NASKAH TUTORIAL

TLB-314
PROYEK DESAIN INSTALASI PENGOLAHAN AIR MINUM

Semester Genap 2025/2026

Disusun Oleh:

Dr. Ir. Rachmawati Sugihhartati Djembarmanah, M.Env.Stud

PROGRAM STUDI TEKNIK LINGKUNGAN

FAKULTAS TEKNIK SIPIL DAN PERENCANAAN

INSTITUT TEKNOLOGI NASIONAL

2026

YAYASAN PENDIDIKAN DAYANG SUMBI

INSTITUT TEKNOLOGI NASIONAL

FAKULTAS TEKNIK SIPIL DAN PERENCANAAN

PROGRAM STUDI TEKNIK LINGKUNGAN

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SURAT KETERANGAN

Yang bertandatangan dibawah ini Ketua Program Studi Teknik Lingkungan Fakultas Teknik Sipil dan Perencanaan ITENAS, menerangkan bahwa :

Dr. Ir. Rachmawati Sugihhartati Djembarmanah, M.Env.Stud

Adalah **Pembuat Naskah Tutorial Proyek Desain Instalasi Pengolahan Air Minum** Prodi Teknik Lingkungan Periode Semester Genap Tahun Ajaran 2025/2026.

Demikian surat keterangan ini kami buat untuk digunakan sebagaimana mestinya.

Bandung, 9 Februari 2026

Ketua Program Studi Teknik Lingkungan

itenas

Prof. Dr. M. Rangga Sururi, S.T., M.T.

LEMBAR PENGESAHAN

NASKAH TUTORIAL TLB-314
PROYEK DESAIN INSTALASI
PENGOLAHAN AIR MINUM

Mengetahui
Ketua Jurusan
Teknik Lingkungan

Prof. Dr. M. Rangga Sururi, S.T., M.T.

TLB 314 Proyek Desain Instalasi Pengolahan Air Minum

Dosen: Rachmawati S. Dj.

SEMESTER GENAP 2025/2026

Mata Kuliah Prasyarat	Mekanika Fluida I & II, Desain Pengolahan Fisika Kimia I, Desain Pengolahan Fisika Kimia II, Gambar Teknik, Teknik Penyediaan Air Minum

- 3 sks
- Tatap muka = 3*50 menit; Asistensi = 2*50 menit

Kuliah	dosen
Asistensi/Tugas	asisten

Etika perkuliahan

- Mahasiswa masuk kelas tepat pada waktunya, toleransi waktu s/d 15 menit
- Absensi minimal 80%, kurang dari itu ybs tidak boleh mengikuti UTS & UAS
- Mahasiswa diwajibkan membaca pustaka sebelum perkuliahan berlangsung

01

INTRODUCTION

PETA CAPAIAN PEMBELAJARAN

Kompetensi Utama :

Mahasiswa mampu merancang dan menghasilkan tugas perancangan instalasi pengolahan air minum (IPAM) untuk setiap unit IPAM tingkat ***primary, secondary*** dan ***tertiary treatment*** melalui pendekatan *resource recovery*, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku; dalam bahasa Indonesia yang baik dan benar.

↑

Mahasiswa mampu menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, conditioning*, dan *dewatering*) secara tepat

↑

Mahasiswa mampu menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi secara tepat

↑

Mahasiswa mampu menjelaskan *primary treatment*; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat

↑

Mahasiswa mampu menjelaskan *preliminary treatment*; menganalisis dan merancang *intake* dan *grit chamber*; serta perlengkapannya secara tepat

↑

Mahasiswa mampu menjelaskan rangkaian proses sistem penyediaan air minum (SPAM) secara tepat beserta kriteria desain & peraturan terkait yang berlaku (jika ada) untuk setiap sub-SPAM terkait

↑

Mahasiswa mampu menjelaskan tahapan proyek pengerjaan perancangan sistem penyediaan air minum (SPAM), khususnya instalasi pengolahan air minum (IPAM)

↑

Mahasiswa mampu menganalisis dan memberikan solusi untuk mengatasi masalah kualitas, kuantitas dan kontinuitas air minum, serta dampaknya terhadap kesehatan masyarakat dan lingkungan dengan baik dan benar, berdasarkan prinsip rencana pengamanan air minum (RPAM)

01 INTRODUCTION

Pustaka	Utama:
	1. *Pedoman Rencana Pengamanan Air Minum, Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR), 2021* 2. *Rich, Linvil G. "Unit Operation of Sanitary Engineering" John Wiley & Sons, Inc. USA, 1963.* 3. *Reynolds, Tom D. "Unit Operations and Processes in Environmental Engineering", Brooks/Cole Engineering Division Monterrey, California, 1982* 4. *Fair, Geyer, Okun. "Water and Wastewater Engineering", John Wiley. 1968.* 5. *Tchobanoglous, G., Burton, F.L., Stensel, H. D. "Wastewater Engineering Treatment and Reuse" Fourth Edition, Metcalf & Eddy, Inc., New York, USA, 2004.* 6. *Qasim, S. R. "Wastewater treatment Plants Planning, Design and Operation", CBS College Publishing, New York, USA, 1985*
	Pendukung:
	1. Undang-Undang No. 17 Tahun 2019 tentang Sumber Daya Air 2. Peraturan Presiden Republik Indonesia Nomor 12 Tahun 2025 tentang Rencana Pembangunan Jangka Menengah Nasional Tahun 2025-2029 3. Peraturan Pemerintah No. 22 Tahun 2021 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air 4. Peraturan Pemerintah Republik Indonesia No. 122 Tahun 2015 tentang Sistem Penyediaan Air Minum 5. Peraturan Menteri Kesehatan Republik Indonesia No. 2 Tahun 2023 tentang Peraturan Pelaksanaan Peraturan Pemerintah Nomor 66 Tahun 2014 Tentang Kesehatan Lingkungan 6. Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat No. 27/PRT/M/2016 tentang Penyelenggaraan Sistem Penyediaan Air Minum 7. Peraturan Menteri Pekerjaan Umum Republik Indonesia No. 01/PRT/M/2014 tentang Standar Pelayanan Minimal Bidang Pekerjaan Umum dan Penataan Ruang

01 INTRODUCTION

Bahan Kajian/Materi Pembelajaran	1. Konsep dasar SPAM 2. Karakteristik air minum yang meliputi kualitas serta kuantitasnya 3. Rangkaian proses SPAM *Preliminary treatment: Bar screen* 4. *Primary treatment:* a. Prasedimentasi b. Sedimentasi c. Filtrasi 5. *Secondary treatment:* a. Koagulasi b. Flokulasi c. Desinfeksi 6. *Tertiary treatment:* pengolahan lumpur: *a. Sludge thickening* *b. Sludge conditioning* *c. Sludge dewatering*

CPL PADU- YANG DIBEBANKAN PADA MATAKULIAH	
CPL 2	Mampu bekerja sama, memiliki kepekaan sosial, dan kepedulian terhadap keberagaman masyarakat serta lingkungan (21%).
CPL 5	Mampu menganalisis dan menyelesaikan permasalahan lingkungan serta dampaknya terhadap kesehatan lingkungan dengan menerapkan prinsip-prinsip dasar pengelolaan lingkungan yang berbasis *resource recovery* (30%).
CPL 6	Mampu merancang prasarana bidang Teknik Lingkungan (air, udara, tanah serta limbah) melalui pendekatan *resource recovery* untuk mewujudkan masyarakat yang sehat (33%).
CPL 9	Mampu berkomunikasi secara lisan dan tulisan dalam bahasa Indonesia maupun bahasa Inggris dengan baik (16%).

CAPAIAN PEMBELAJARAN MATA KULIAH (CPMK)
CPMK-2 : Mampu bekerjasama dalam perancangan Instalasi Pengolahan Air Minum berdasarkan prinsip RPAM (21%).
CPMK-5: Mampu menganalisis dan memberikan solusi untuk mengatasi masalah air minum, serta dampaknya terhadap kesehatan masyarakat dan lingkungan dengan baik dan benar (30%).
CPMK-6 : Mampu mendisain prasarana berupa Instalasi Pengolahan Air Minum sesuai dengan kondisi eksisting yang ditemukan untuk mewujudkan masyarakat yang sehat (33%).
CPMK-9 : Mampu menghasilkan tugas dalam bahasa Indonesia yang baik dan benar (16%)

01 INTRODUCTION

KEMAMPUAN AKHIR TIAP TAHAPAN BELAJAR (SUBCPMK)	
Sub-CPMK-2.1: Mampu bekerja sama dalam membuat laporan tugas perancangan Instalasi Pengolahan Air Minum (IPAM) untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku (21%).	
Sub-CPMK-5.1: Mampu menganalisis dan memberikan solusi untuk mengatasi masalah kualitas, kuantitas dan kontinuitas air minum, serta dampaknya terhadap kesehatan masyarakat dan lingkungan dengan baik dan benar berdasarkan prinsip RPAM (30%)	
Sub-CPMK-6.1: Mampu menjelaskan tahapan pengerjaan perancangan IPAM dan rangkaian proses SPAM secara tepat serta kriteria desain & peraturan yang berlaku (jika ada) untuk setiap unit pengolahan terkait (7%)	
Sub-CPMK-6.2: Mahasiswa mampu menjelaskan *preliminary treatment*; menganalisis dan merancang intake, grit chamber; dan perlengkapannya secara tepat (5%)	
Sub-CPMK-6.3: Mahasiswa mampu menjelaskan *primary treatment*; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat (10%)	
Sub-CPMK-6.4: Mahasiswa mampu menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi secara tepat (6%)	
Sub-CPMK-6.5: Mahasiswa mampu menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, sludge conditioning, sludge dewatering)* secara tepat (5%)	
Sub-CPMK-9.1: Mampu menghasilkan tugas perancangan IPAM dalam bahasa Indonesia yang baik dan benar (16%)	

01 INTRODUCTION

Sub CPMK	Bobot (%)		CPMK			Media / Rubrik					
		2	5	6	9	ETS	EAS	Tugas kelompok	Tugas kelas	Pra UAS	Sub-total
2.1	21	√				0	0	12	9	0	21
5.1	30		√			30	0	0	0	0	30
6.1	7			√		7	0	0	0	0	7
6.2	5			√		0	0	0	0	5	5
6.3	10			√		0	10	0	0	0	10
6.4	6			√		0	6	0	0	0	6
6.5	5			√		0	5	0	0	0	5
9.1	16				√	0	0	10	6	0	16
Total	100										100

01 INTRODUCTION

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
1-14 1-2	1	Mahasiswa mampu bekerja sama dalam membuat laporan tugas perancangan Instalasi Pengolahan Air Minum sesuai dengan tahapan pengerjaan perancangan IPAM, konsep dasar SPAM, peraturan, dan kriteria desain yang berlaku	Ketepatan dalam membuat laporan sesuai dengan tahap *preliminary design*, konsep dasar SPAM, peraturan, dan kriteria desain yang berlaku	Tugas	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu Tahapan pengerjaan perancangan IPAM, konsep dasar SPAM, peraturan, dan kriteria desain yang berlaku: 2*3*50 menit	20%
3-4	2	Mahasiswa mampu menjelaskan karakter air baku air minum yang meliputi kualitas serta kuantitasnya secara tepat	Ketepatan dalam menjelaskan karakter air baku air minum yang meliputi kualitas serta kuantitasnya	UTS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu Karakter air baku air minum (kualitas & kuantitas): 2*3*50 menit	15%

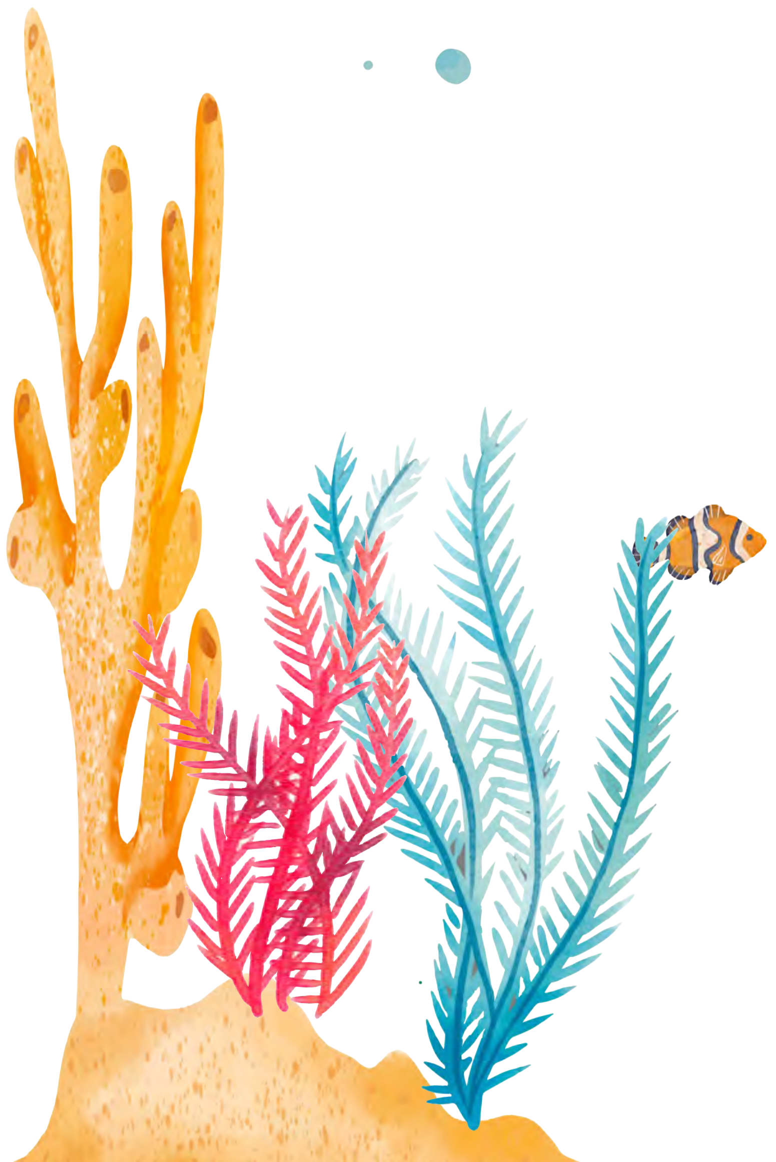
01 INTRODUCTION

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
4	3	Mahasiswa mampu menjelaskan rangkaian proses SPAM secara tepat	Ketapatan dalam menjelaskan rangkaian proses SPAM	UTS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu Rangkaian proses SPAM: 1*3*50 menit	5%
5-6	4	Mahasiswa mampu menjelaskan *preliminary treatment*; menganalisis dan merancang *bar screen* secara tepat	Ketepatan dalam menjelaskan *preliminary treatment*; menganalisis dan merancang *bar screen*	UTS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu *Preliminary treatment* dan *bar screen*: 2*3*50 menit	10%
7, 9-11	5	Mahasiswa mampu menjelaskan *primary treatment*; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat	Ketepatan dalam menjelaskan *primary treatment*; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi	UTS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu *Primary treatment,* prasedimentasi, sedimentasi dan filtrasi: 4 *3*50 menit	10%
				PRA-UAS		15%
8	UTS					

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian [10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
12-13	6	Mahasiswa mampu menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi secara tepat	Ketapatan dalam menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi	UAS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu *Secondary treatment,* koagulasi, flokulasi dan desinfeksi: 2*3*50 menit	15%
14-15	7	Mahasiswa mampu menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)* secara tepat	Ketepatan dalam menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)*	UAS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu *Tertiary treatment*; pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)*: 2*3*50 menit	10%
16	UAS					

THANKS!

Does anyone have any questions?



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TLB 314 Proyek Desain PAM

Dosen: Rachmawati S. Dj.

week 3

FUNDAMENTAL CONCEPT OF WATER SUPPLY SYSTEM

Semester genap 2025/2026

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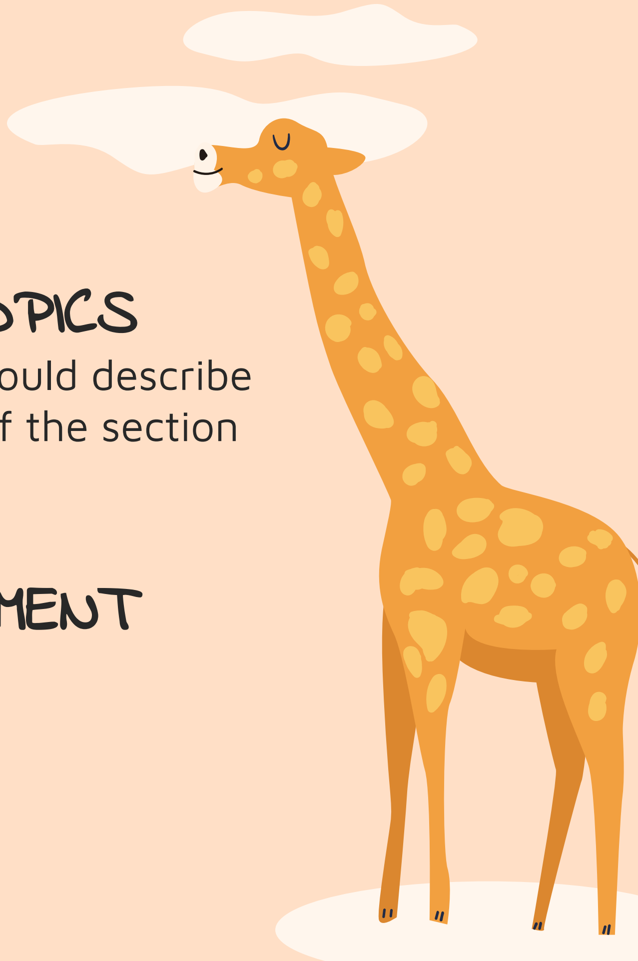


01

Introduction

01 INTRODUCTION

Sub CP MK *Week 2*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]; Metode Pembelajaran[8]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5]	Teknik[6]	Luring	
1	2	3	4	5	6	9
1-14	2.1	Mampu bekerja sama dalam membuat laporan tugas perancangan Instalasi Pengolahan Air Minum (IPAM) untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	Ketepatan dalam membuat laporan tugas perancangan IPAM untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	Tugas	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu tugas perancangan IPAM untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	21%
	9.1	Mampu menghasilkan tugas perancangan IPAM dalam bahasa Indonesia yang baik dan benar				16%
1-2	5.1	Mampu menganalisis dan memberikan solusi untuk mengatasi masalah kualitas, kuantitas dan kontinuitas air minum, serta dampaknya terhadap kesehatan masyarakat dan lingkungan dengan baik dan benar berdasarkan prinsip RPAM	Ketepatan dalam menganalisis karakteristik air baku air minum yang meliputi kualitas, kuantitas serta kontinuitasnya; dan pengaruhnya terhadap manusia & lingkungan	Tugas UTS	Tatap Muka, Asistensi, Diskusi Tugas: 1*50 menit/minggu Analisis karakteristik air baku air minum (kualitas & kuantitas): 1*3*50 menit	30%

WHAT IS THIS TOPIC ABOUT?

"It's about the fundamental concept of water supply system"

DEFINITION OF CONCEPTS

water safety plan

An effective tool to supply water, that is safe to be directly consumed and not harming the consumers, through risk and management approach analysis from the point of drawing it at the source, via the treatment process to the consumer taps (WHO, 2004)

Hazard

A biological, chemical, physical or radiological agent in, or condition of, water, with the potential to cause an adverse health effect (WHO, 2016)

Risk

Frequency * Severity

Hazardous event

A process whereby a hazard is introduced in to a water supply

02

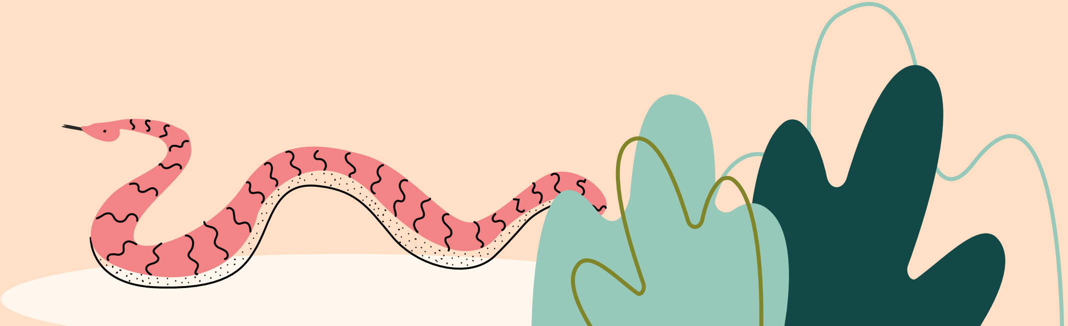
Sub-topics

water safety plan

water supply system

water safety plan

03



Apa tujuan RPAM?

RPAM bertujuan untuk secara konsisten menjamin suplai air minum yang aman, dapat diterima dan mencukupi kebutuhan

Aman, dapat diterima

Mencukupi kebutuhan

Sumber: WHO, 2019; WHO, 2020; Kementerian PU-3, 2013

Apa yg dimaksud dg RPAM?

