develop, usually accompanied by death of the vegetation cover, the most suitable cover generally being grass pastures. Waterlogging, by reducing aeration, promotes anaerobic decomposition. Therefore in preparing land for effluent disposal, localised hollow pockets where effluent can collect, stagnate and bring about anaerobic conditions, should be eliminated as far as possible.

Anaerobic decomposition of organic matter, with its attendant noxious smells accelerates acidification of the soils. Should such conditions and death of plants occur, the damage to the soil is almost always relatively easy to rectify. It is usually sufficient to allow the soil to dry out, plough or scarify to promote aeration and apply lime to neutralise any acidity that may have developed. It is for this latter reason that calcareous soils and other soils that are not leached (i.e. have moderately high base saturations) are high up on the list in Table 4 of land/soils suitable for the disposal of this group of effluents.

TABLE 4 - Descending order of suitability of land/soils for disposal of high organic matter, low SAR effluents

(a)	Moderately shallow soils other than sands underlain by relatively impermeable rock on relatively steep slopes only if drains and catchment dam at lower end.
(b)	Reddish brown medium textured soils not highly weathered and leached, deeper than 50 cm, on gentle to moderate slopes.
(c)	Calcareous soils deeper than 50 cm that are moderately permeable, on gentle to moderate slopes.
(d)	Moderately deep to deep, red, highly weathered soils, on gentle to moderate slopes.
(e)	Brown, grey and dark grey medium-textured soils, deeper than 50 cm, on gentle to moderate slopes.
(f)	Sands and loamy sands, deeper than 50 cm, on gentle to moderate slopes.
(g)	Dark grey to black clays (vertisols or black cotton soils), deeper than 50 cm, on gentle to moderate slopes.
(h)	Soils with impermeable, alkaline sodic horizons commencing between 20 cm and 50 cm, on gentle to moderate slopes.
(i)	Soils with a naturally occurring water table at depths of less than 1 m.

Disposal of alkaline high SAR effluents

These are the most problematic of the four effluent categories, mainly on account of the serious soil deterioration that can, and often does, result when they are disposed of on land. They have a high sodium content relative to other cations and in addition often have a high chemical oxygen demand as a result of dissolved and sometimes suspended organic compounds. Unlike all of the other groups of effluents discussed so far, it is essential in most cases that with these effluents ameliorants such as gypsum be incorporated into either the soil or the effluent from the very beginning. There are, moreover, much wider differences in the degree of suitability of soils for the disposal of the alkaline high SAR effluents than is the case with the effluents hitherto discussed. In fact, the soils listed below in Table 5, are all basically unsuited to the disposal of such effluents and should only be used when there is no other alternative and then only subject to rigorous ameliorative and management practices.

The disposal of these effluents on land leads to a proportion of the sodium in the effluent being adsorbed by the clay fraction of the soil, usually to the extent that in time the exchangeable sodium percentage of the soil equals or even exceeds the SAR of the effluent. This, as stated earlier, tends to deflocculate the clay fraction and this, in most cases, reduces permeability drastically. However, a high concentration of dissolved salts (TDS), especially strong electrolytes such as chlorides and sulphates, have the reverse effect, i.e. they tend to maintain a reasonable degree of soil permeability in spite of the elevated exchangeable sodium percentage (ESP)*. It is therefore highly desirable that at all times there is a surplus of gypsum in or on the surface soils, not only to reduce adsorption of sodium by the soil, but also to maintain an appreciable concentration of electrolyte in the soil solution during rainy periods when leaching could lead to a marked reduction in electrolyte concentration and consequent lowering of soil permeability and infiltration.

TABLE 5 - Descending order of suitability of land/soils for disposal of alkaline high SAR effluents

(a)	Moderately deep to deep, red highly weathered soils on gentle to moderate slopes.
(b)	Reddish brown medium-textured soils not highly weathered and leached, deeper than 50 cm, on gentle to moderate slopes.
(c)	Calcareous soils, deeper than 50 cm that are moderately permeable, on gentle to moderate slopes.
(d)	Moderately shallow soils, other than sands, underlain by relatively impermeable rock on relatively steep slopes only if drains and catchment dam at lower end.
(e)	Sands and loamy sands, deeper than 50 cm, on gentle to moderate slopes.
(f)	Brown, grey and dark grey medium-textured soils, deeper than 50 cm, on gentle to moderate slopes.
(g)	Dark grey to black clays (vertisols or black cotton soils), deeper than 50 cm, on gentle to moderate slopes.
(h)	Soils with impermeable, alkaline sodic horizons between 20 cm and 50 cm on gentle to moderate slopes.
(i)	Soils with a naturally-occurring water table at depths less than 1 m.