RPAM merupakan pendekatan analisis dan manajemen risiko yang komprehensif, meliputi semua langkah-langkah dalam penyediaan air minum, mulai dari *catchment area* sampai dengan keran konsumen

Sumber: WHO, 2019; Kementerian PUPR, 2014; Kementerian PUPR, 2015, Kementerian PUPR, 2017

RPAM termasuk...

Mencegah kontaminasi di sumber

Sumber: WHO, 2019; Kementerian PUPR-3, 2013; Anonim, 2013

RPAM termasuk...

Menghilangkan/meminimasi kontaminan dengan melakukan pengolahan

Sumber: Bappenas, WASPOLA, AUSaid, 2014

RPAM termasuk...

Mencegah rekontaminasi di jaringan distribusi

Sumber: WHO, 2019; Kementerian PUPR-3, 2014; https://medan.tribunnews.com/2020/12/31/pipa-pdam-tirtanadi-bocor-bagai-air-mancur-warga-bergantian-tampung-air-pakai-ember, 2020)

RPAM termasuk...

Mencegah rekontaminasi di rumah tangga

https://batam.tribunnews.com/2015/09/12/catat-atb-kembali-ubah-sistem-penggiliran-air-jadi-21-atau-31, 2015;
https://kalsel.prokal.co/read/news/33030-9-jam-leding-stop-pelanggan-pdam-diminta-menampung-air.html,

Bagaimana RPAM melakukan semua hal tsb??

Catchment area → Sumber → Transmisi → IPAM → Distribusi → Keran konsumen

RPAM = pengelolaan risiko, *multiple barriers*

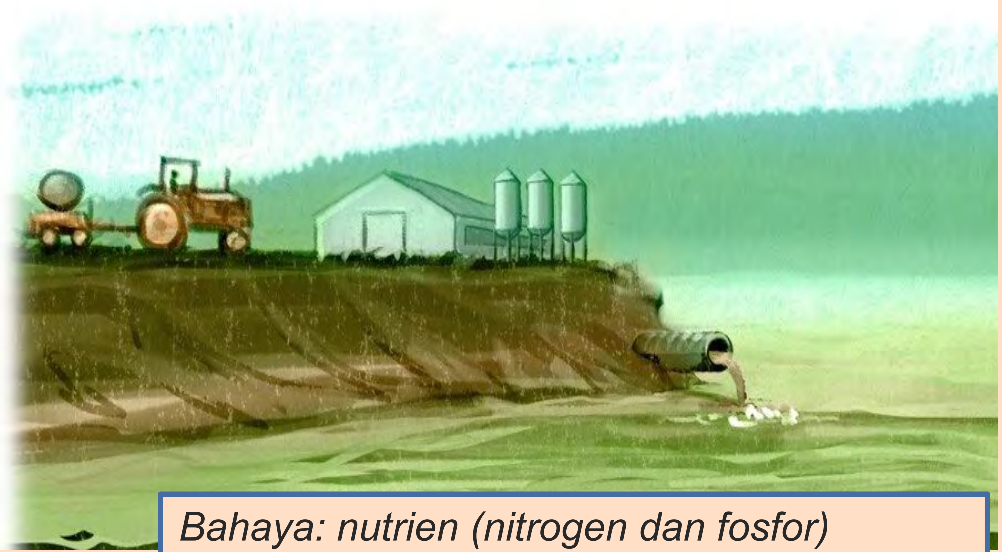
Sumber: WHO, 2019; Kementerian PU-3, 2013

Bahaya vs Kejadian Bahaya

Bahaya:
kata benda

Kejadian bahaya:
peristiwa, mengandung kata kerja

Kejadian Bahaya: pencemaran air karena penggunaan pupuk yang tidak terkendali.



Bahaya: nutrien (nitrogen dan fosfor)

MENGGAMBARKAN Kejadian Bahaya

Ketika menggambarkan kejadian bahaya, HARUS SPESIFIK!
Nyatakan dengan jelas: bahaya apa yang bisa masuk dan bagaimana cara masuk ke dalam SPAM

TIP

Pernyataan kejadian bahaya yang baik akan tertulis sebagai berikut:

X terjadi di Y *(pada SPAM)* karena Z

MENGGAMBARKAN Kejadian Bahaya

X terjadi di Y *(pada SPAM)* **karena Z**

- Kontaminasi feses (X) di sumber air (Y) karena pembuangan air limbah domestik (dari rumah tangga) yang tidak diolah (Z)
- Kontaminasi air (X) di jaringan pipa distribusi (Y) karena praktek perbaikan pipa yang tidak higienis (Z)
- Air kelebihan atau kekurangan klorin (X) di outlet klorinasi (Y) karena pelatihan untuk operator yang tidak memadai (Z)

X = Apa yang akan terjadi terhadap SPAM

Y = Dimana hal tsb terjadi

Z = Bagaimana hal itu terjadi (penyebab)

Contoh Kejadian Bahaya

PDAM Kota X Tahun 2013

Kontaminasi **mikrobiologis** (X) terjadi terhadap air baku di *broncaptering* (Y) karena **masuknya kotoran ayam dari peternakan ayam di hulu *broncaptering*** (Z).

Kejadian Bahaya di Sumber

Peternakan Ayam di Hulu *Broncaptering* Sumber Air Baku Sungai X

Risiko

Skor risiko = Skala Peluang X Skala Dampak Keparahan Kejadian Bahaya

TINDAKAN PENGENDALIAN

PDAM X Tahun 2015

Air yang berbusa terjadi di IPAM PDAM X.
 Kontaminasi dari deterjen akibat aktivitas penduduk di hulu intake.

Tindakan pengendalian yang sudah dilakukan:
 Pengolahan air baku di IPAM.

Tidak dapat mengatasi akar masalah aktivitas penduduk di hulu intake.

Apakah Tindakan Pengendalian tambahan diperlukan?

Kejadian Bahaya di Sistem Pengolahan

Air Baku yang Masuk ke IPAM PDAM X Berbusa

Diagram skematik SPAM

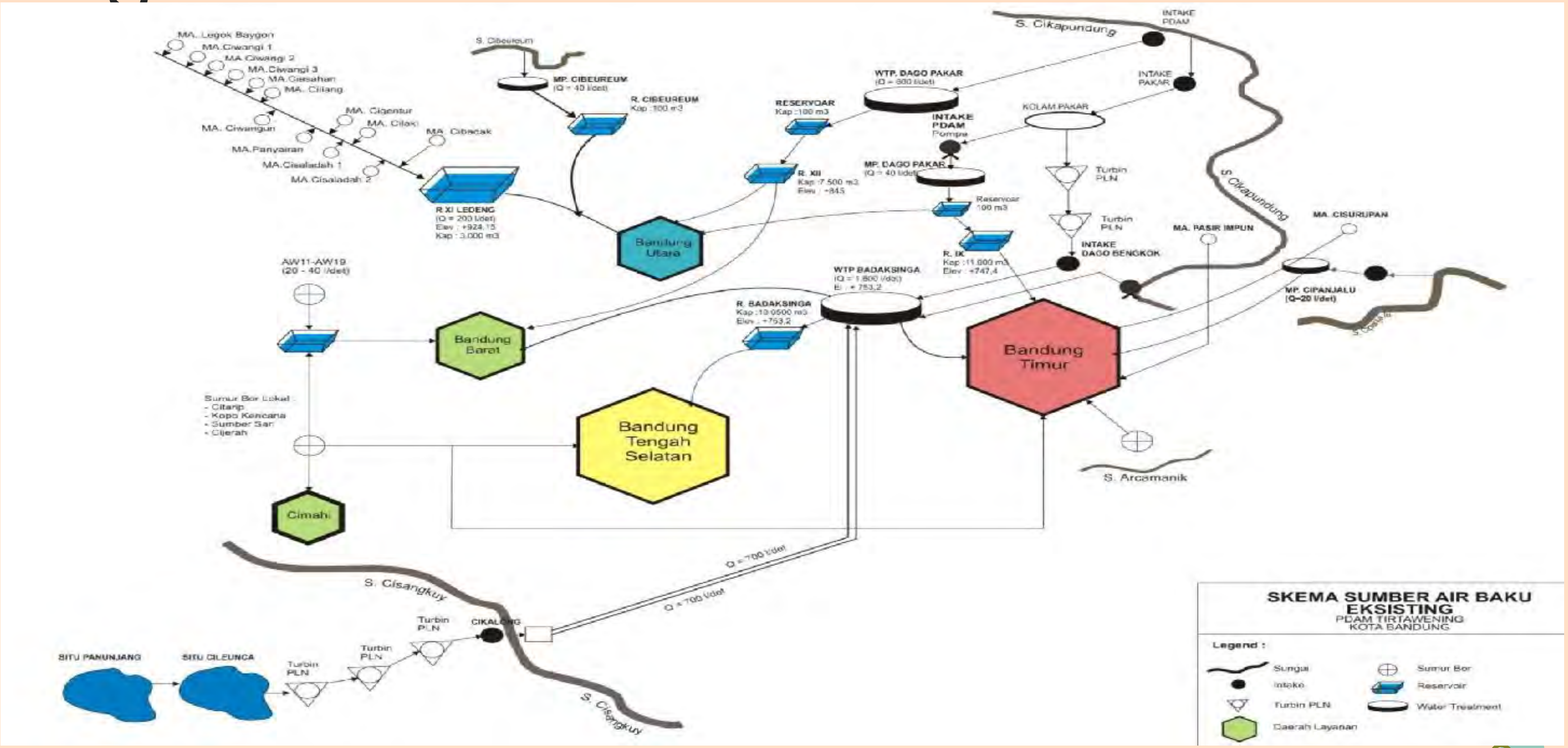
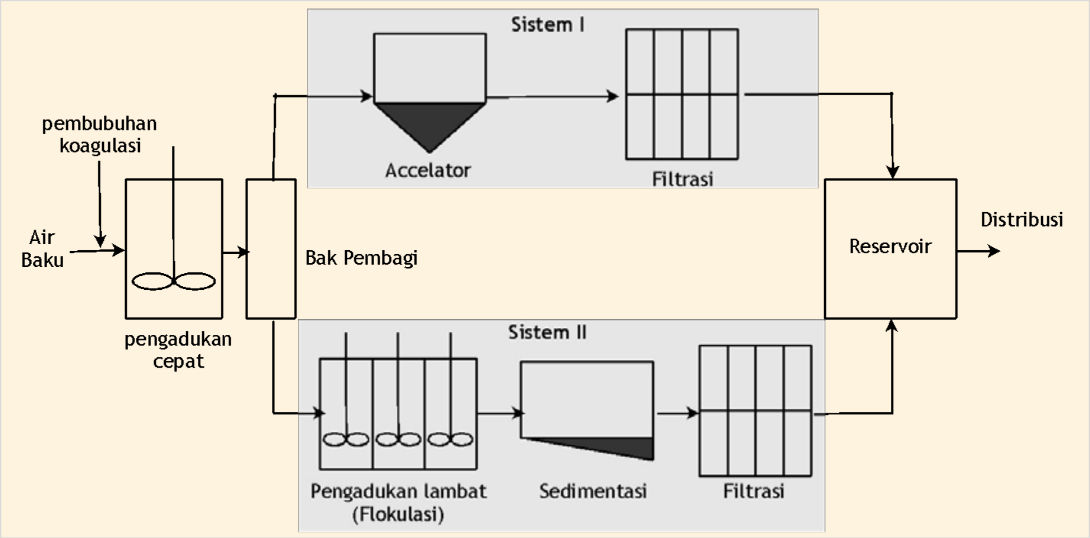


Diagram skematik IPAM

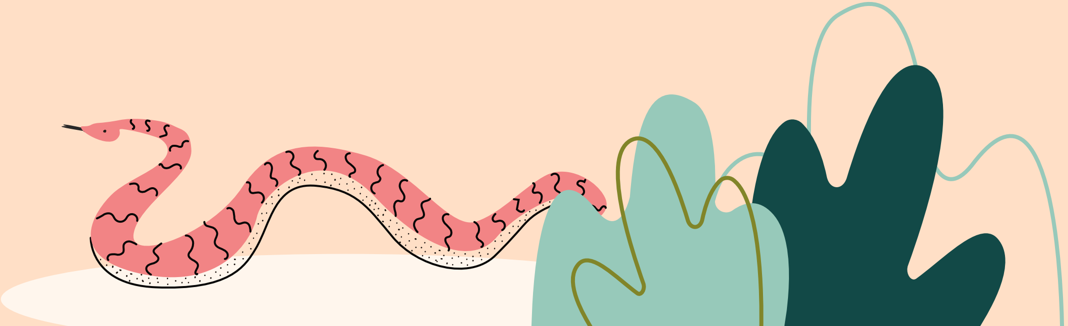


Tabel Kejadian Bahaya dan Tindakan Pengendalian

No	Komponen SPAM	Kejadian Bahaya	Tipe Bahaya	Tindakan Pengendalian

water supply system

03



water supply system

Catchment area → Sumber → Transmisi → IPAM → Distribusi → Keran konsumen

RPAM = pengelolaan risiko, *multiple barriers*

Sumber: WHO, 2019; Kementerian PUPR, 2014; Kementerian PUPR, 2015, Kementerian PUPR, 2017

Sumber

Persyaratan:

1. Kualitas
2. Kuantitas

Intake

Persyaratan:

Kuantitas

WTP

- Persyaratan:
  1. Kuantitas
  2. Kualitas
- Sistem: RSF?

Distribusi

Persyaratan:

1. Kualitas
2. Kuantitas
3. Kontinuitas

Konsumen

Persyaratan:

1. Kualitas
2. Kuantitas
3. Kontinuitas

Aman, dapat diterima

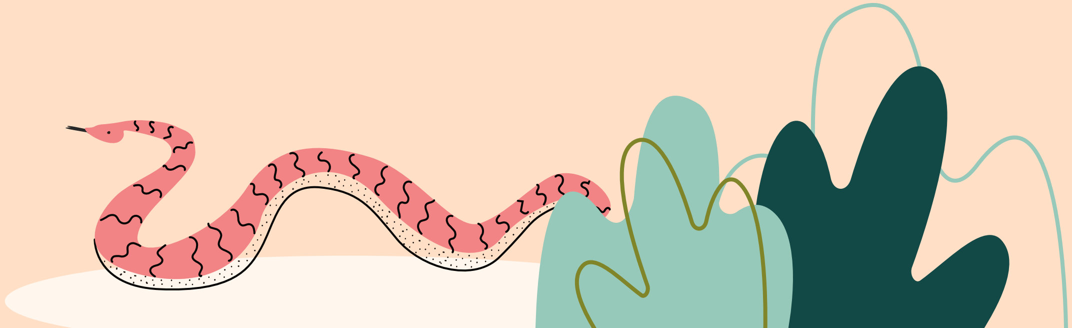
Mencukupi kebutuhan

CONCLUSION

Konsumen dapat langsung minum:

- Tanpa harus mendidihkannya dan
- Tidak membahayakan kesehatannya

Assignment



Fundamental concept of water supply system

Buat konsep dasar SPAM, mulai dari sumber sampai dengan keran konsumen:

1. Diagram skematik SPAM & IPAM
2. Tabel Kejadian Bahaya & Tindakan Pengendalian
3. Persyaratan SPAM

Tabel Kejadian Bahaya dan Tindakan Pengendalian

No	Komponen SPAM	Kejadian Bahaya	Tipe Bahaya	Tindakan Pengendalian
1	Sumber			
2	Transmisi			
3	*Bar screen*			
4	Intake			
5	IPAM: RSF			
6	Distribusi			
7	Konsumen			

Tabel Persyaratan SPAM

No	Komponen SPAM	Persyaratan		
		Kualitas	Kuantitas	Kontinuitas
1	Sumber			
2	Transmisi			
3	*Bar screen*			
4	Intake			
5	IPAM: RSF			
6	Distribusi			
7	Konsumen			

Thanks

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TLB 314 Proyek Desain Instalasi Pengolahan Air Minum

Dosen: Rachmawati S. Dj.

Week 3

TAHAPAN PROYEK PENGERJAAN IPAM

SEMESTER GENAP 2025/2026

01

INTRODUCTION

02

SUB TOPICS

03

ABOUT THE SUB TOPICS

04

ASSIGNMENT

Sub CP MK *Week 3*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]; Metode Pembelajaran[8]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5]	Teknik[6]	Luring	
1	2	3	4	5	6	9
1-14	2.1	Mampu bekerja sama dalam membuat laporan tugas perancangan Instalasi Pengolahan Air Minum (IPAM) untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	Ketepatan dalam membuat laporan tugas perancangan IPAM untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	Tugas	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 2*50 menit/minggu ▪ tugas perancangan IPAM untuk setiap unit IPAM, berdasarkan konsep dasar SPAM, prinsip RPAM, peraturan, dan kriteria desain yang berlaku	21%
	9.1	Mampu menghasilkan tugas perancangan IPAM dalam bahasa Indonesia yang baik dan benar				16%
3	6.1	Mampu menjelaskan tahapan proyek pengerjaan perancangan IPAM	Ketepatan dalam menjelaskan tahapan pengerjaan perancangan IPAM	Tugas, UTS	• Tatap Muka, Asistensi, Diskusi • Tugas: 1*50 menit/minggu • Tahapan pengerjaan perancangan IPAM 1*3*50 menit	7%

WHAT IS THIS TOPIC ABOUT?

Tahapan proyek pengerjaan DPAM, mulai dari *feasibility study* sampai dengan *detailed design*

DEFINITION OF CONCEPTS

FEASIBILITY STUDY

Studi kelayakan proyek

MASTER PLAN

Perencanaan induk

PRELIMINARY DESIGN

Perencanaan pendahuluan

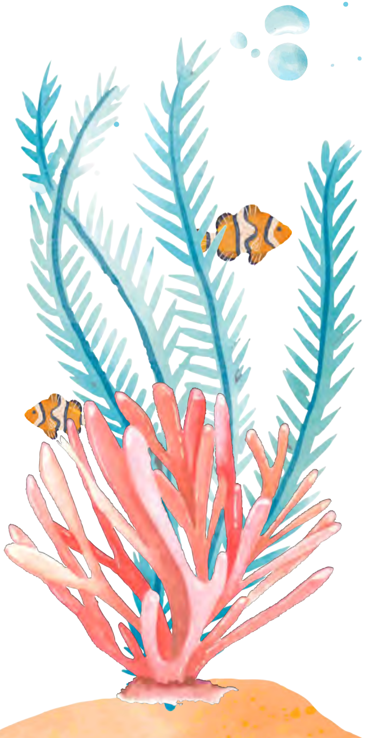
DETAILED DESIGN

Perencanaan detil

FEASIBILITY STUDY VS. DETAILED DESIGN

FEASIBILITY STUDY

- PLANNING
  - ☐ Master Plan
- DESIGN
  - ☐ Preliminary Design



DETAILED DESIGN

DESIGN

☐ Detailed design

02 SUB TOPICS

FEASIBILITY STUDY

MASTER PLAN

PRELIMINARY DESIGN

DETAILED DESIGN

FEASIBILITY STUDY (FS)

FEASIBILITY STUDY

- Studi untuk melihat kelayakan suatu proyek (mis. pengerjaan IPAM)
- Kelayakan ini dapat ditinjau dari 3 segi, yaitu
  1. Segi teknik
  2. Segi ekonomi *(affordable)*
  3. Segi lingkungan

FEASIBILITY STUDY

SEGI TEKNIK

- Satuan Proses
- Satuan Operasi

SEGI LINGKUNGAN

SEGI EKONOMI

- Beban biaya tidak terlalu besar
- Dapat dipikul oleh masyarakat luas

HAKEKAT FS

ALTERNATIF

Minimal 3 buah

ANALISIS ALTERNATIF

- Teknik
- O & M
- Ekonomis

ALTERNATIF TERPILIH

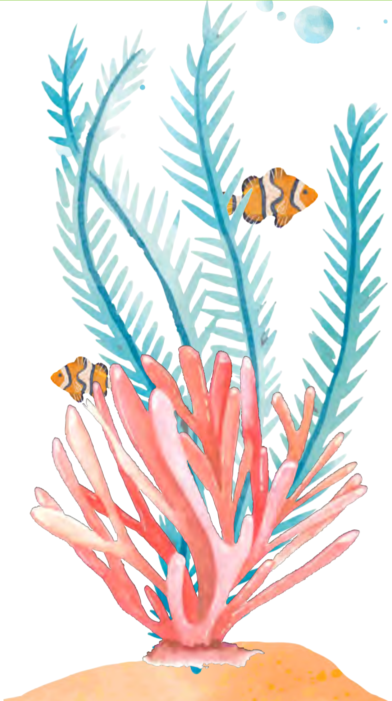
Terbaik

ANALISIS ALTERNATIF

SEGI TEKNIK

- Teknologi
- Satuan proses
- Satuan operasi
- *Space*
- Hidrolik
- Konstruksi
- Operasional
- Pemeliharaan

SEGI LINGKUNGAN



SEGI EKONOMI

- Biaya investasi:
  - Lahan
  - Teknologi
  - Konstruksi
- Biaya operasional:
  - Tenaga manusia,
  - Bahan bakar,
  - Bahan kimia
- Biaya pemeliharaan

KRITERIA PERENCANAAN

- Kapasitas yang harus dibangun
- Persyaratan air minum
- Proses yang digunakan
- Segi ekonomi

Term of Reference (TOR)

MASTER PLAN

MASTER PLAN

- Tahapan *planning* (perencanaan) untuk membuat rencana jangka panjang minimal 20 tahun.

Waktu perencanaan diambil minimal selama 20 tahun:

- Kesalahan perencanaan menjadi tidak terlalu besar
- Beban biaya bagi masyarakat tidak terlalu berat.

MASTER PLAN

- 2 hal penting yang harus dipertimbangkan dalam pembuatan *Master Plan* IPAM:
  1. Kebutuhan
  2. Proses

- Kualitas
- Kuantitas

AIR BAKU

IPAM →

- Kualitas
- Kuantitas

AIR MINUM

PRELIMINARY DESIGN (PD)

PRELIMINARY DESIGN

- Desain dari alternatif terpilih yang diperoleh dari *feasibility study*
- *Preliminary design* berbeda dengan *detailed design* karena disain yang dilakukan tidak berupa disain rinci melainkan hanya bersifat umum.

KELUARAN FS

- Laporan *FS* atau *Master Plan*
- *Preliminary Design*
- Gambar:
    - *Flow diagram*,
    - Profil hidrolis,
    - *Lay out*,
    - Gambar situasi,
    - Gambar tampak

DETAILED DESIGN

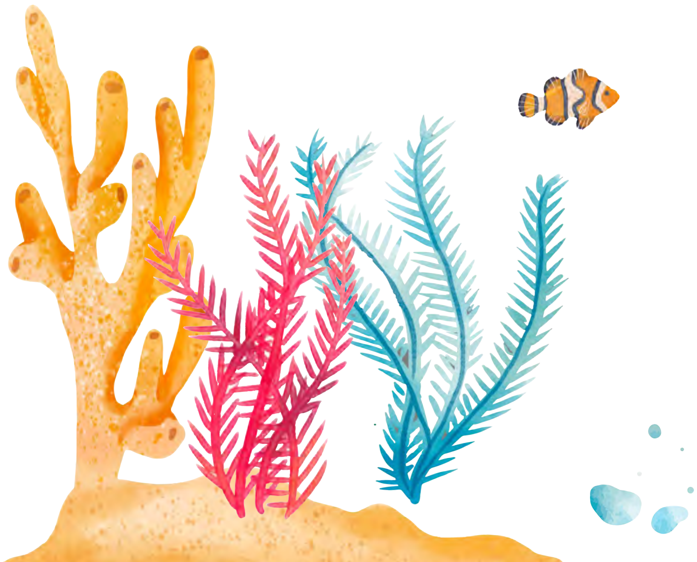
DETAILED DESIGN

REKAYASA

RANCANG BANGUN

LANGKAH-LANGKAH DETAILED DESIGN

1. *Review Preliminary Design*
2. Membuat kriteria perencanaan
3. Dimensionering
4. Membuat gambar detail
5. Menghitung biaya
6. Membuat tender dokumen



1. REVIEW PRELIMINARY DESIGN

- PD harus dicek kembali untuk meninjau objek perancangan.
- Hal-hal yang harus ditinjau kembali, misalnya
  - *flow diagram*
  - *lay out*, dll
- dengan pertimbangan bahwa *FS* yang dibuat sudah tidak sesuai lagi dengan kondisi sekarang.

2. MEMBUAT KRITERIA DESIGN

Kriteria desain perlu ditetapkan, seperti kriteria teknik untuk

- proses yang digunakan
- konstruksi dari masing-masing satuan atau unit bangunan.

3. DIMENSIONERING

Penghitungan ukuran masing-masing unit

4. MEMBUAT GAMBAR DETIL

Gambar detil harus dibuat untuk seluruh system, seperti:

- flow diagram,
- profil hidrolis,
- gambar tampak,
- gambar arsitektur,
- gambar konstruksi.

Untuk setiap bangunan harus dibuatkan:

- denah,
- potongan, dan
- detail bagian penting.

5. MENGHITUNG BIAYA

Biaya pembuatan BPAM harus dihitung secara rinci

6. MEMBUAT TENDER DOKUMEN

Tender dokumen yang harus dibuat meliputi:

- Spesifikasi teknik beserta persyaratan-persyaratan teknik yang diperlukan
- Rencana Anggaran Biaya (RAB), didalamnya juga terdapat volume pekerjaan
- Gambar-gambar

04. ASSIGNMENT

TAHAPAN PROYEK PENGERJAAN IPAM

Suatu IPAM akan dibangun untuk melayani kebutuhan air minum di sebuah kota. Sebutkan dan jelaskan tahapan-tahapan yang perlu dilakukan untuk membangun IPAM tsb.

Due date: minggu depan sehari sebelum kuliah jam 23.59

THANKS!

Does anyone have any questions?
Please submitted via moodle

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TLB 314 Proyek Desain Instalasi Pengolahan Air Minum

Dosen: Rachmawati S. Dj.

Week 4

TAHAPAN PERANCANGAN IPAM -RANGKAIAN PROSES SPAM

SEMESTER GENAP 2025/2026

01

INTRODUCTION

02

SUB-TOPICS

04

ASSIGNMENT

03

ABOUT SUB-TOPICS

Sub CP MK *Week 4*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]; Metode Pembelajaran[8]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5]	Teknik[6]	Luring	
1	2	3	4	5	6	9
4	6.1	Mampu menjelaskan rangkaian proses SPAM secara tepat serta kriteria desain & peraturan yang berlaku (jika ada) untuk setiap unit pengolahan terkait	Ketepatan dalam menjelaskan rangkaian proses SPAM secara tepat serta kriteria desain & peraturan yang berlaku (jika ada) untuk setiap unit pengolahan terkait	Tugas, UTS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 1*50 menit/minggu ▪ Rangkaian proses SPAM ▪ 1*3*50 menit	7%

WHAT IS THIS TOPIC ABOUT?

Langkah-langkah yang dilakukan untuk merancang IPAM ketika mengerjakan *FS*, mulai dari menganalisis kualitas air baku sampai dengan menyusun *lay-out plan*

DEFINITION OF CONCEPTS

IMPURITIES

Natural contents within source water generally depend on the type of the source water

SUSPENDED MATTER

Small solid particles which remain in suspension in water

DISSOLVED MATTER

Particles that dissolved in water

COLLOIDAL PARTICLE

Small size particle ranging in size from 10^{-6}-10^{-3} mm

HAKEKAT *FS*

ALTERNATIF

Minimal 3 buah

ANALISIS ALTERNATIF

- Teknik
- O & M
- Ekonomis

ALTERNATIF TERPILIH

Terbaik

MULTI DISIPLIN

Untuk membangun IPAM ahli Teknik Lingkungan (TL) tidak bisa bekerja sendiri, harus bekerjasama dengan: ahli Arsitektur (AR), Sipil (SI), Elektro (EL),, serta *estimator* harga.

Proyek pengerjaan IPAM merupakan pekerjaan multi disiplin, dimana ahli TL bertindak sebagai *leader*-nya.

TAHAPAN PERANCANGAN IPAM

Perancangan IPAM

1. Analisis kualitas air baku
2. Identifikasi *impurities*
3. Identifikasi unsur kimia
4. Teknologi pengolahan
5. *Flow* diagram & profil hidrolis
6. *Lay out plan*

1. ANALISIS KUALITAS AIR BAKU

IPAM

Proses pengolahan dilakukan untuk menurunkan kandungan:

- o fisis,
- o kimia
- o bakteri

AIR BAKU

Kualitas
☐ dianalisis di lab

IPAM

perbaikan kualitas

AIR MINUM AMAN

Kualitas
☐ Standar Kemenkes

KUALITAS AIR BAKU

AIR TANAH

Umumnya mengandung unsur kimia, mis. *Fe, Mn, DO, alkalinity*

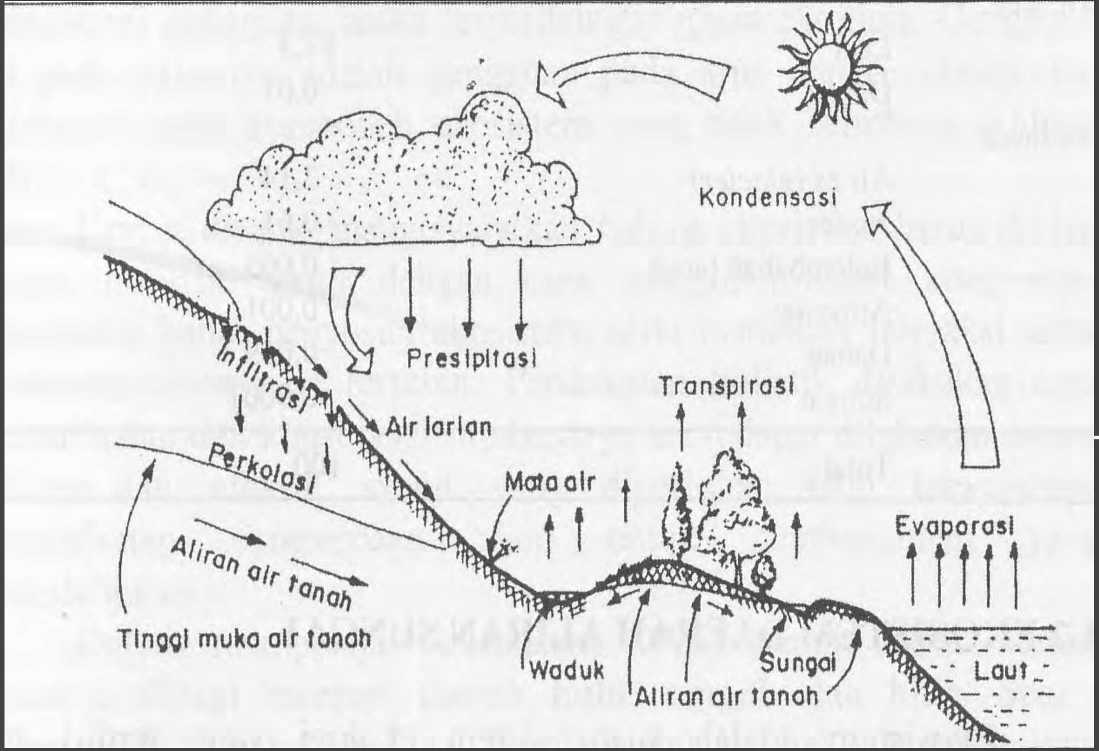
MATA AIR

Biasanya mengandung bakteri

AIR PERMUKAAN

Umumnya mengandung unsur fisis

SIKLUS HIDROLOGI



Al-Layla, 1980

AIR PERMUKAAN

Jika ada unsur kimia dalam air permukaan:
□ telah terjadi pencemaran pada air permukaan tersebut, atau
□ air tersebut sebelumnya telah melewati tanah dengan kandungan kimia yang tinggi

Pengolahan
□ menurunkan kandungan fisis:
- *clay* (tanah):
- *suspended solid (SS)*
- *coloidal matters*

□ menghilangkan kandungan bakteri □desinfeksi

ESTETIKA

- Umumnya terjadi pada hotel atau industri, seperti *laundry*, tekstil.
- Unsur yang dihilangkan biasanya Fe dan Mn, karena unsur-unsur ini menyebabkan:
  - air menjadi berwarna kuning kecoklatan
  - baju berwarna kuning kecoklatan
- Syarat kandungan Fe dalam air minum = 0,3 mg/L; Mn = 0,4 mg/L

2. IDENTIFIKASI *IMPURITIES*

IMPURITIES

IMPURITIES & SUMBER AIR BAKU

Impurities biasanya tergantung dari sumber air (baku) tsb

AIR PERMUKAAN

Unsur yang harus diperiksa: *clay* (*SS* dan c*oloidal matters*) & bakteri

IMPURITIES

- Faktor utama dalam pengolahan air. (lihat Al-Layla).
- Kandungan alami yang terdapat pada suatu air baku

ANALISIS AIR

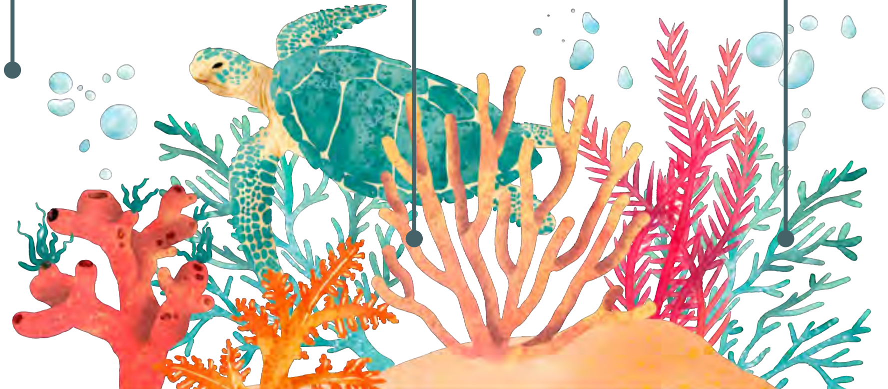
Jangan dilakukan pemeriksaan untuk semua unsur.
Kecuali, jika ada masukan dari industri, harus dicek dari hulu ke hilir:

- industri apa saja yang membuang limbahnya ke air permukaan tsb
- unsur apa saja yang terdapat dalam limbah air industri tsb □ dapat diperkirakan dari bahan baku industri tsb (bahan kimia utama/ pembantu)

IDENTIFIKASI IMPURITIES

Mengidentifikasi apakah impurities tsb berupa unsur yang:

- Terbawa aliran (kasar)
- Terbawa aliran (tersuspensi/ partikel)
- Koloidal
- Terlarut
- Gas



Process Selection Chart by Impurities Size

1A⁰

1mµ

1µ

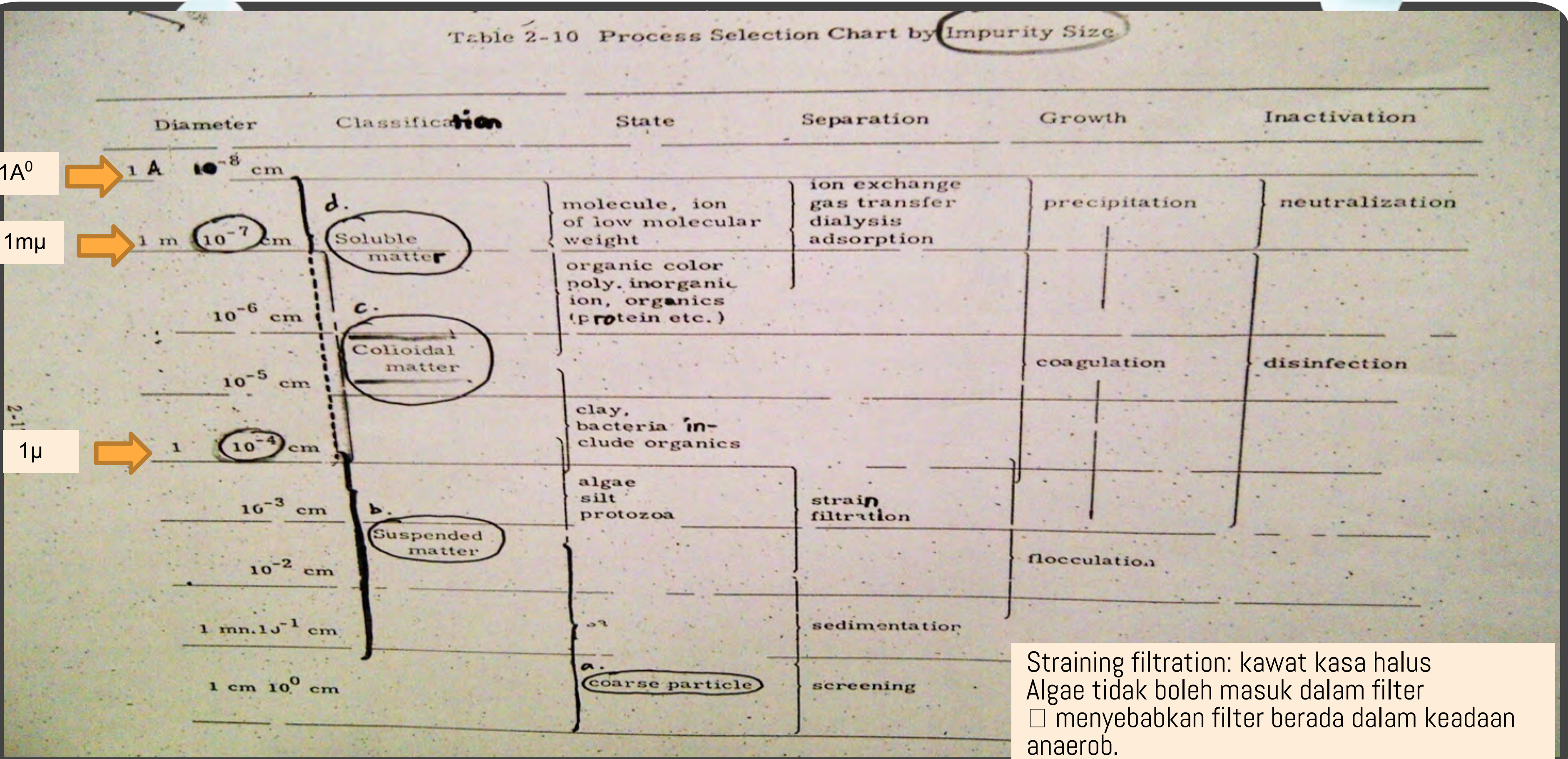


Table 2-10 Process Selection Chart by Impurity Size

Diameter	Classification	State	Separation	Growth	Inactivation
1 A 10^{-8} cm					
1 mµ 10^{-7} cm	d. Soluble matter	molecule, ion of low molecular weight	ion exchange, gas transfer, dialysis, adsorption	precipitation	neutralization
10^{-6} cm		organic color, poly. inorganic ion, organics (protein etc.)			
10^{-5} cm	c. Colloidal matter			coagulation	disinfection
1 µ 10^{-4} cm		clay, bacteria include organics			
10^{-3} cm	b. Suspended matter	algae, silt, protozoa	strain filtration		
10^{-2} cm				flocculation	
1 mm 10^{-1} cm			sedimentation		
1 cm 10^{0} cm	a. coarse particle		screening		

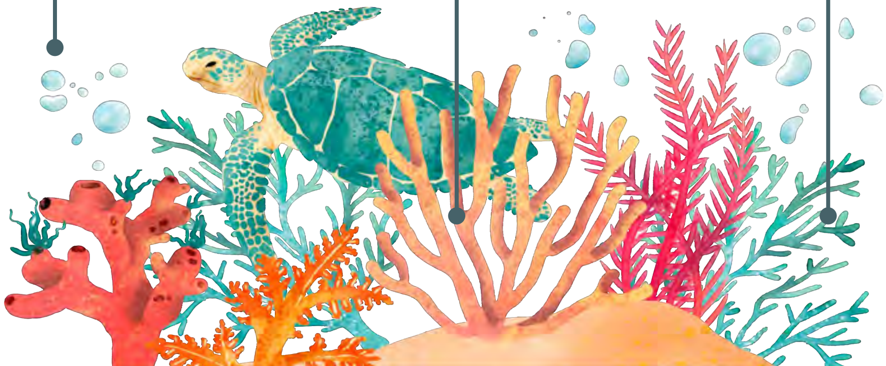
Straining filtration: kawat kasa halus
Algae tidak boleh masuk dalam filter
☐ menyebabkan filter berada dalam keadaan anaerob.

3. IDENTIFIKASI UNSUR KIMIA

IDENTIFIKASI UNSUR KIMIA

Mengidentifikasi apakah unsur kimia tsb berupa unsur yang:

- Terbawa aliran (kasar)
- Terbawa aliran (tersuspensi/ partikel)
- Koloidal
- Terlarut
- Gas



Konsentrasi unsur tsb juga perlu diketahui.