It has been shown (Thompson, 1983) that ammonium salts applied either in the effluent or to the soil, exert an appreciably greater effect than expected in reducing adsorption of sodium by soils. This effect was noted on a wide range of soils with very different fundamental properties such as clay mineralogy, pH and base saturation. This has important implications in regard to the disposal of these difficult effluents. If ammonium salts are applied as an additional ameliorant together with gypsum, it should aid considerably in disposing of the alkaline high SAR effluents, especially on soils that are not really suitable for such effluents. Since ammonium sulphate is the most acidifying of the commonly used nitrogen fertilisers, it is frequently, though not invariably, the most suitable.

The continued application of sodium-rich effluent together with ameliorants such as gypsum and ammonium salts leads to leaching and depletion of other soil bases, notably magnesium and potassium, unless of course these happen also to be present in the effluent applied. If not, it will be necessary to apply them from time to time, the magnesium being most conveniently applied as dolomitic lime once or twice a year depending on soil type and rate of effluent application. A further macro plant nutrient that likewise may need to be supplemented occasionally, is phosphorus.

It is commonly accepted that ESP values greater than the 10 - 15% range, usually result in a drastic reduction of soil permeability especially when soil TDS contents are low. This holds true for almost all of the soils listed in Table 5, many of the red clay soils, especially the highly weathered ones being exceptions. It is thus general practice to recommend that the SAR of the effluent in effect be maintained below 10 by adding gypsum either to the effluent or to the soil. In the case of certain of the red highly weathered rich in sesquioxides of iron and aluminium, it has been established beyond doubt (Thompson, unpublished data) that the soil remains permeable with ESP values approaching 40 when the conductivity (a measure of TDS) of the saturation extract is reasonably high (greater than about 300 millisiemens/metre). These high ESP values have, however, only been measured in deep subsoils below 1 - 2 metres and, *inter alia*, clearly indicate that sodium not adsorbed by the soil will tend to accumulate in the ground water. Since di-valent cations such as calcium, and to a lesser extent magnesium, are preferentially adsorbed by the soil, the SAR of the saturation extracts of the soil increases progressively with depth. Thus, even in the case of the red highly weathered clays, it is sound policy to try to maintain the effective SAR of the effluent, as described above, below 10.

CLIMATIC FACTORS

In order to minimise the rate at which dissolved salts in any effluent will percolate towards the groundwater, the total amount of effluent applied per annum should be considered in relation to the annual rainfall an annual evapotranspiration data for the region in which the disposal area is situated. Obviously, broad information of this nature can only provide a rough basis from which to obtain an approximate estimate of the minimum size of the disposal area required for a given flow of effluent,

$$\text{*Exchangeable sodium percentage} = \frac{\text{Exch. sodium}}{\text{Cation exchange capacity}} \times 100$$

when exchangeable sodium and cation exchange capacity are expressed as milligram equivalents per 100 g assuming that other factors such as the quality of the effluent itself are not more limiting, such as organic loading in the case of some of the high organic matter, low SAR effluents.

The seasonal pattern of rainfall, i.e. whether summer or winter is also an important consideration. This has probably a greater implication for the high organic matter group of effluents than for the other groups since wet conditions imposed in conjunction with low temperatures in winter can seriously retard the rate at which organic matter can be decomposed aerobically.

In general the more arid and warmer the climate, the less likelihood of problems arising in the disposal of the first three groups of effluents, often to the extent that relatively poor soil/land sites can successfully be used. However, in the case of the alkaline, high SAR effluents the aridity of the climate itself precludes the formation of the red sesquoioxic soils and in these regions the most suitable soils will be either calcareous or sandy soils depending on depth and site conditions. In such regions it is usually more difficult to maintain a good vegetation cover on account of the increased tendency for salts to accumulate in the soil. Consequently, the rate at which salts will migrate towards streams and any underground water table, will be retarded accordingly.

CONCLUSION

Although the desirable soil/land conditions for the disposal of particular types of effluent have been described together with specific recommendations in regard to disposal, it is recognised that at established industrial undertakings, the choice, in practical terms, of disposal sites is more often than not, limited. In these cases the best of the available land/soil sites has then to be chosen. It should be borne in mind that if only poor land/soil sites are available for effluent disposal, lighter applications of effluent over a larger area may often be necessary together with high levels of management and/or ameliorative treatment.