Summary of the Important Chemical & Biological Impurities Found in Water

TABLE 2.1

Summary of the Important Chemical and Biological Impurities Found in Water

	IMPURITY				
	Ionic and Dissolved				
ORIGIN	Positive ions	Negative ions	Colloidal	Suspended	Gases
Contact of water with minerals, soils, and rocks	Calcium (Ca^{2+}) Iron (Fe^{2+}) Magnesium (Mg^{2+}) Manganese (Mn^{2+}) Potassium (K^+) Sodium (Na^+) Zinc (Zn^{2+})	Bicarbonate (HCO_3^-) Carbonate (CO_3^{2-}) Chloride (Cl^-) Fluoride (F^-) Nitrate (NO_3^-) Phosphate (PO_4^{3-}) Hydroxide (OH^-) Borates ($H_2BO_3^-$) Silicates (H_3SiO_4) Sulfate (SO_4^{2-})	Clay Silica (SiO_2) Ferric oxide (Fe_2O_3) Aluminum oxide (Al_2O_3) Magnesium dioxide (MnO_2)	Clay, silt, sand, and other inorganic soils	Carbon dioxide (CO_2)
The atmosphere, in rain	Hydrogen (H^+)	Bicarbonate (HCO_3^-) Chloride (Cl^-) Sulfate (SO_4^{2-})	—	Dust, pollen	Carbon dioxide (CO_2) Nitrogen (N_2) Oxygen (O_2) Sulfur dioxide (SO_2)
Decomposition of organic matter in the environment	Ammonium (NH_4^+) Hydrogen (H^+) Sodium (Na^+)	Chloride (Cl^-) Bicarbonate (HCO_3^-) Hydroxide (OH^-) Nitrite (NO_2^-) Nitrate (NO_3^-) Sulfide (HS^-) Organic radicals	Vegetable coloring matter, organic wastes	Organic soil (topsoil), organic wastes	Ammonia (NH_3) Carbon dioxide (CO_2) Hydrogen sulfide (H_2S) Hydrogen (H_2) Methane (CH_4) Nitrogen (N_2) Oxygen (O_2)
Living organisms in the environment			Bacteria, algae, viruses, etc.	Algae, diatoms, minute animals, fish, etc.	Ammonia (NH_3) Carbon dioxide (CO_2) Methane (CH_4)
Municipal, industrial, and agricultural sources and other human activity	Inorganic ions, including a variety of heavy metals	Inorganic ions, organic molecules, color	Inorganic and organic solids, coloring matter, chlorinated organic compounds, bacteria, worms, viruses	Clay, silt, grit, and other inorganic solids; organic compounds; oil, corrosion products, etc.	Chlorine (Cl_2) Sulfur dioxide (SO_2)

Source: Adapted in part from Refs. [2.3] and [2.7]

4. TEKNOLOGI PENGOLAHAN

Application of Treatment Methods

(3)

4 of 12

Table 2-11 Application of Treatment Methods*

Water Quality: Constituents	Concentration	Pretreatment: Screening	Prechlorination	Plain Settling	Aeration	Treatment: Lime Softening	Coagulation and Sedimentation	Rapid Sand Filtration	Slow Sand Filtration	Post chlorination	Special Treatment: Superchlorination or Chlorammoniation	Active Carbon	Special Chemical Treatment	Salt Water Conversion
Coliform MPN per 100ml (monthly average)	0-20								O	E				
	2-100			O			O	O	O	E				
	100-5,000		E				E	E		E				
	>5,000		E	O			E	E		E	O			
Turbidity-units	0-100	O							O					
	10-200	O					E	E						
	>200	O		O			E	E						
Color-mg/l	20-70						O	O			O			
	>70						E	E			O			
Tastes and odors	noticeable		O		O				O		O	E	E	
Calcium carbonate-mg/l	200					E	E	E						
Iron and manganese-mg/l	0.3		O	O	O			S	O					
	0.3-1.0		E		E		E	E	O					
	1.0		E		E		E	E	O					
Chloride-mg/l	0-250													
	250-500													
	500+													
Phenolic compounds-mg/l	0-0.005										O	O		
	0.005										O	O		
Toxic chemicals**							O E E O	O E E O			O E E O	O O O	O E	
Less critical chemicals														

* E- essential; O- optional; S - special justification required.
Superchlorination shall be followed by dechlorination.

As alternate, dilute with low-chloride water.
Presettling shall be provided for coliform exceeding 20,000 m.p.n.

** For extreme muddy water, presedimentation by plain settling may be provided.

18

E

S

E

Application of Treatment Methods

Table 2-11 Application of Treatment Methods*

Water Quality		Pretreatment				Treatment					Special Treatment			
Constituents	Concentration	Screening	Prechlorination	Plain Settling	Aeration	Lime Softening	Coagulation and Sedimentation	Rapid Sand Filtration	Slow Sand Filtration	Post chlorination	Superchlorination or Chlorammoniation	Active Carbon	Special Chemical Treatment	Salt Water Conversion
Coliform MPN per 100ml (monthly average)	0-20			O			O	O	O	E				
	2-100						E	E	O	E				
	100-5,000		E				E	E	O	E				
	>5,000		E	O						E	O			
Turbidity-units	0-100	O					E	E						
	10-200	O					O	O						
	>200	O		O**			E	E						
Color-mg/1	20-70						E	E						
	>70						E	E						
Tastes and odors	noticeable		O		O				O		O O O	E	E	
Calcium carbonate-mg/1	200					E	E	E						
Iron and manganese-mg/1	0.3		O	O	O		E	S	O					
	0.3-1.0				E		E	E	O					
	1.0		E		E		E	E	O					
Chloride-mg/1	0-250		E											
	250-500													
	500+											O		
Phenolic compounds-mg/1	0-0.005											O	E	
	0.005												O	
Toxic chemicals*							O E E E	O E E E			O O	O O O		
Less critical chemicals											O E E E			

* E- essential; O- optional; S - special justification required. Superchlorination shall be followed by dechlorination. As alternate, dilute with low-chloride water. Plain settling shall be provided for coliform exceeding 20,000 m.p.n.

** For extreme muddy water, presedimentation by plain settling may be provided.

E

E

S

E

TEKNOLOGI PENGOLAHAN

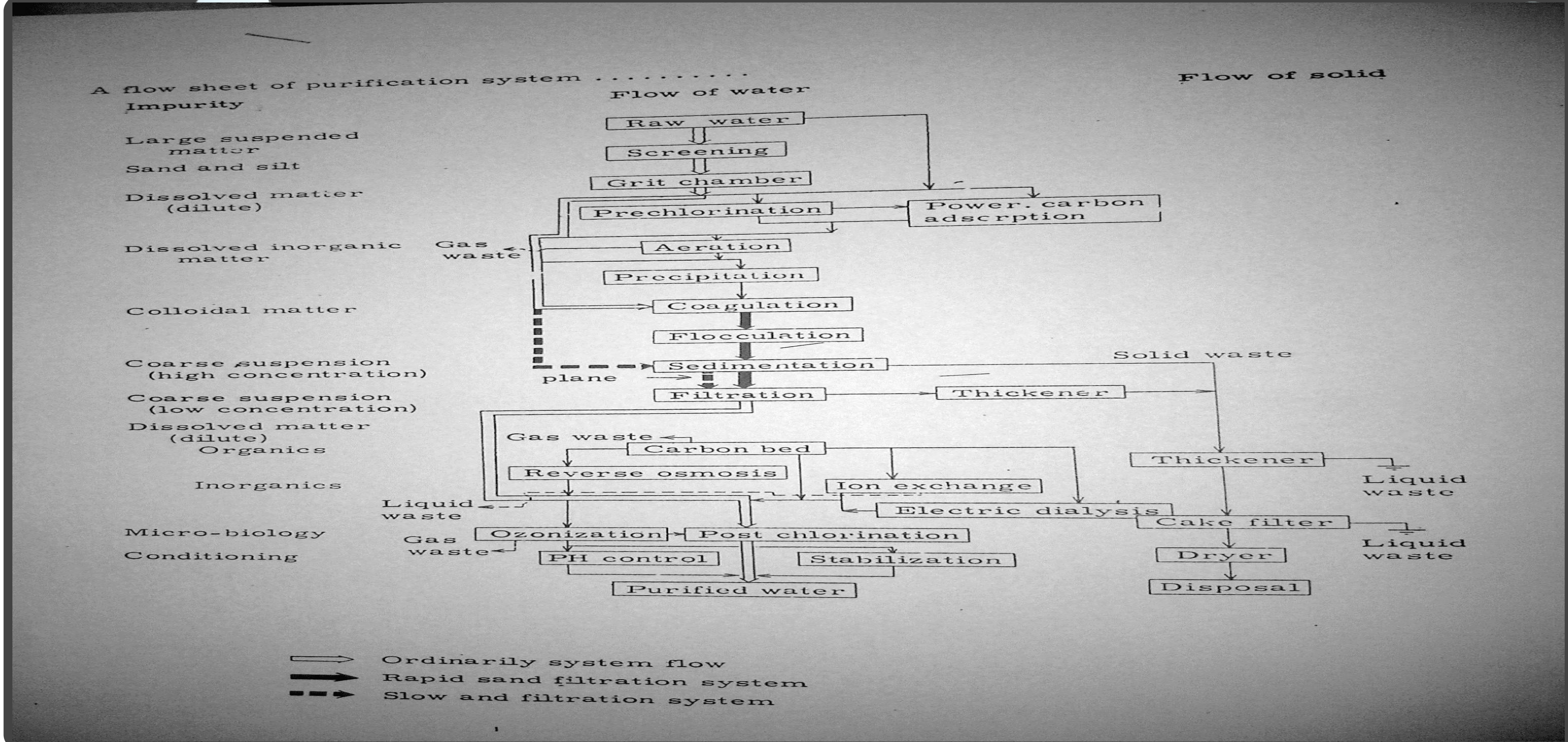
- Kadar turbidity > 200 □ *plain sedimentation: E= Essential*
- Kesadahan □ coagulation dan sedimentasi
- Beberapa koagulan yang bisa digunakan:
  - Al
  - Al dan kapur. Fungsi kapur disini adalah untuk menetralkan air.
  - PAC dan Al
  - PAC dan kapur
- Besi dan mangan -□ *rapid sand filter (RSF)* □ *S: special justification required*
- *P= post chlorination* = klorinasi yg dilakukan setelah RSF
- *Superchlorination should be followed by dechlorination*
- *Clear well*, td min=30 menit, dengan tujuan untuk memberi waktu untuk terjadinya desinfeksi.

TEKNOLOGI PENGOLAHAN

- *Perbedaan RSF dengan slow sand Filter (SSF):* Baca *Fair & Geyer*
  - Pasir > SSF
  - Kecepatan tinggi
  - Porositas >
- Hasil dari SSF sama dengan RSF □ turbidity ≈ 0
- RSF digunakan untuk kecepatan yang lebih besar karena removal sudah 80% sebelumnya (melalui sedimentasi) karena itu cukup dengan kecepatan yang besar untuk menghilangkan yang 20% lagi.
- *Plain sedimentation basin* □ SSF□ Baca Fair & Geyer
  - Material masih bervariasi
  - Investasi mahal

5. *FLOW* DIAGRAM & PROFIL HIDROLIS

Flow Chart of Water Purification System



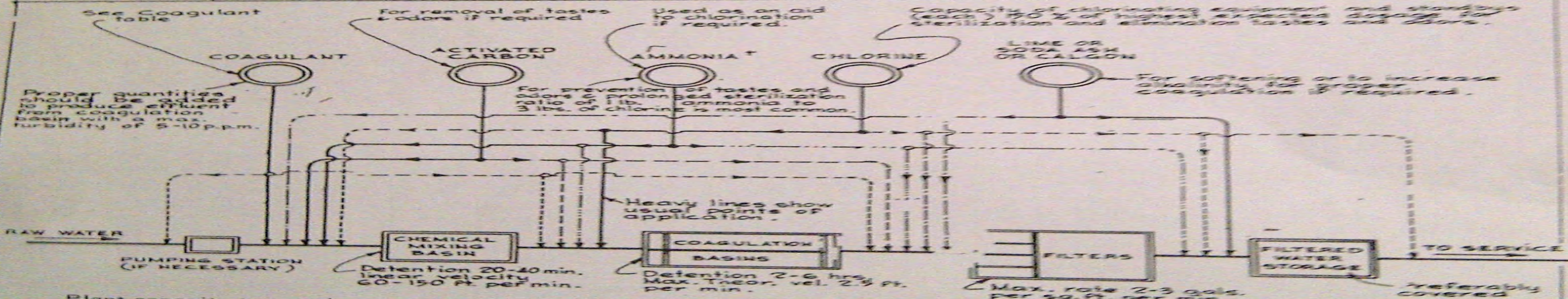
Flow Chart of Rapid Sand Filter

21—0'

WATER PURIFICATION — RAPID SAND FILTERS — 1

TABLE A — CHARACTERISTICS OF RAPID-SAND FILTERS

Adaptability	Satisfactory means of eliminating turbidity, bacteria, micro-organisms, and, to some extent tastes, odors, and color.
Capacity	Normal rate 2 g.p.m. per sq. ft., except in some cases may be extended to 3 g.p.m. per sq. ft.
Flexibility	Rate of filtration may be varied with demand.
Turbidity Limitations	Effective in treatment of highly polluted waters as well as those subject to extreme variations in turbidity and pollution.
Bed Layout	Minimum of two units should be provided, but three are preferable. Sizes vary from fraction of to multiple of 1 million gallons per day. Maximum size constructed 5 M.G.D. Filters generally constructed rectangular, of concrete.
Underdrain System	Older type consists of a grid of manifolds, headers, and laterals. Newer types consist of false bottom with pyramidal openings (Wheeler), vitrified clay (Leopold) and system of aluminum oxide porous plates (Aloxite) by Carborundum Co.
Wash-Water Troughs	Constructed of steel, cast iron, concrete, Transite, prestressed plastic and Fiberglas, and aluminum. Troughs spaced generally 5 to 7 ft. between weir edges.
Wash Water	Recommended rate of rise = 2 to 3 f.p.m.
Surface Wash	Fixed nozzles or rotating type recommended. Water pressure 45 to 75 p.s.i. at 4 to 8 g.p.m. per sq. ft.



Plant capacity to equal average daily demand if filtered water storage is large and provides for maximum demand. If filtered water storage is small, plant capacity to be 150 to 225% of average daily demand.

FIG. B — FLOW DIAGRAM FOR MODERN RAPID SAND FILTER PLANT*

+ NOTE: Ammonia is used very infrequently.
* Adapted from Manual of Water Quality and Treatment, by American Water Works Association, 1941.

Flow Chart of RSF System

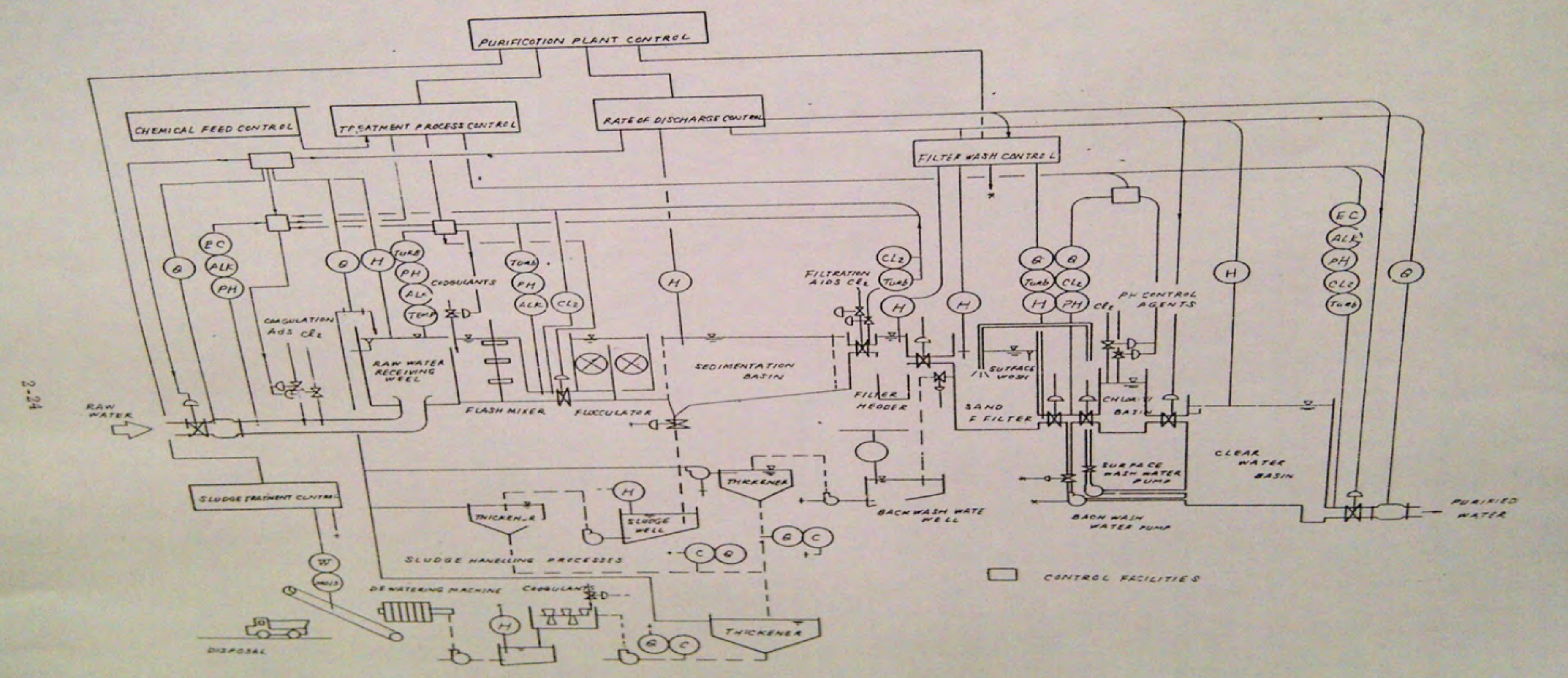


Fig. 2-7 A Flow Diagram of A Rapid Sand Filtration System

05 FLOW DIAGRAM & PROFIL HIDROLIS

- *Screening* dilakukan untuk *coarse matters* dengan tujuan supaya materi kasar ini tidak merusak pompa, karena pompa harganya mahal.
- *Grit chamber* digunakan untuk mengendapkan pasir
- Waktu detensi (td) yang digunakan = 30-60 detik
- Untuk *plain sedimentation* yang digunakan untuk mengendapkan *clay*, td = 4-8 jam (luar negeri). Untuk Indonesia, td= 2-3 jam karena *suspended matter*-nya lebih besar, sehingga kecepatan mengendap (Vs) lebih besar dan td lebih kecil.
- *Text book* dari Negara Barat, biasanya turbiditinya rendah, sehingga tidak ada *plain sedimentation* seperti di Indoonesia.

05 FLOW DIAGRAM & PROFIL HIDROLIS

- Jika kadar Fe tinggi, gunakan *aeration* □*precipitation*-□koagulasi dst
- Gunakan *carbon adsorption* jika bahan baku mengandung bahan organik.
- □ Hal ini dilakukan untuk mencegah terbentuknya *mono, di, trichloramine* karena akan membentuk *Tri Halo Methane* (THM), jika kemudian dilakukan *post chlorination*.
- Cara lain untuk mencegah terbentuknya THM adalah dengan ozonisasi karena tidak dioksidasi dengan klor.
- Jika tidak ada *suspended matter*, dari *screening* langsung ke *reverse osmosis*, contohnya untuk pengolahan air laut.
- *Solid waste* dalam air minum harus 0.
- *Plain sedimentation* bisa diletakkan di lokasi sumber dengan tujuan supaya mudah membuang Lumpur ke alirannya.

05 FLOW DIAGRAM & PROFIL HIDROLIS

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6. *LAY OUT PLAN*

LAY OUT PLAN

- Tata letak atau penempatan unit bangunan.
- Unit-unit perlu dibuat lebih banyak daripada 1 buah, dengan tujuan sebagai:
  - *stand by unit*
  - tahapan desain
- Cakupan IPAM: mulai dari *water intake* sampai dengan keluar dari *clear well*
- Untuk bisa mendisain IPAM perlu didasari oleh pengetahuan akan:
  - Satuan operasi: proses fisik
  - Satuan proses: satuan proses (kimia).
- IPAM lebih menitikberatkan pada proses fisik. Misalnya *thickener* dimana proses yang terjadi adalah pemadatan secara *zone*.

Plan of RSF Plant

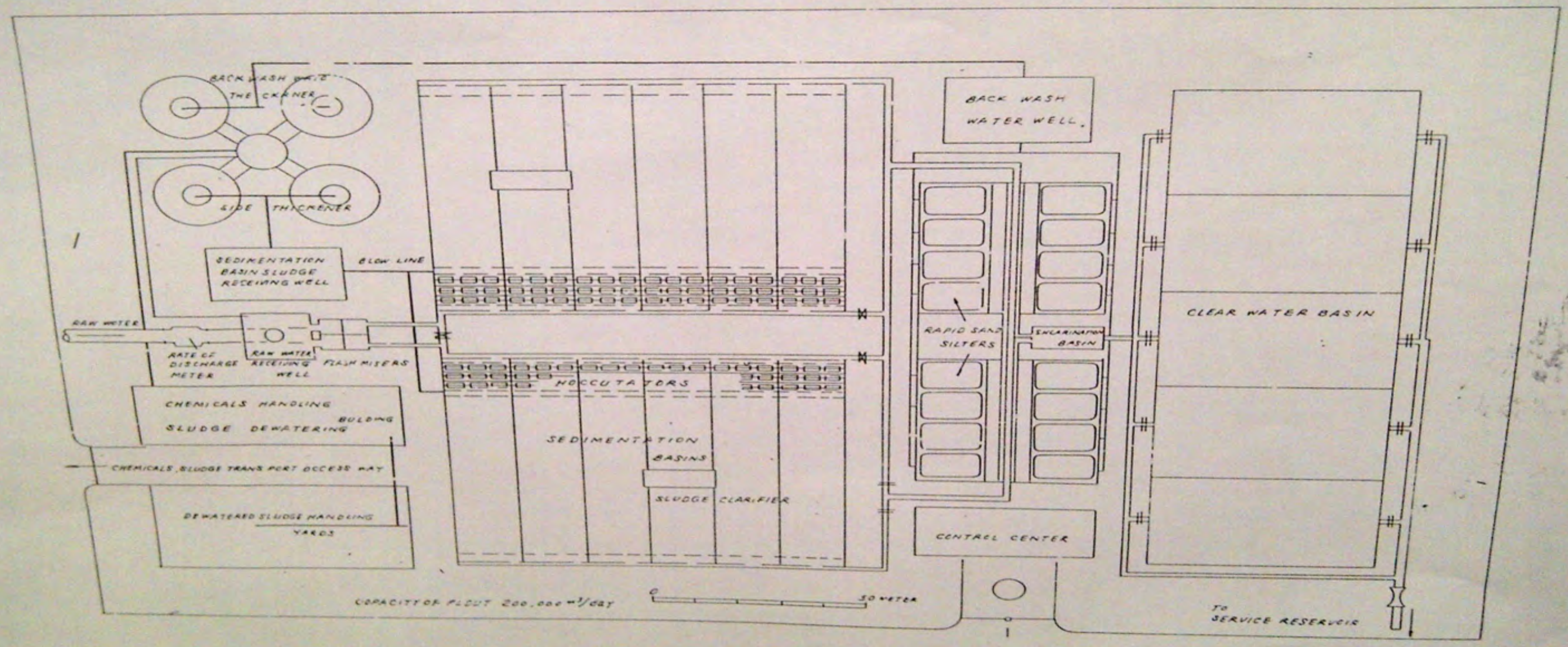

Fig. 2-8 Plan of A Rapid Sand Filtration Plant

04. ASSIGNMENT

TAHAPAN PERANCANGAN IPAM

1. Suatu IPAM akan dibangun untuk melayani kebutuhan air minum di sebuah kota. Sebutkan dan jelaskan tahapan-tahapan yang perlu dilakukan untuk merancang IPAM tsb.
2. Jelaskan teknologi pengolahan yang terdapat pada Tabel 2-11 berdasarkan unsur-unsur yg terdapat dalam air bakunya (kualitas air). Analisis harus dilakukan per-unsur dan mencakup semua simbol yang tertera dalam tabel tsb (O, E, S).

3. *Due date*: minggu depan sehari sebelum kuliah jam 23.59

THANKS!

Does anyone have any questions?
Please submitted via moodle

CREDITS

- Presentation template by Slidesgo
- Icons by Flaticon
- Infographics by Freepik
- Author introduction slide photo created by Freepik
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slidesgo

TLB 314 PDIPAM

Dosen: Rachmawati S. Dj.

Week 5

Water Intake

Semester Genap 2025/2026

Introduction

Sub-Topics

About the Sub-Topics

01

Introduction

Sub CP MK Week 5 & 6

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
5-6	6.2	Mampu menjelaskan *preliminary treatment*; menganalisis dan merancang *intake* dan *grit chamber*; dan perlengkapannya secara tepat	Ketepatan dalam menjelaskan *preliminary treatment*; menganalisis dan merancang *intake* dan *grit chamber*; dan perlengkapannya secara tepat	Tugas, UTS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 2*50 menit/minggu ▪ Rangkaian proses SPAM: 1*3*50 menit	5%
7	UTS					

WHAT IS THIS TOPIC ABOUT?

Preliminary treatment: bar screen, grit chamber, alat ukur debit dan intake

Definition of concepts

Preliminary treatment

Removal of wastewater constituents (rags, sticks, floatables, grease, grit) causing OM problems with the treatment operations, processes & ancillary systems

Alat ukur debit

To monitor debit

Bar screen

To remove materials from raw water

Intake

To collect surface water

Grit chamber

To settle grit by gravitation

Fundamental concept of water supply system

To deliver safe water to the customers

Extracted from

Al-Layla, M. A., et al.
Water Supply Engineering Design
Ann Arbor Science Publishers
Inc., 1977, Michigan

02

Sub-Topics

Sub-Topics

- Factors to be considered in the location of an intake
- Reservoir intake
- River intake
- Direct intake
- Canal intake
- Elements of an intake
- Design criteria
- Examples

03 ABOUT SUB-TOPICS

03

Factors to be considered in the location of an intake

Factors to be considered in the location of an intake

No fast current

Damage the intake interruption in the water supply

Ground should be stable

straight section is preferable risk of erosion is minimum

Free from obstacles

Inlet should be well below the surface of the river/the lake

Receive cooler water river

Prevent the entry of floating matter

Factors to be considered in the location of an intake

- Inlet should be well below above the bottom of the water body
- Prevent the entry of suspended matter near the bottom
- Located at some distance from the bank
- Avoid possible contamination of the bank
- Located on the upstream of the town
- Main current

Factors to be considered in the location of an intake

Lowest water level

Navigation facilities

Curtain walls

divert water into intake structures at the bank
- to draw clear water from the stream

Construction of intake structures, coarse & fine screen

- won't be damaged by floods
- safe from scouring or silt deposition

Factors to be considered in the location of an intake

Lowest water level

Navigation facilitis

Curtain walls

divert water into intake structures at the bank

- to draw clear water from the stream

Construction of intake structures, coarse & fine screen

- won't be damaged by floods
- safe from scouring or silt deposition

Factors to be considered in the location of an intake

Provision of coarse & fine screen

- Floating matter may not enter the supply system
- safe from scouring or silt deposition

Provision of inlets at various water levels

- anticipate the fluctuation of the water level (Fig. 4.28).
If the fluctuation >>>
- a small weir across the river stream

Once the water level is constant & river bank is steep

- intake can be constructed adjacent to the bank

Factors to be considered in the location of an intake

Once the water level is constant & river bank is steep

- intake can be constructed adjacent to the bank
- water is drawn via a horizontal pipe (Fig. 4. 29)

Inlet is provided with a coarse screen & strainers,

and firmly anchored (Fig. 4. 30)

03

River Intake

Fig. 4.28: River intake

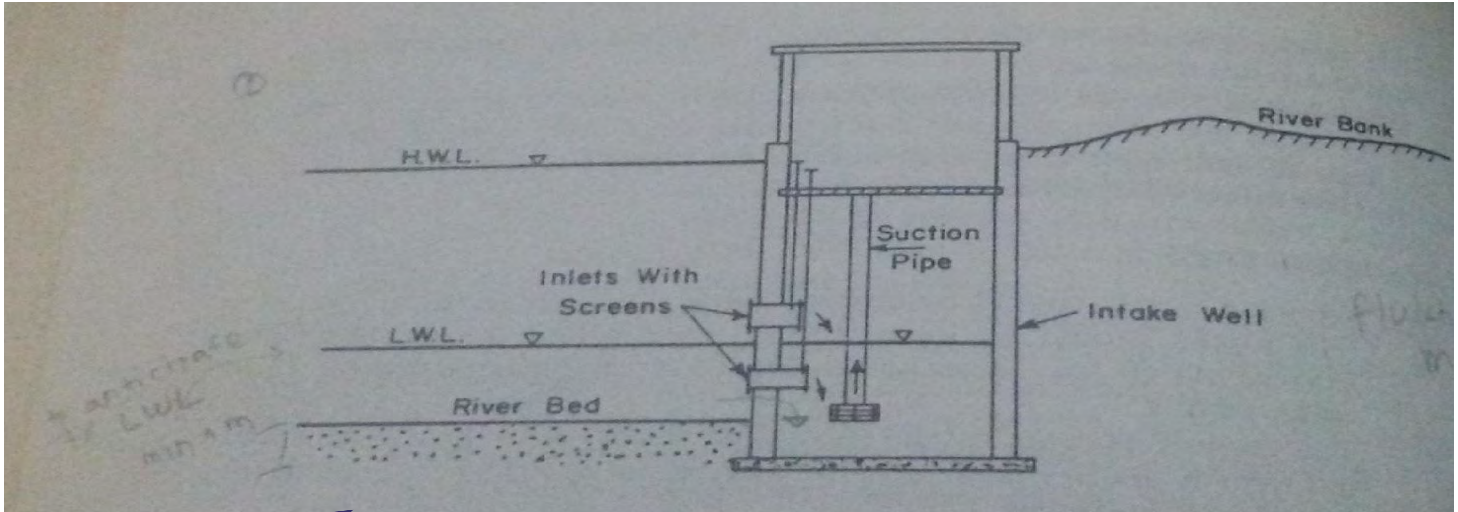


Figure 4.28. River intake.

River intake

Fig. 4.29: River intake

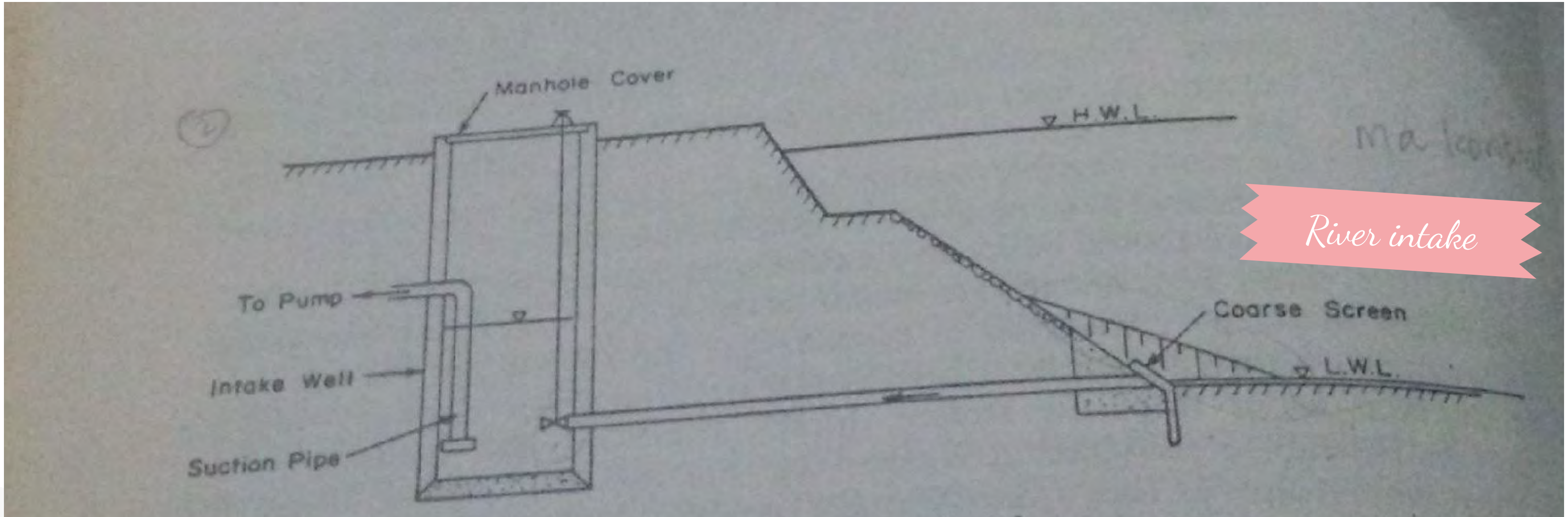


Figure 4.29. River intake.

Fig. 4.30: River intake

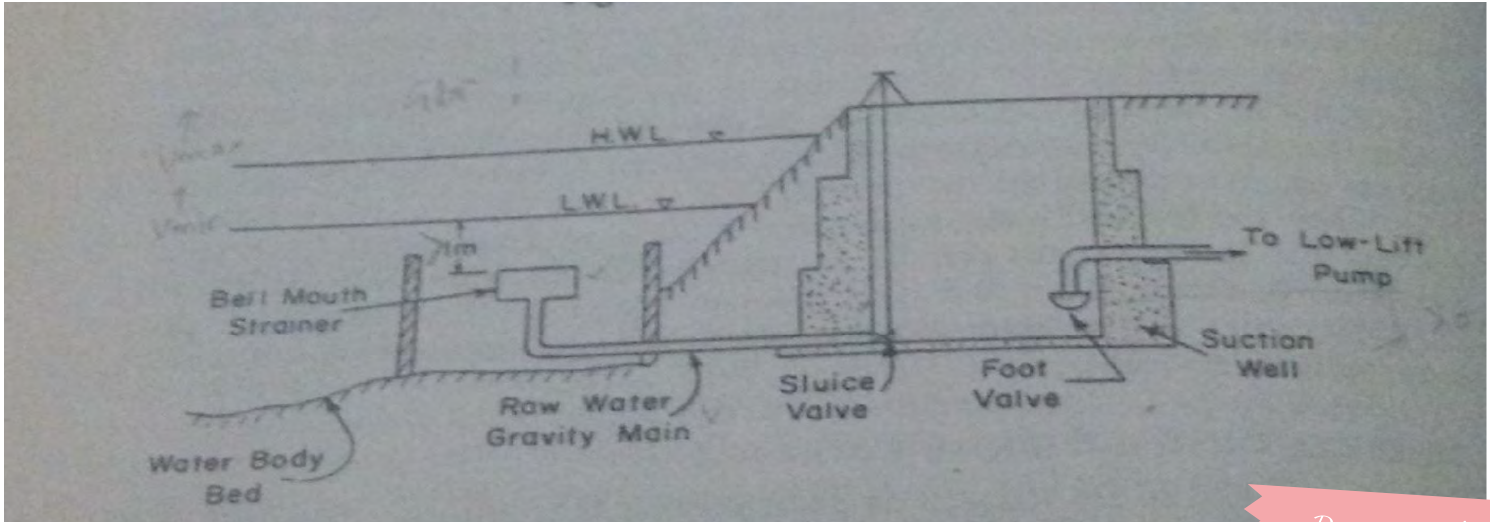


Figure 4.30. River intake.

River intake

03

Direct Intake

Direct Intake (Fig. 4.31)

In deep waters

Cheaper

Used sutably once:

The source is deep i.e. rivers, lakes

The embankment is resistant to erosion & sedimentation

Fig. 4.31: Direct intake

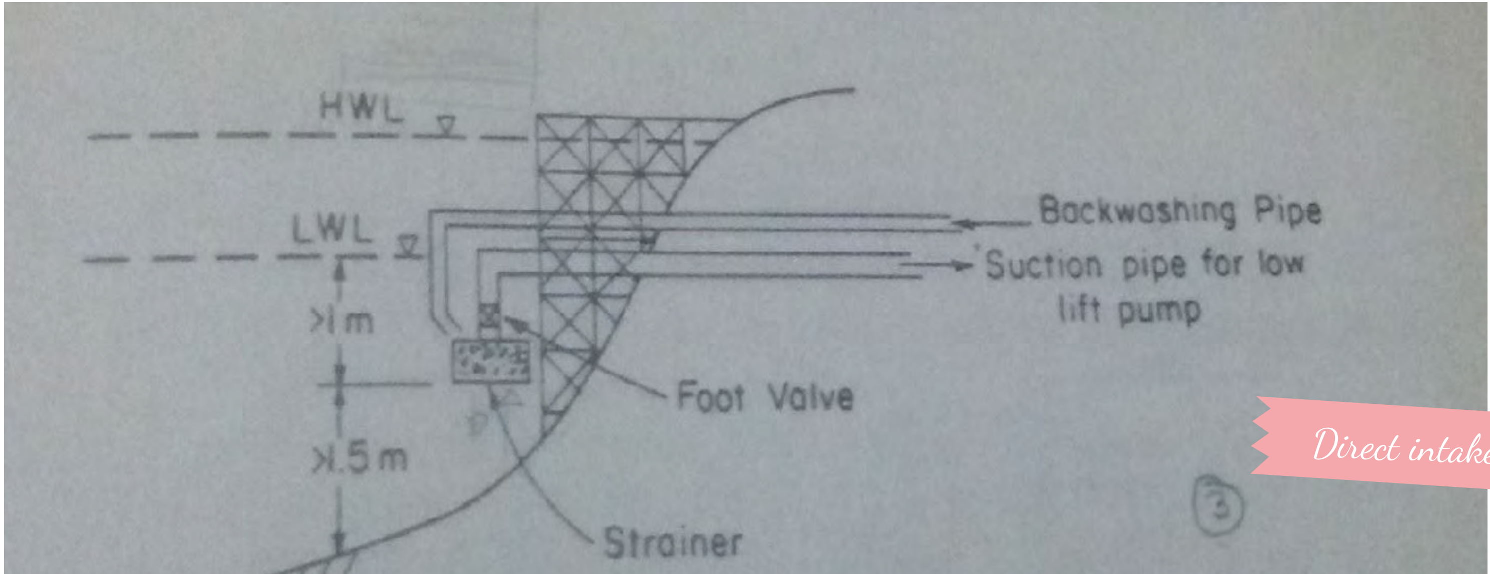


Figure 4.31. Direct intake.

03 ABOUT SUB-TOPICS

03

Canal Intake

Canal intake

Once water is drawn from the canal

- a masonry chamber with an opening is built partially in the canal bank
- the opening is provided with a coarse screen (Fig. 4.32)
- from the chamber, water is drawn by a pipe having a bell mouth covered with a perforated hemispherical cover.
- the area of the hole in the cover = 1/3 of the hemisphere.
- due to the construction of the chamber in the canal :
  - the width of the canal is reduced
  - increase in the velocity
  - scour the soil
  - the approaches in the upstream & downstream are lined with rip-rap.

Fig. 4.32: Canal intake

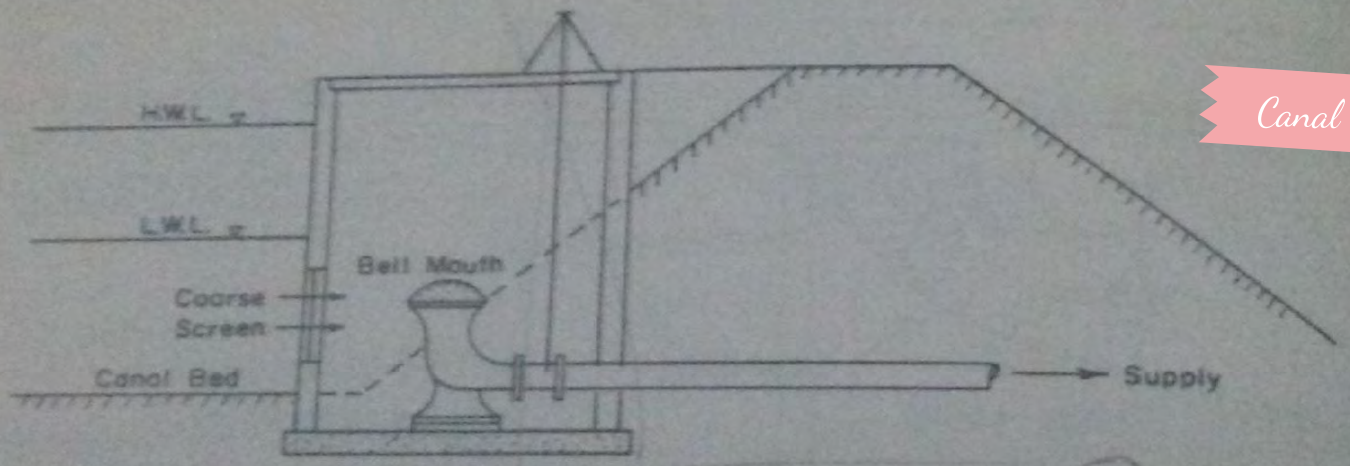


Figure 4.32. Canal intake.

Canal intake

03

Reservoir Intake

Reservoir intake

- At the spillway section (Fig. 4.33) or
- Near the toe of an earthen dam (Fig. 4.34)
- The foundation of the tower is separated from that of the dam constructed on the upstream side.
- To compensate for water level fluctuations inlets at various levels.
- Once gravity takes control water tower is not required (Fig. 4.34).