In view of our deteriorating water quality in South Africa, it is important that in future one of the determining factors to be included in the selection of an area for an industry that produces effluent necessitating land disposal, should be the availability of a reasonably good effluent disposal site.

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APPENDIX C

FACTORY DRAINAGE GUIDELINES

General

These notes are intended as a general guide and reminder of factors to be considered. They do not constitute a comprehensive specification, nor do they necessarily cover all types of factory or process.

The assistance of Langeberg Co-op (Ltd) who provided information on their in-house drain construction specifications, is acknowledged.

Planning

During the construction stage of a factory it costs very little extra to design and install correct drainage systems. Alterations to drainage systems in an operating and complete factory are difficult and expensive, not only in terms of the actual costs of the modifications but also because of the resultant disruption of production.

Makers' drawings of equipment often label various outlets 'to drain', and do not differentiate between strong, weak, continuous or occasional flows. Factory effluent management requirements are also often poorly defined at the factory design stage. If incomplete data of this nature is given to an architect, structural engineer or contractor who has insufficient expertise in effluent treatment, a common drainage system is likely to result with all discharges being mixed and interconnected without the necessary facilities to monitor, control and treat the various streams.

Segregation of effluent flows

One of the fundamental requirements in factory drain design is to segregate effluent streams rationally, for example separating weak and strong streams and streams containing different types of pollutants.

Domestic sewage, for example from toilets and ablution facilities, must be kept completely separate from industrial effluents, otherwise treatment of the latter can be made very difficult or impossible.

Complete segregation of storm water from industrial and domestic sewers is also essential. Storm-water discharge into industrial drains is unacceptable, as is any industrial discharge into a storm-water drain.

Major problems can arise with poorly designed storm-water drainage of open areas, for example where vehicles or containers drip pollutants onto a paved surface and where these accumulated pollutants are then washed into the storm-water drain either by rain, or deliberately by means of a hose.

It may prove necessary to combine the segregated streams (other than storm-water) before they leave the site, for example to provide a single connection to a municipal sewer. Such a combining point should however be located downstream of facilities enabling the individual streams to first be monitored, controlled and treated separately.

It is much cheaper and easier to combine streams which may have been unnecessarily segregated, than to separate streams which should not have been combined.

Balancing

Storage or balancing facilities can be very useful in a drainage system, as they smooth out the strength and flow-rate peaks.

Any treatment facility will operate better if it receives a stream which is more uniform in terms of composition and flow rate. The capital cost of the treatment facility can also be reduced if it is designed to handle average, rather than peak, conditions.

It is often possible to combine balancing with treatment, for example separation of pollutants by settling and/or natural flotation.

If on-site effluent balancing is likely to be needed in the short or long term, provision must be made at the initial planning stage of the drainage design, otherwise future problems are likely to arise with regard to drain levels, site space for tanks and foundation restraints.

Screening

Screening is a relatively simple, inexpensive and effective treatment option. Wherever possible, screening out of solids should be incorporated before effluents discharge to drains. This will minimise leaching of dissolved substances into the effluents, problems of drain blockages and the suspended solids pollution load in the final effluent.

Screening should be carried out above ground wherever possible. Basket screens placed in sumps and catch pits require very close control and supervision if they are to be successful. "Cleaning" of such screens is often incorrectly carried out by removing the basket, emptying the contents down the drain, and replacing the basket, thereby negating the purpose of the screen.

If it is necessary to screen liquid which is in an underground drain, the best solution is usually to incorporate a sump and to pump the liquid over a self-cleaning screen positioned above ground.

Cartridge-type filters, especially those requiring manual cleaning or cartridge replacement, should be avoided in polluted effluent screening applications. Even relatively low suspended solids concentrations can block such a filter within a short time.

Pumping

The most important design aspect of effluent pumping is that the pump must be able to handle the expected (and unexpected) solids in the effluent. The passages through the impeller must be sufficiently large to accommodate the maximum size of solids, and the impeller must not be prone to blockage by stringy or similar substances, if these are present.

Where the flow rate is low, a small pump may appear suitable from the head/flow curve, but the overriding factor must be the solids handling capability, even if this implies an overdesigned pump from the flow point of view.