Fig. 4.33: Reservoir intake

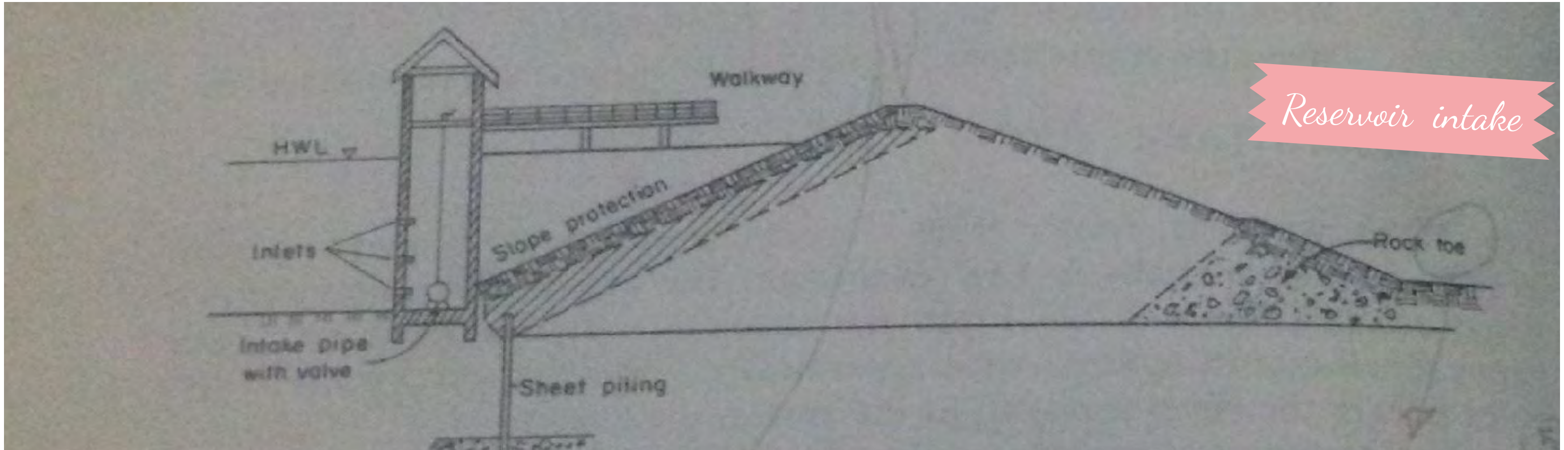
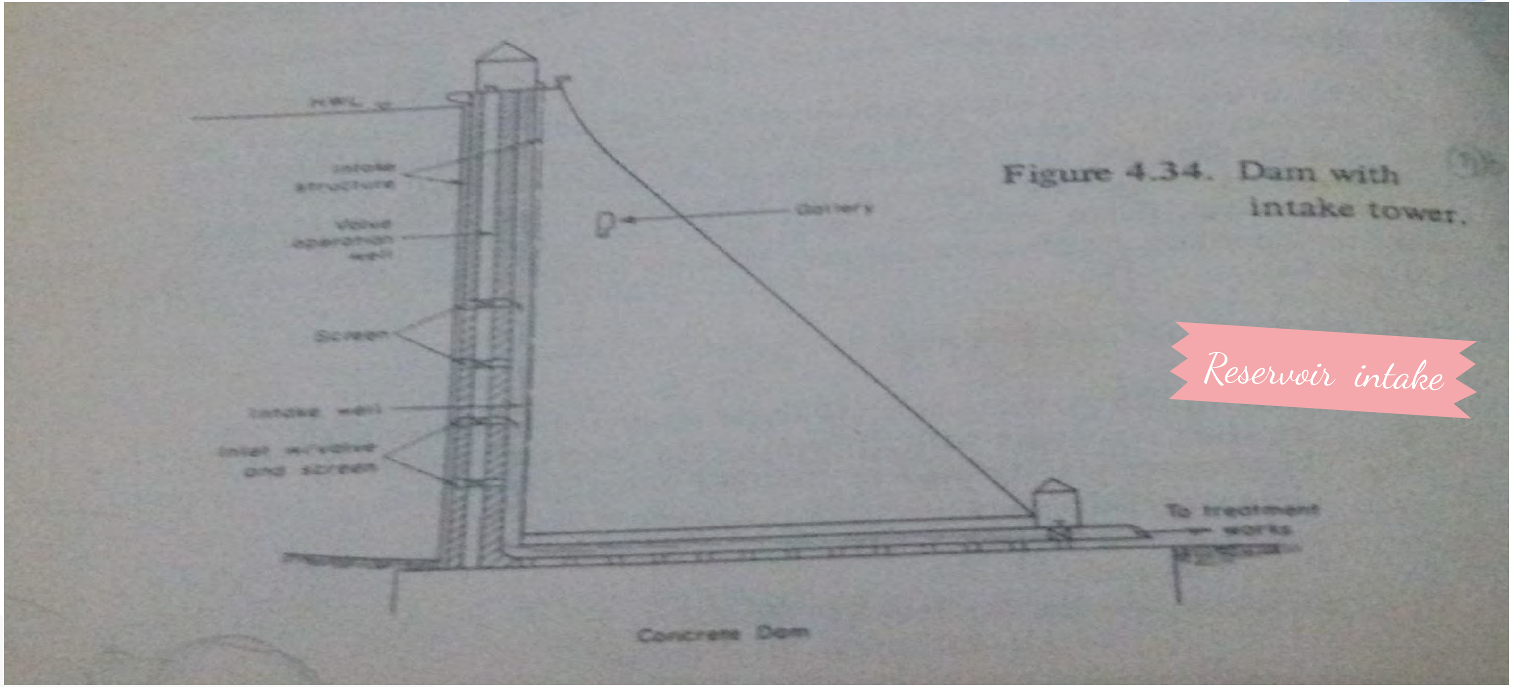


Figure 4.33. Dam with intake tower.

Fig. 4.34: Reservoir intake



03

Elements of an intake

Elements of an intake

1. Bell mouth strainer or cylindrical strainer (Fig. 4.32).
2. Strainer structure & arrangements for its protection
3. Raw water gravity pipe or channel (Fig. 4.30)
4. Gate or sluice-valve (Fig. 4.30)
5. Suction well (intake well) (Fig. 4.30)
6. Foot valve (Fig. 4.30)
7. Suction pipe for the low lift pipe (Fig. 4.29).

03 ABOUT SUB-TOPICS

03

Design criteria

Bell mouth strainer

1. Velocity via the strainer hole = 0.15 – 0.30 m/s
   Recommendation: near the lower limit prevent the entry of impurities.
2. Opening of the hole = 6-12 mm diameter
3. The gross area of the strainers = 2 x the effective area (=the total area of the holes).

Cylindrical strainer

= bell mouth strainer

Should be used once there is a high head of water above the strainer.

If it does not have holes at the top should be 0.6-1 m below the lowest water level

If has should be > 1 m below the lowest water level

Raw water gravity pipe

1. To prevent sedimentation & erosion velocity should be 0.6-1.5 m/s.
2. The pipe is sized such that:

    the velocity at the LWL > 0.6 m/s

    At the HWL < 1.5 m/s

     knowing the head & velocity diameter can be selected properly.

Suction well (intake well)

1. At least 2 wells maintenance factors
2. Detention times at least 20 min, or the well must be large enough to enter for cleaning.
3. The bottom of the well at least 1m below the river bed or 1.52 m below the LWL.
4. The height of the foot valve above the bottom of the well should not < 0.6 m
5. Should be water tight & constructed of durable material i.e. reinforced concrete
6. Wall thickness ≥ 20 cm.
7. Heavy enough to withstand the uplift pressure

Suction pipe of low lift pump

- The velocity in the pipe should be 1.0 m/s – 1.5 m/s
- The difference in height between the LWL and the center of the pump should be not more than 3.7 m
- Once the level of the pump > LWL the suction distance should be < 4 m.
- A pump located below the LWL with a flooded suction line is preferable economically

Backwashing pipe for cleaning foot valve & strainer

1. Velocity in the pipe should not be < 3 m/s.
2. Treated water should be used
3. The quantity of backwash water = 1/3 flow in the suction pipe.

03

Examples

Example 4.8

Design the suction pipe & backwashing pipe for a flow = 3,790 L/min

Solution for example 4.8

Suction pipe

- Assume the velocity of water through the suction pipe = 1.5 m/s.
- A cross = Q/V = 3,790 L x 1,000L/m^3/min/ (1.5 m/s x 60 s/min) = 0.042 m^2
- D = $(4A/\pi)^{1/2}$ = $(4 \times 0.042\ m^2/\ \pi)^{1/2}$ = 0.23 m =230 mm □ 250 mm

Backwashing pipe

- Q for bw = 1/3 Q = 1/3 x 3,790 L/min = 1,263.33 L/min
- Assume the velocity of water in the bw pipe = 3.05 m/s
- A cross = Q/V = 1,263.33 Lx 1,000L/m^3/min/ (3.05 m/s x 60 s/min) = 0.007 m^2
- D = $(4A/\pi)^{1/2}$ = $(4 \times 0.007\ m^2/\ \pi)^{1/2}$ = 0.094 m = 94 mm □ 100 mm

Example 4.9

Design a strainer for a flow = 3,790 L/min

Solution for example 4.9

Assume the velocity through the strainer = 0.15 m/s

- Q = AV; A = effective area, V = velocity of water
- A = Q/V = 3,790 L x 1,000L/m^3/min/ (0.15 m/s x 60 s/min) = 0.42 m^2
- Gross area = 2A = 2 x 0.42 m^2 = 0.84 m^2

For the bell-mouth strainer:

D = $(4A/\pi)^{1/2}$ = $(4 \times 0.84\ m^2/\ \pi)^{1/2}$ = 1.034 m = 1034 mm 1100 mm

For the cylindrical strainer without holes on the top and assuming a height of 0.61 m:

- Perimeter = Gross area/h = 0.84 m^2/0.61 m = 1.312 m
- D = Perimeter/π = 1.312 m/3.14 = 0.42 m

Example 4.10

Design a suction well (intake well) for a flow = 3,790 L/min if the HWL = 9 m and the LWL = 4.27 m above the river bed. Ground level = 9.76 m above the river bed.

Solution for example 4.10

Assume the detention time, td = 20 min

- Vol of well = Q x td = 3,790 L/min x 20 min = 75,800 L
- Choose 2 wells O & M
- Vol of each = 75,800 L/1,000 L/m^3 /2 = 37.9 m^3
- The bottom of well will be located 1.5 m below the LWL
- Effective depth of well = (9- (4.27 – 1.5)) m = 6.23 m

Assume a free board = 0.61 m

- total depth of well, h = 6.23 m + 0.61 m = 6.84 m
- As = Vol/h = 37.9 m^3/ 6.84 m = 5.54 m^2
- Using a circular well, d = $(4A/\pi)^{1/2}$ = $(4 \times 5.54\ m^2/\ \pi)^{1/2}$ = 2.66 m = 2660 mm 2700 mm

Thanks!

TLB 314 PDIPAM

Dosen: Rachmawati S. Dj.

Week 5

Desain Intake

Genap 2025/2026

https://www.pikiran-rakyat.com/bandung-raya/pr-01324839/semarangku?page=2

Sub CP MK *Week 5 & 6*

Problem Set

- Suatu BPAM direncanakan akan menghasilkan produksi air minum rata-rata sebesar 250 L/det.
- Faktor maksimum per jam adalah 2,5 dan maksimum per hari adalah 1,75.
- Air baku diambil dari sungai.
- Fluktuasi muka air minum: maksimum + 8,5 m, minimum + 7,0 m.

1. Rencanakan saluran pembawa, *bar screen*, *intake* dan rumah pompa.
2. Gambarkan denah secara keseluruhan dan potongan memanjangnya.
3. Gambarkan *cross section* untuk setiap unit tersebut.

Kriteria

- Dasar sumur intake = 1,40 m dari muka air minimum.
- Waktu detensi di sumur intake = 30 menit.
- *Free board* = 20% dari tinggi efektif air.
- Kecepatan melalui:
  - *strainer* = 0,2 m/det,
  - *raw water gravity pipe* = 0,8 m/det,
  - *suction pipe* = 1,0 m/det,
  - *backwashing pipe* = 3,1 m/det,
  - saluran pembawa = 0,6 m/det
- Air baku dari sumur intake dipompa (pompa diletakkan 0,4 m di atas muka tanah) ke sebuah tanki air yang terletak di ketinggian + 4,0 m dari muka tanah.
- Lebar sumur pembawa = 0,7 m.
- Diameter *bar screen* = 70 mm; faktor bentuk β = 1,79; jarak antara bar = 50 mm; kemiringan bar = 60^0.

Saluran Pembawa

Sumber: PDAM Tirtawening Kota Bandung, 2013

Sumber: PDAM Tirtawening Kota Bandung, 2013

Saluran Pembawa

- V = 0.5-1.5 m/s 0.6 m/s
- Q yang dipakai: ????
  - Q av ???
  - Q maks/hari ???
  - Q maks/jam ???
  - *safety factor* ???

Mencari dimensi saluran pembawa ???

- V = ...???
- Q = ...???
- A =....???
- Ac ???
- As ???
- L = ...???
- H = ...???
- H air ???
- *Free board* ???
- H saluran pembawa ???

Bar screen

https://jabar.antaranews.com/berita/123760/air-pdam-kota-bandung-keruh-akibat-banjir-bandang-di-sungai-cikalong

Bar screen

Jumlah *bar* yang diperlukan:

Lsp = nw + (n+1) b

Lebar efektif:

Le = (n+1) b

- Lsp = lebar saluran pembawa
- n = jumlah *bar* yg diperlukan
- b = lebar bukaan
  - *Fine screening* = (3-10) mm
  - *Medium screening* = (10-25) mm
  - *Coarse screening* = (50-100) mm
- w = diameter *bar*
- n + 1 = jumlah bukaan

Gambar

Bar screen

Kemiringan:

Sin 45 = Hsp/H'

Luas efektif:

Ac' = H' x Le

- H' = Hsp/sin 45
- Hsp = Hsaluran pembawa
- H'=batang miring
- Ac' = Luas efektif penampang
- Le = lebar efektif

Gambar

Sumber: WHO, 2019; Kementerian PUPR-1, 2015

Bar Screen

Kecepatan melalui bar screen:

$$Ac \times Vh = Ac' \times V'h$$

Kehilangan tek akibat perbedaan kec.:

$$h_v = V'h^2/2g$$

- Ac = luas saluran pembawa
- Vh = kec melalui saluran pembawa
- V'h = kec melalui *bar screen*
- Ac' = Luas efektif penampang
- hv = Kehilangan tek akibat perbedaan kec
- g = percepatan gravitasi

Gambar

Bar Screen

Penurunan ma melalui *bar*

$\Delta H = \beta (w/b)^{4/3} hv \sin 45$

Tinggi air setelah melewati *bar screen*

$Ha' = Ha - \Delta H$

- Δ H = Penurunan ma melalui *bar*
- β = faktor bentuk
- w = diameter *bar*
- b = bukaan
- hv = Kehilangan tek akibat perbedaan kec
- Ha’ = Tinggi air setelah melewati *bar screen*
- Ha = Tinggi air

Perencanaan *intake*

Sumber: Kementerian PUPR-2, 2014

Perencanaan *intake*

- Q yang dipakai: ????
  - Q av ???
  - Q maks/hari ???
  - Q maks/jam ???
  - *safety factor* ???
- Vol intake ??
- td = ???
- Jumlah intake ???

Sumber: Kementerian PUPR, 2015

Perencanaan *intake*

Gambar:
- ma maks
- ma av
- ma min
- dasar sumur
- *free board*
- *effective depth*
- *total depth*

- Area
  - Ac ??
  - As ??
- Bentuk well
  - *Rectangular*?
  - *Circular*?
- dimensi

Sumber: Kementerian PUPR-2, 2014

Perencanaan intake

- Strainer
  - V =
  - --> Why ??
  - d=
- Raw water gravity pipe
  - V =
  - --> Why ??
  - d=

- Suction pipe
  - V =
  - --> Why ??
  - d=
- Backwashing pipe
  - Q =
  - V =
  - --> Why ??
  - d=

Sumber: Kementerian PUPR-2, 2014

Sumber: Kementerian PUPR-2, 2014

Pompa

Sumber: Kementerian PUPR-2, 2014

Pompa

Daya pompa

$P = \rho g\, HQ/\eta$

Total head

$H = h + hf$

$H = hs + hd + hfs + hfd$

Gambar

- P = Daya pompa
- ρ = *density of fluid*
- g = percepatan gravitasi
- Q = debit
- H = *total head*
- hs = suction head
- hd = delivery head
- hfs = head losses on the suction head
- hfd = head losses on the delivery head

Total head

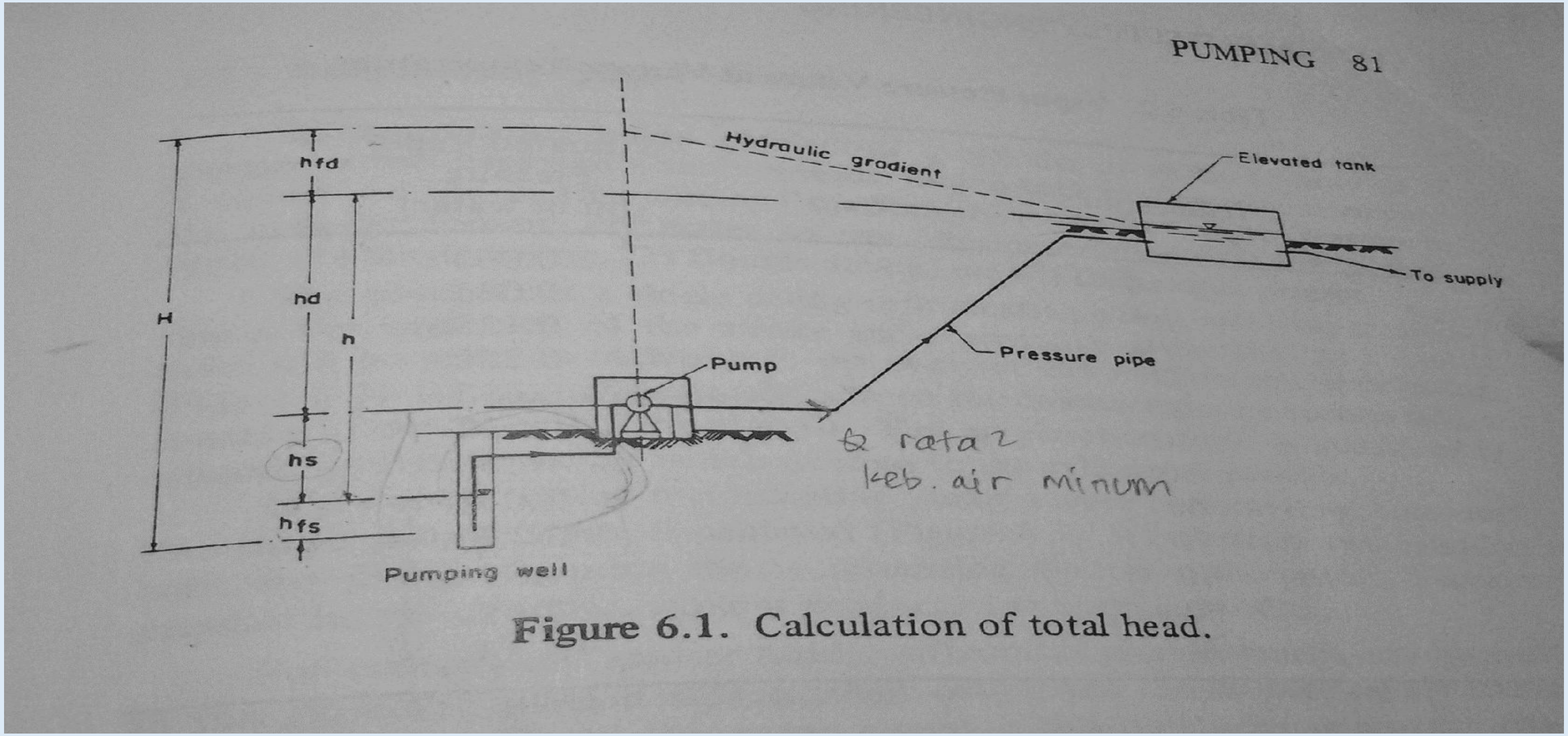


Figure 6.1. Calculation of total head.

Al-Layla., et al. 1977

Jumlah pompa

Q ≤ 1,895 L/min □ 2 pompa
- □ 1 working
- □ 1 standby

1,895 L/min < Q < 5,685 L/min □ 3 pompa
- □ 2 working
- □ 1 standby

5,685 L/min < Q < 11,370 L/min□ 4 pompa
- □ 3 working
- □ 1 standby

Q > 11,370 L/min□ 6 pompa
- □ 4 working
- □ 2 standby

Al-Layla., et al. 1977

Operation of > one pump

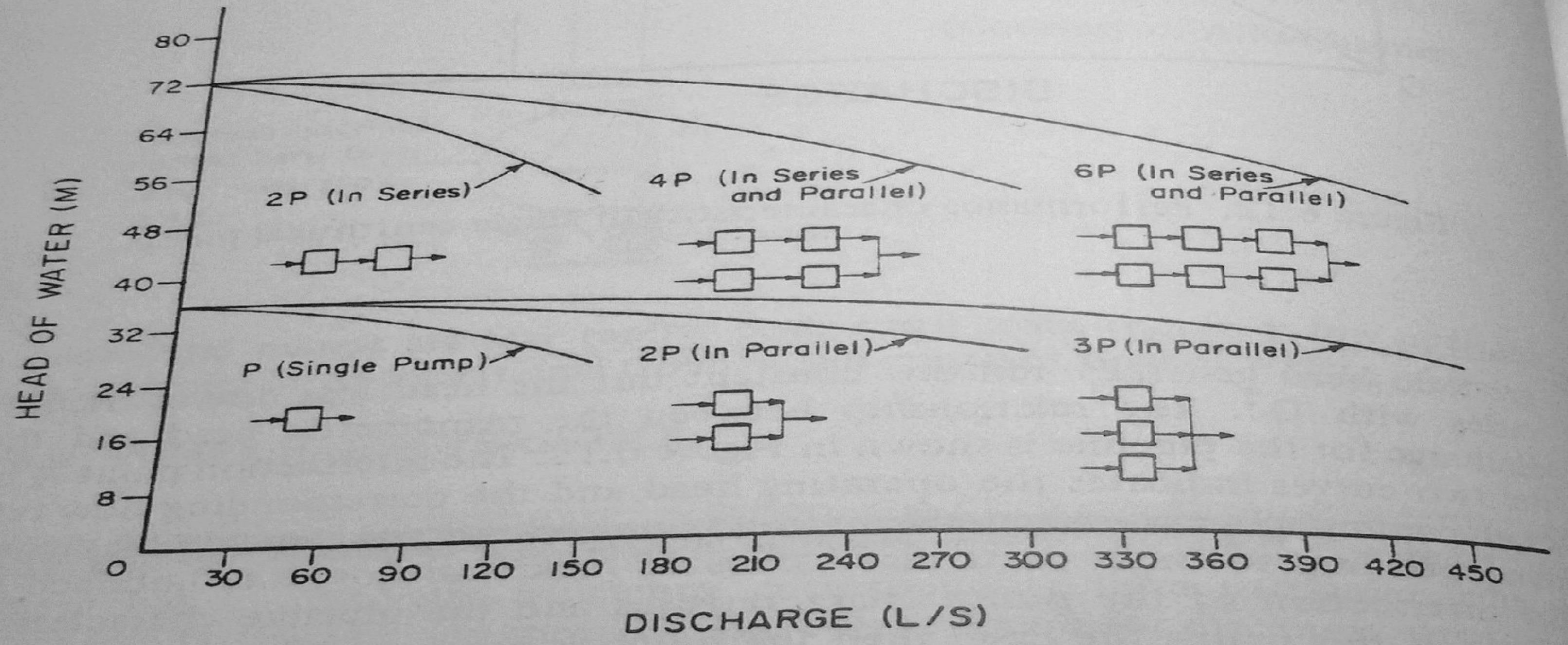


Figure 6.13. Performance characteristics of centrifugal pumps in series and parallel.