Pump material should be compatible with the fluids being handled. Factors to take into account include pH and temperature. It may however prove economically justifiable to install a pump with poorer corrosion resistance, and accept ongoing replacement costs, rather than to use a pump made of very expensive material which will also wear out in time, rather than corrode

In the case of large submersible pumps, provision must be made to lift them out of their sumps. The lowest permissible water level may have to be higher than the top of a submersible pump to ensure adequate cooling. This may severely reduce the usable capacity of a sump.

Floor drainage

Where hosing or spillage on floors is to flow naturally to a drain point, a floor slope of 1 in 150 or steeper is usually necessary.

The distance from any point to a drain should not be further than about 3 m, which implies drains at about 6 m centres.

The floor surface must be chosen so that it is not slippery when wet or covered with product, and is not so rough that it traps particulate matter.

Low "bunds" or "humps" on the floor may be beneficial around areas where particularly strong or high-volume spillage occurs, to segregate these discharges into one drain rather than another.

Drainage piping

Drainage piping should not have a nominal bore (N.B.) of less than 100 mm. to permit cleaning and to reduce blockages.

Care must be exercised that pipes are not unnecessary oversized, as this will facilitate settling out of solids. Pipes must however be sized to accommodate peak flows, to prevent "backing up" and flooding of drain points.

The preferred slopes are 1 in 40 for 100 mm N.B.; 1 in 60 for 150 mm N.B. and 1 in 90 for 225 mm N.B. These slopes are slightly steeper than conventional building practice, in order to ensure adequate flow velocity to minimise settling-out of solids.

Manholes must be provided wherever pipes change direction or join. The bottoms of the manholes should be "benched" to permit through-flow of solids. "Dead spaces" lower than pipes in manholes collect debris and are difficult to clean.

Manholes deeper than about 500 mm must be sufficiently wide to permit a man to bend over during cleaning or rodding operations.

Where gross solids are present in the effluent, it is worthwhile plastering the inside of manhole walls, to make cleaning easier, and to improve working conditions.

Drain pipes, manhole walls and covers must be waterproof against the infiltration of ground or storm water, which can increase effluent volumes and treatment problems. Leakage from pipes and manholes into the ground must also be avoided.

APPENDIX D

QUESTIONNAIRE FOR ANNUAL UPDATING OF NATIONAL WATER, WASTE-WATER AND SOLID WASTE STATISTICS FOR THE INDUSTRY

D.1 Notes for completion of questionnaire

(a) The aim of this brief questionnaire is to annually update the national water, waste-water and solid waste statistics for the Industry, and thereby to provide a valid basis for assisting the Industry in progressively managing the problems faced in this context.

(b) All information received will be treated as strictly confidential. Please return completed questionnaires to the SA Fruit and Vegetable Canners' Association, P O Box 3484, Cape Town 8000, for collection and forwarding to the Water Research Commission.

(c) To obtain accurate updating of the national water, waste-water and solid waste situation for the Industry, a 100% response is aimed at. If any part of the questionnaire can not be completed due to lack of information, please submit the semi-complete questionnaire in any event. If insufficient space is provided for completion of any part of the questionnaire, or particular factors of relevance are not provided for, please append any additional notes or data as required. Your cooperation in assisting the Water Research Commission to continue monitoring and assisting the Industry with the management of its water, waste-water and solid waste problems is gratefully acknowledged.

D.2 General information

Name of Company ....

Principal products ....

Is staff increased/decreased during the year ....

If so, in which months and by approximately how many ....

D.3 Production

Year ....

Principal products ....

MONTH	PRODUCT	QUANTITY (t/month)	WATER USED FOR PROCESSING (m^3/month or % estimate of total)
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
TOTALS			

Note: If you have more than one product, please photocopy this table as many times as required

D.4 Water intake

MONTH	TOTAL WATER INTAKE (m^3)			
	MUNICIPAL	BOREHOLE	OTHER	TOTAL
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

Please attach a copy of your water permit if you have one.

D.5 Waste water

Disposal route for factory waste water ....

Estimated annual waste-water volume (m^3) ....

Typical waste-water analysis (year ....)

PARAMETER	CONCENTRATION (mg/ℓ except pH)		
	MIN	MAX	AVERAGE
pH			
Chemical oxygen demand			
Total solids			
Suspended solids			
Dissolved solids			
Other (specify)			

Please attach a copy of your waste-water (effluent) disposal permit if you have one and copies of any relevant correspondence.

D.6 Solid waste

Annual quantity of solid waste(s) with product breakdown if available

....

Disposal route(s) for solid waste ....

If removed by others, by whom ....

Maximum quantity removed per month ....

By-products (quantities, to whom sold and for what purpose) ....