Al-Layla., et al. 1977

Rumah pompa

- *Sufficient space*
  - *repairing work easily*
  - *expansion additional pum unit*
- Jam pompa beroperasi
  - 22 hours M & O

Sumber: Kementerian PUPR, 2017

Rumah pompa

Peletakan pompa
- *series*
- *parallel*

Sumber: Kementerian PUPR, 2017

Sumber: Kementerian PUPR, 2017

Daftar pustaka

- *World Health Organization* (WHO), *Strengthening National Initiatives on Water Safety Plan (WSP) Implementation. Final Report*, September 2019
- Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR)-1, Evaluasi Rencana Pengamanan Air Minum (RPAM) di Perusahaan Daerah Air Minum (PDAM) Tirta Dharma Kota Malang, 2017
- Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR)-1, Dokumen Rencana Pengamanan Air Minum (RPAM) Perusahaan Daerah Air Minum (PDAM) Surya Sembada Kota Surabaya, 2015
- Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR), Bimbingan Teknis Provinsi Rencana Pengamanan Air Minum (RPAM) Penyelenggara Sistem Penyediaan Air Minum (RPAM), 2015
- Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR)-2, Dokumen Rencana Pengamanan Air Minum (RPAM) Perusahaan Daerah Air Minum (PDAM) Tirta Musi Kota Palembang, 2014
- Al-Layla, M. A., et al. ,Water Supply Engineering Design, Ann Arbor Science Publishers Inc., 1977, Michigan

Daftar pustaka

- Putra, Billy Mulya, Komentar PDAM Soal Keruhnya Air Baku di Kota Bandung, 10 Desember 2019, 07:44 WIB https://www.pikiran-rakyat.com/bandung-raya/pr-01324839/semarangku?page=2, diambil 16/01/2021, 12:24
- Rizalidi, Bagus Ahmad, Air PDAM Kota Bandung keruh akibat banjir bandang di Sungai Cikalong, 8 Desember 2019 16:23 WIB https://jabar.antaranews.com/berita/123760/air-pdam-kota-bandung-keruh-akibat-banjir-bandang-di-sungai-cikalong diambil 16/01/2021, 12:24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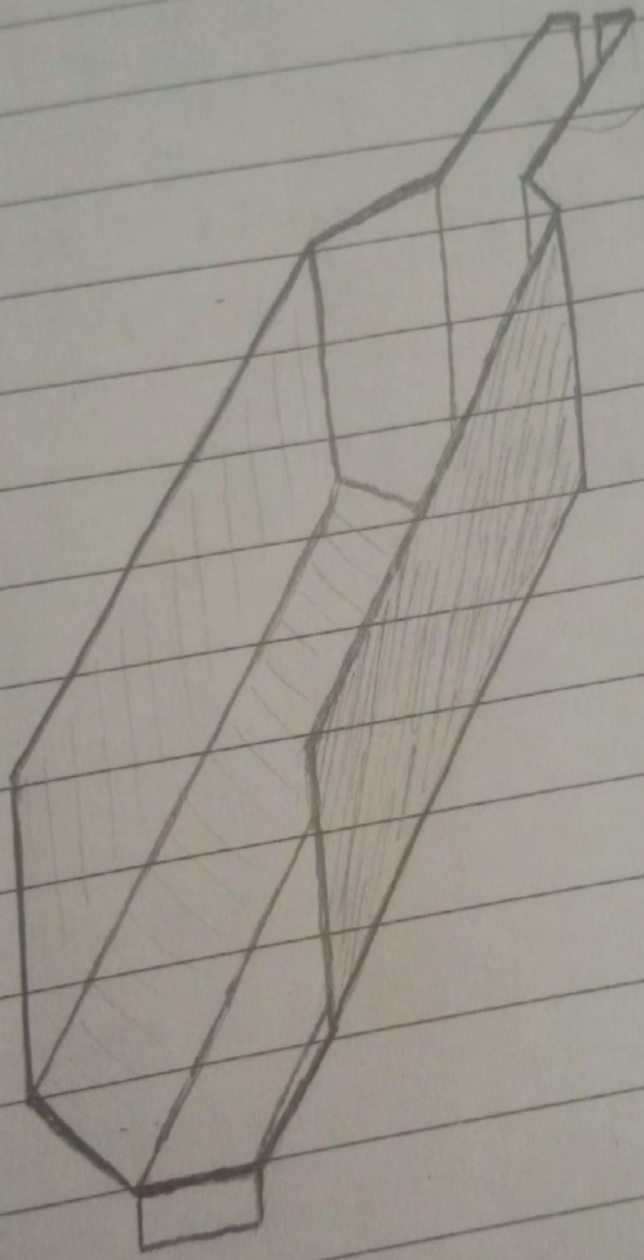
TLB 314 PDIPAM

Dosen: Rachmawati S. Dj.

Week 6

Grit Chamber
&
Flow Measurement Devices

Genap **2025-2026**



Sub CP MK *Week 5 & 6*

Extracted from

- Wastewater Treatment, Metcalf & Eddy, Inc., New York, USA, 1972
- Qasim, S. R., Wastewater Treatment Plants – Plannig, Design and Operation, CBS College Publishing, 1985
- Babbit and Bauman

INTRODUCTION

Grit chambers are designed to remove grit, consisting of:

- Sand
- Gravel
- Cinders (abu, arang)
- Or other heavy materials

- That have subsiding velocities or specific gravities substantially > the organic putresicible solids in (waste) water

Constituents

Grit also includes:

- Eggshells
- Bonechips
- Seeds
- Coffee grounds and
- Large organic particles such as food wastes

Objectives

Grit chambers are provided to:

- protect moving mechanical equipment from abrasion & accompanying abnormal wear
- Reduce formation of heavy deposits in pipelines, channels, and conduits
- Reduce the frequency of digester cleaning that may be required as a result of excessive accumulation of grit in such units.

Location

- May be located ahead of all other units in WTP where removal of grit would facilitate operations
- However, the installation of mechanically cleaned bar racks ahead of grit chambers facilitates operation of grit removal & cleaning facilities

Location

- When it is desirable to locate grit chambers ahead of waste-water pumps, this would normally involve placing them at considerable depth at added expense.
- It is therefore usually deemed more economical to pump the w/w, including grit, to GCs located at a convenient position ahead of the WWTP units, recognizing that the pumps may require greater maintenance than otherwise.

Design of GCs

Will depend on:

- The type selected
- Whether or not mechanical grit-removal equipment is provided
- The requirements of the selected grit-removal equipment
- Recent study:
- The majority of GC installations having a capacity > 1.5 mgd have been provided with mechanical cleaning equipment.

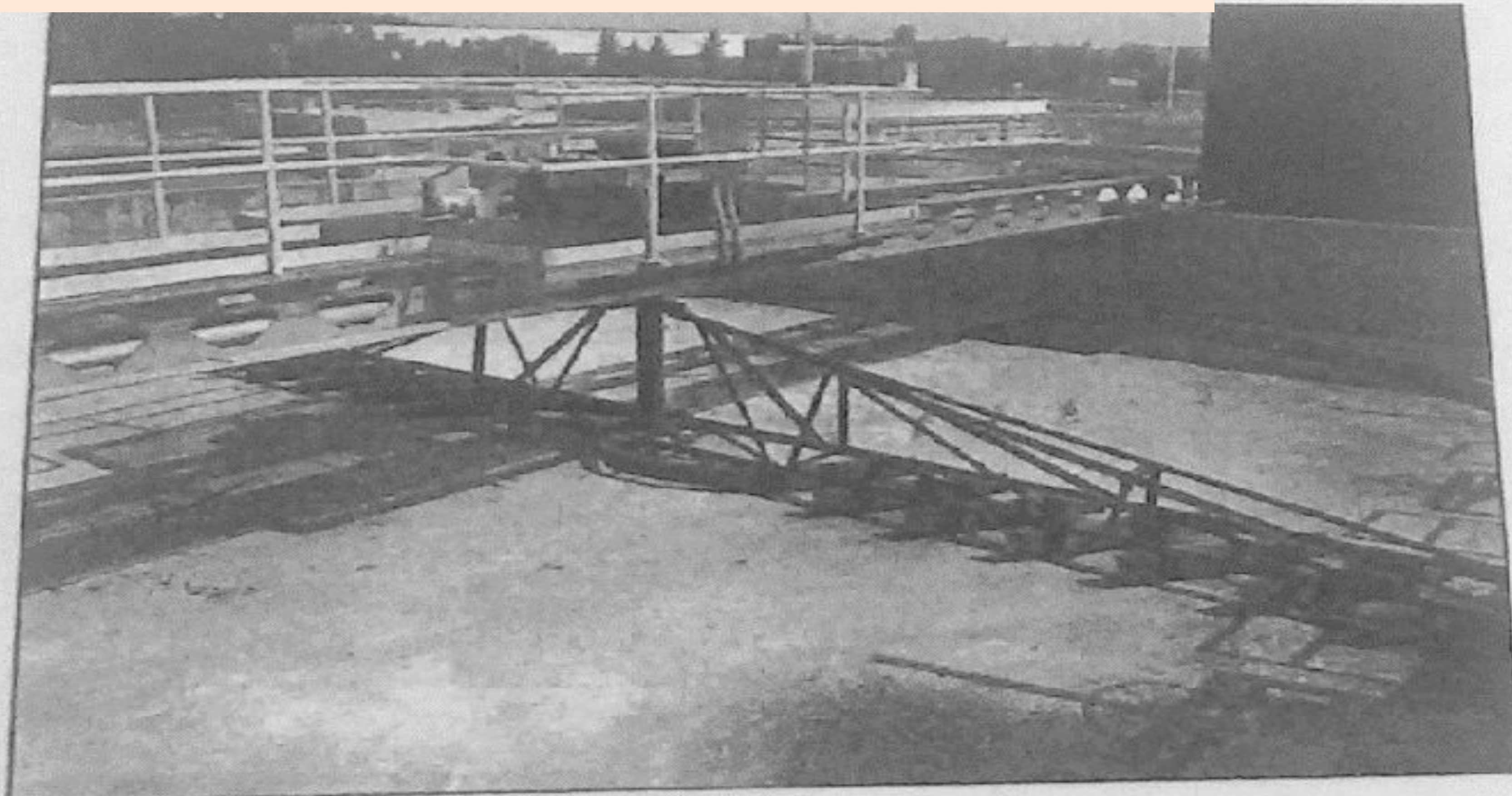
Types

2 general types:

1. Horizontal flow
2. Aerated

Horizontal flow

Typical square horizontal flow grit chamber



(b)

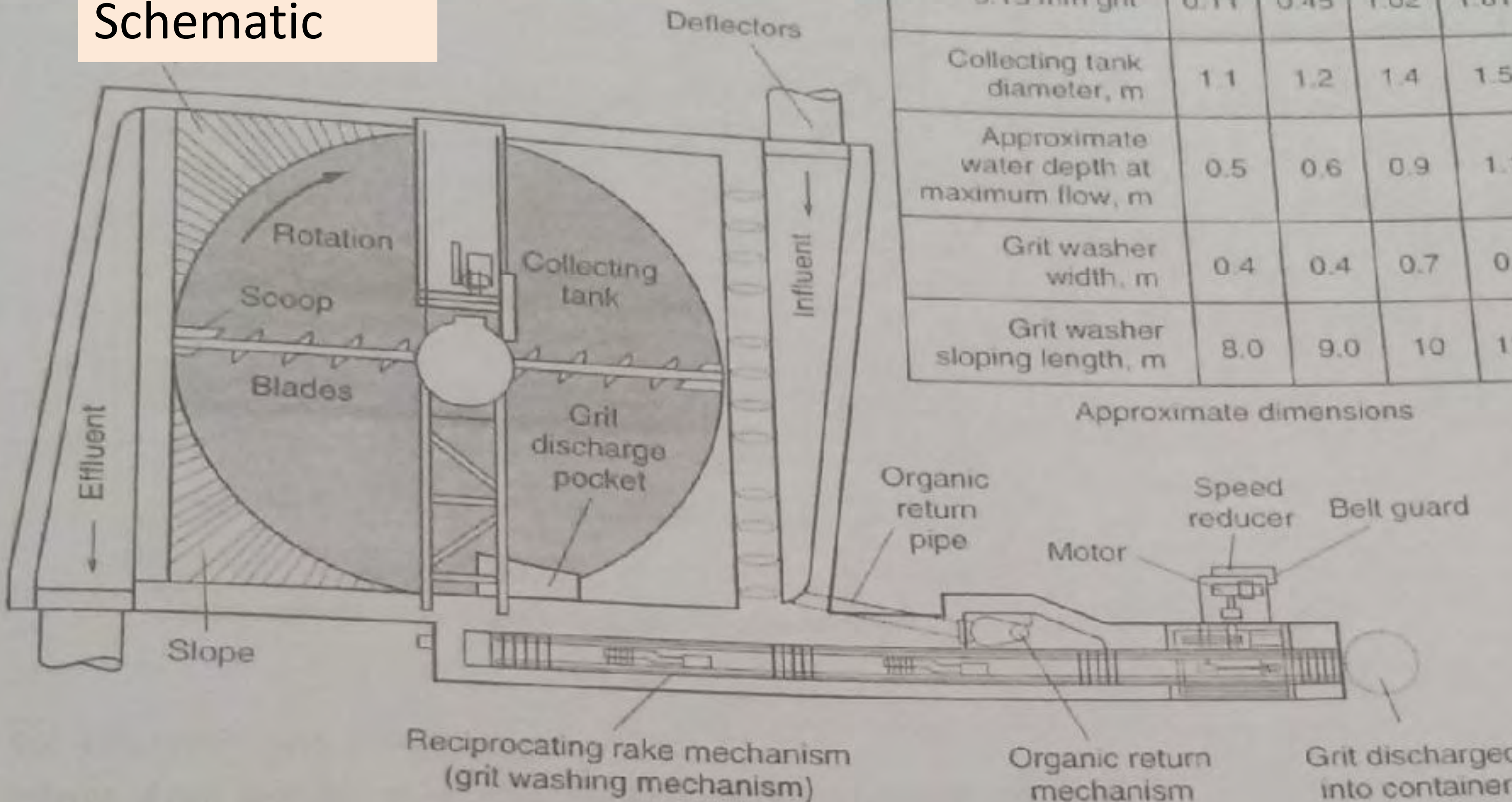
Photo of empty basin. The two rakes are used to move settled grit to the periphery for removal

Horizontal flow

Schematic

Collecting tank diameter, m	3.0	6.0	9.0	12.0
Max. flow, m³/s — 0.21 mm grit	0.17	0.70	1.58	2.80
Max. flow, m³/s — 0.15 mm grit	0.11	0.45	1.02	1.81
Collecting tank diameter, m	1.1	1.2	1.4	1.5
Approximate water depth at maximum flow, m	0.5	0.6	0.9	1.1
Grit washer width, m	0.4	0.4	0.7	0.7
Grit washer sloping length, m	8.0	9.0	10	12.0

Approximate dimensions



Note: m × 3.2808 = ft; m^3/s × 22.8245 = Mgal/d; mm × 0.03937 = in.

(a)

Horizontal flow

- The flow passes through the chamber in a horizontal direction,
- The straight-line velocity of flow being controlled by the:
  - dimensions of the unit or
  - Use of special weir sections at the effluent end

Aerated type

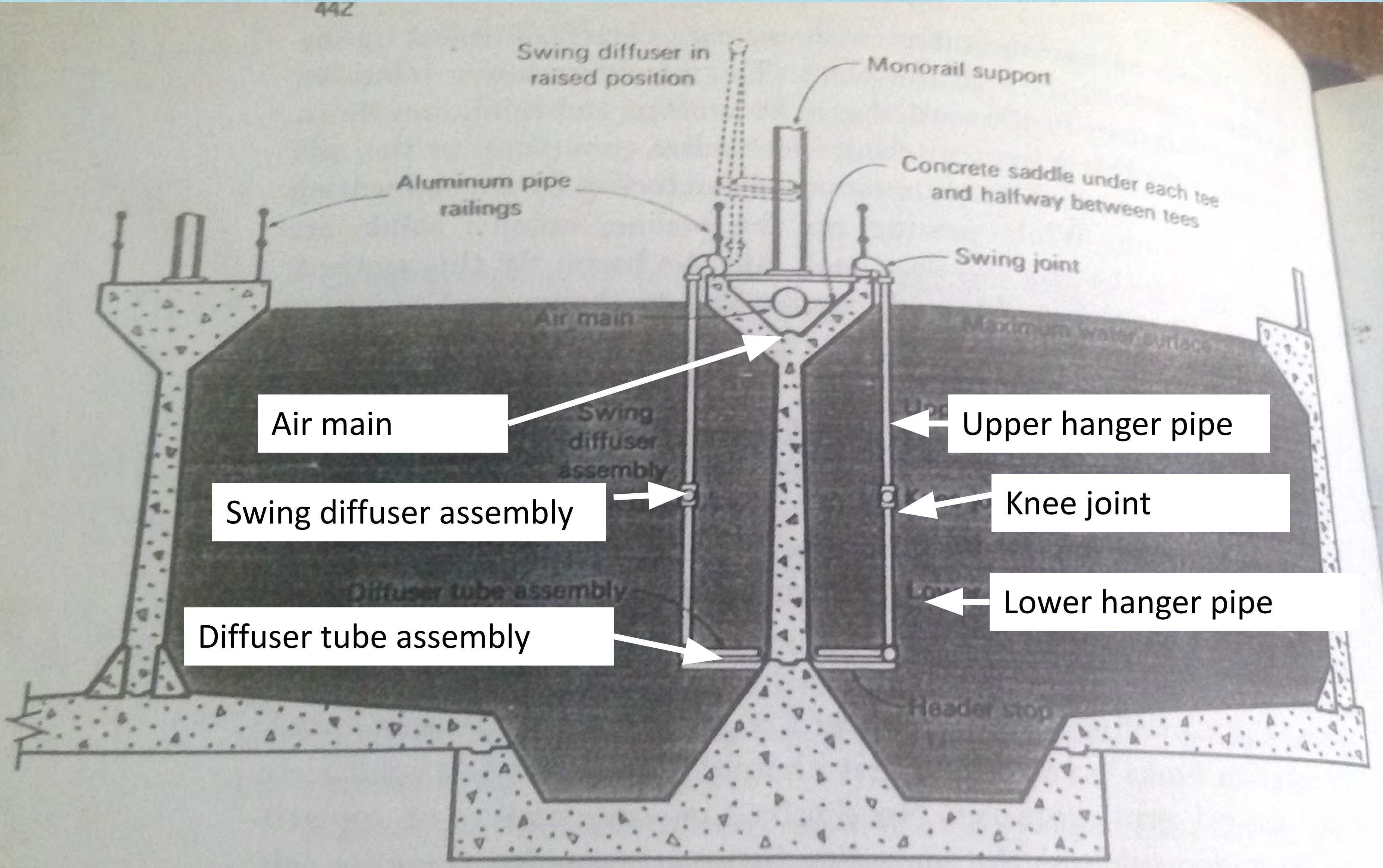
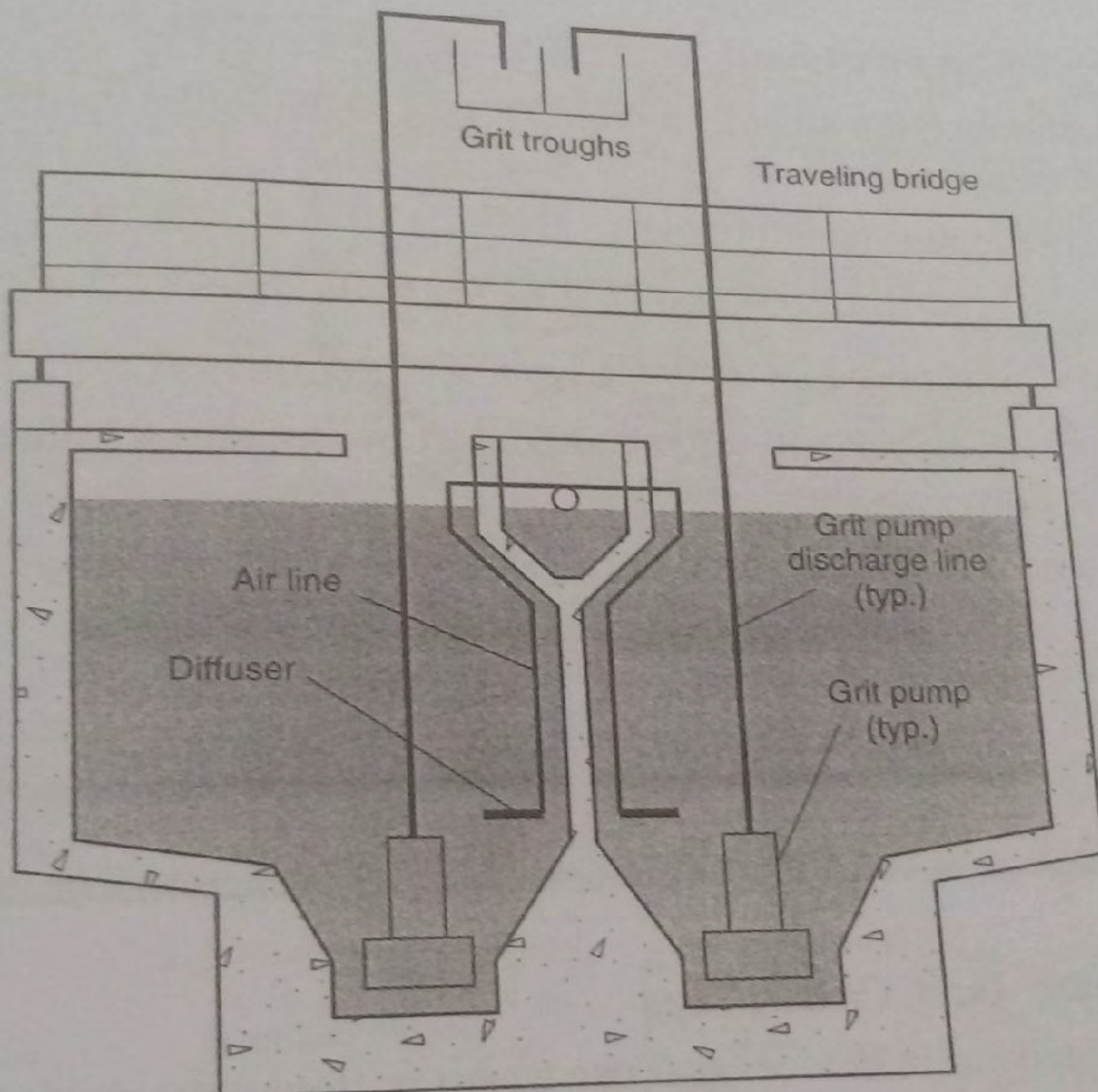


FIG. 11-9 Typical cross section of an aerated grit chamber.

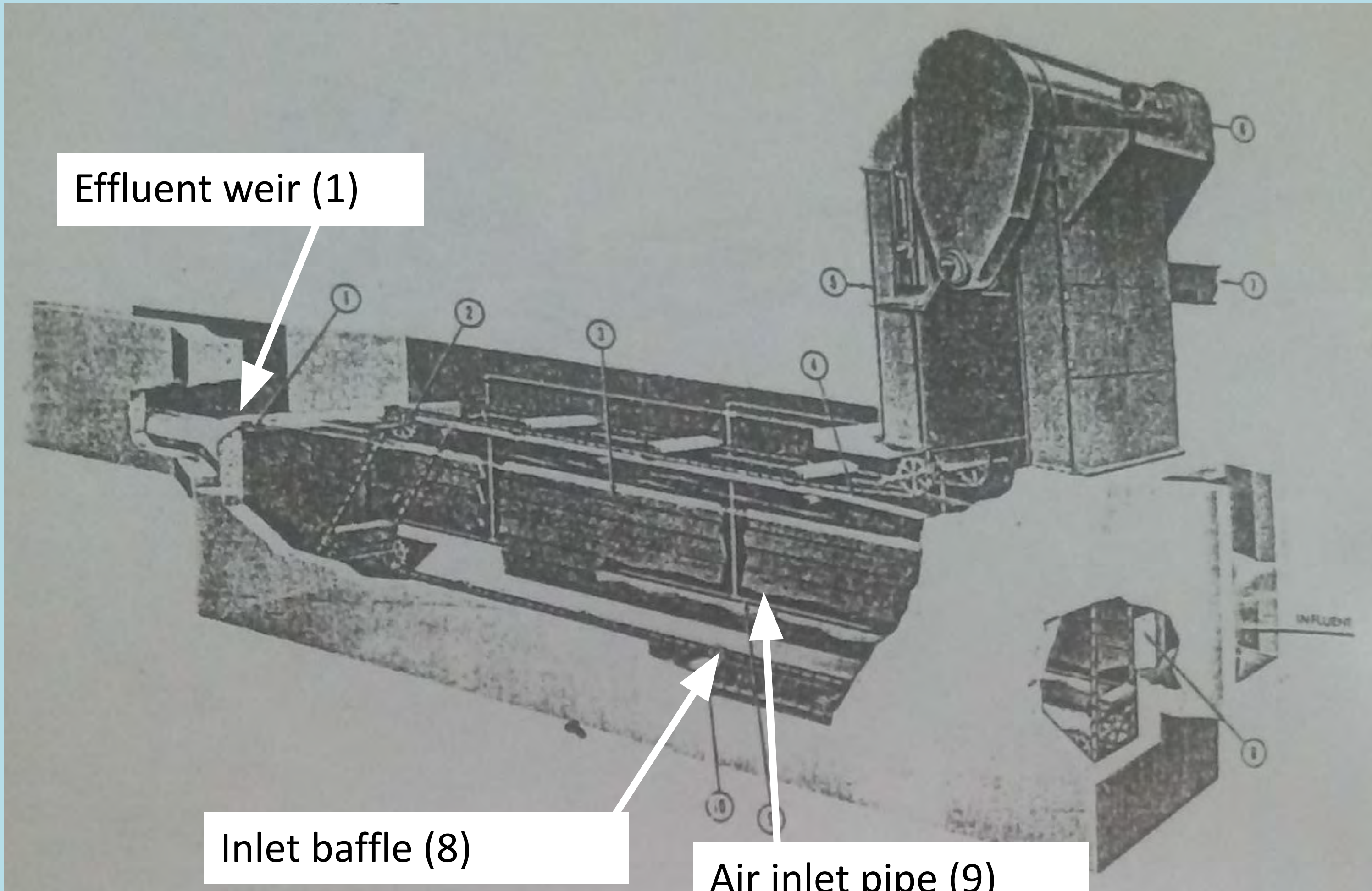
Aerated type

Figure 5–36

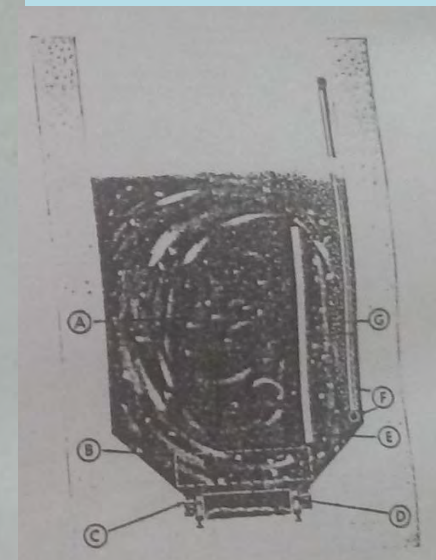
Aerated grit chamber with traveling-bridge-type grit removal system. Pumps are mounted on the traveling bridge for removal of grit from the grit hopper. The diffusers create the helical flow pattern as shown in Fig. 5–34.



Aerated type



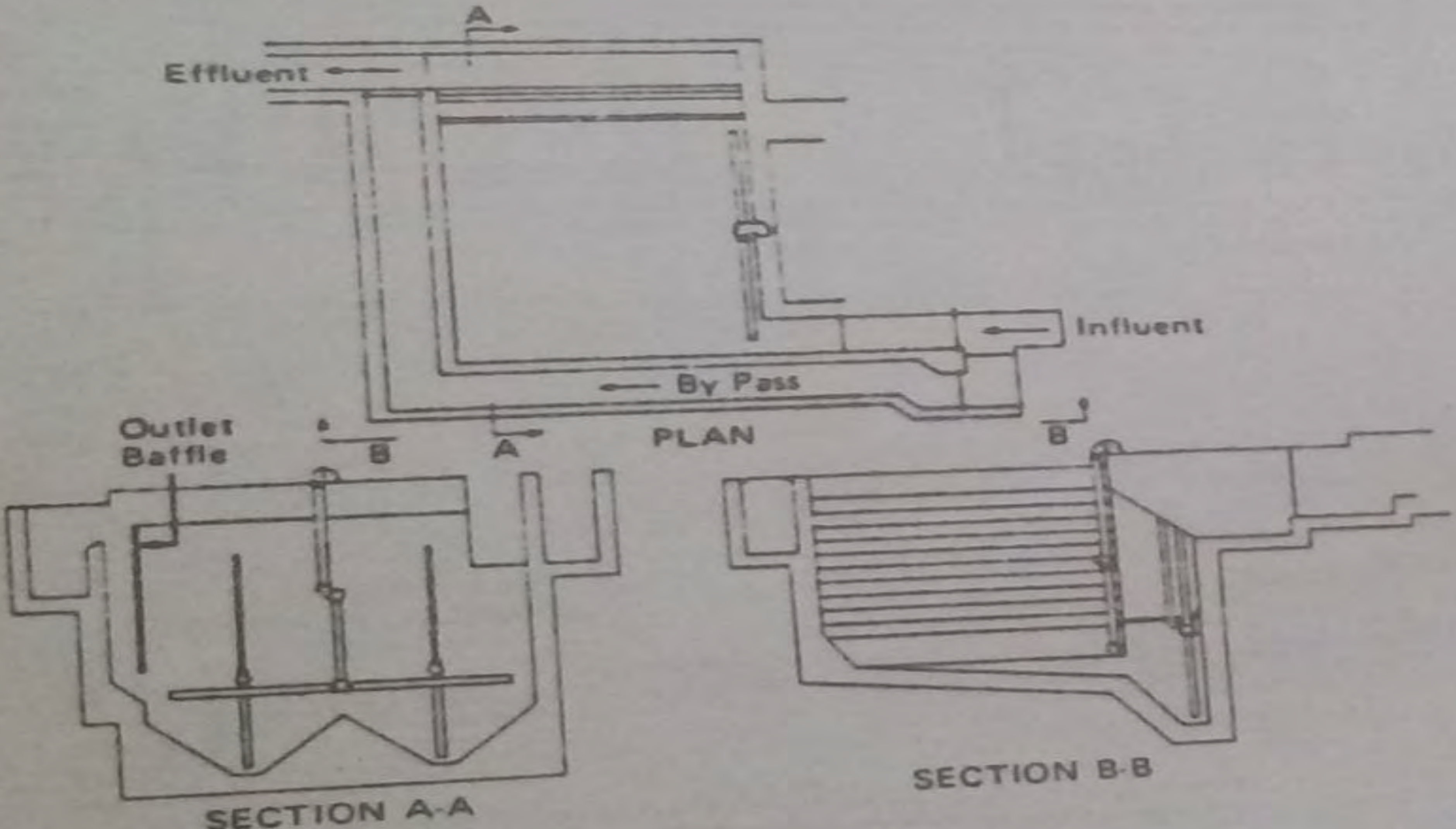
(b)



(c)

Figure 11-2 Details of Aerated Grit Chamber. (a) Components of aerated grit removal facility. 1. Effluent weir 2. Sprockets 3. Wooden circulation baffle 4. Guided chain support 5. Housing 6. Motorized drive unit 7. Screw conveyor 8. Inlet baffle 9. Air inlet pipe and headers 10. Chain and bucket collector mechanism. (Courtesy Envirex Inc., a Rexnord Company.) (b) Aerated grit chamber inlet and outlet arrangement. [From Ref. 6. Used with permission of Water Pollution Control Federation, and American Society of Civil Engineers.] (c) Simplified cross section of aerated grit removal facility. A. Flow through zone B. Grit and organic separation zone C. Collection chain guard D. Chain and bucket grit collector E. Circulation baffle F. Air inlet pipe and header G. Air circulation and grit conditioning zone. (Courtesy Envirex Inc., a Rexnord Company.)

Aerated type – inlet & outlet arrangement



(b)

Grit removal

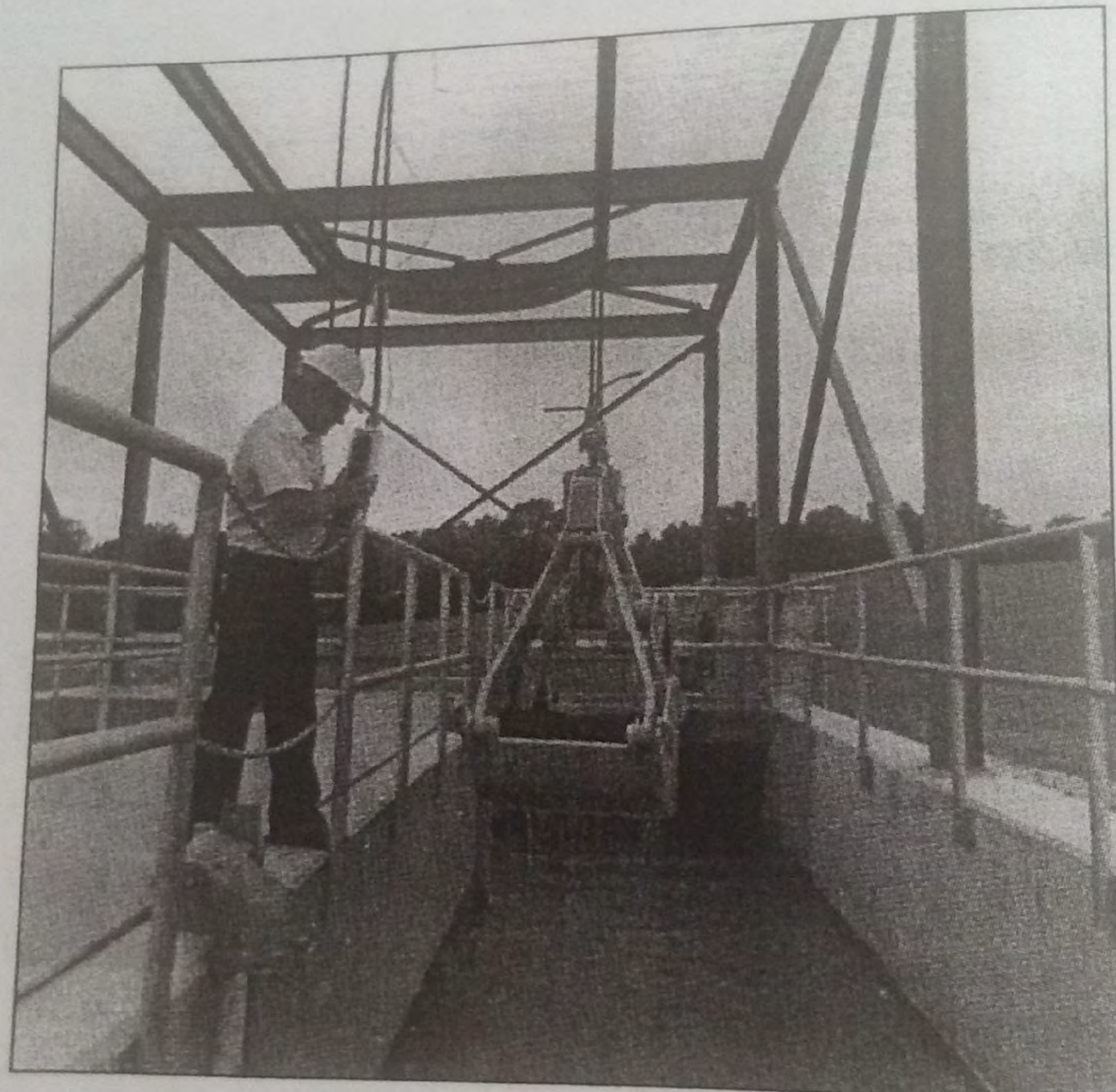
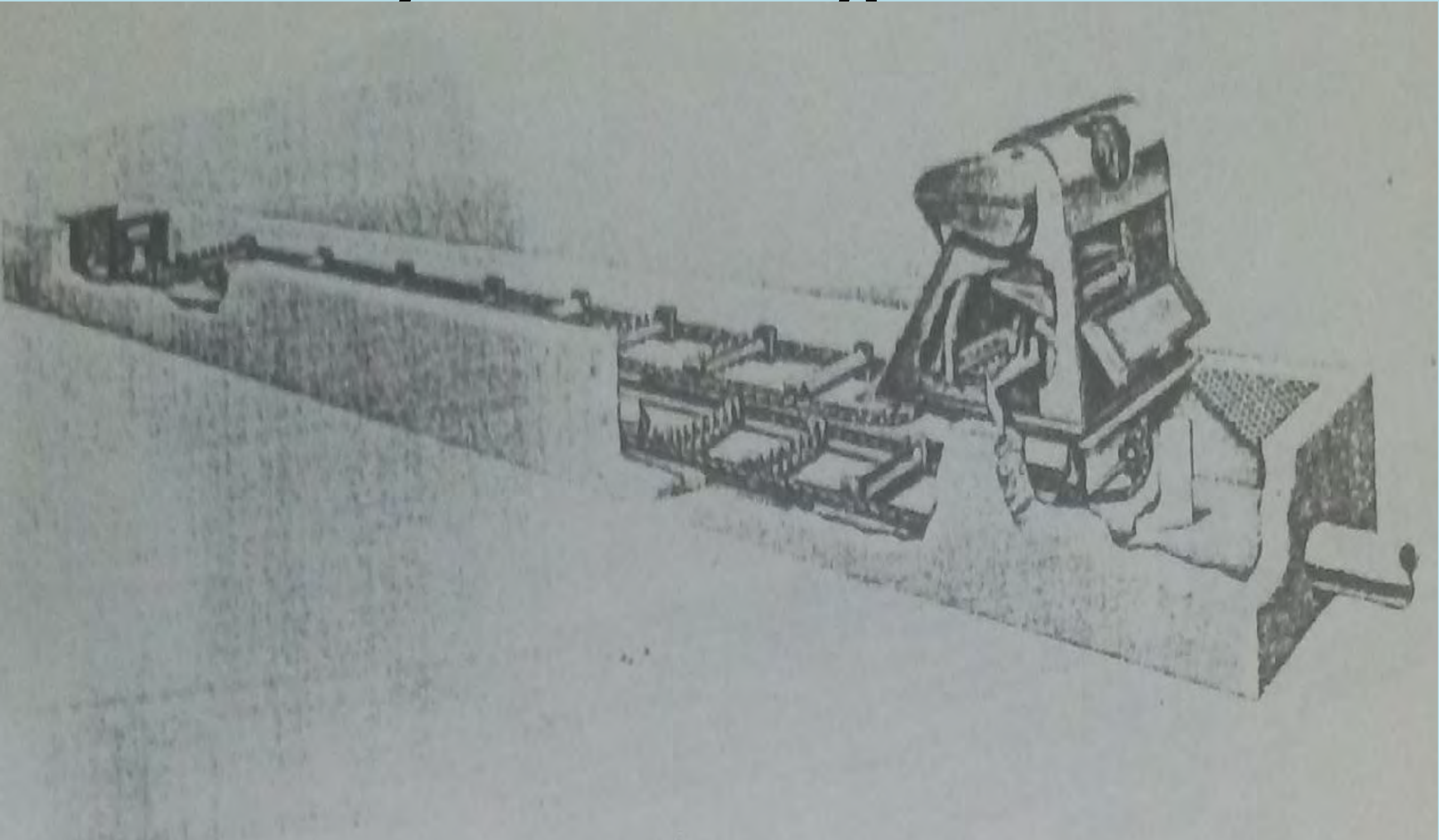


Figure 5–35

Grab bucket used to remove grit from aerated grit chamber.

Velocity controlled grit chamber



(a)

Horizontal flow GCs

- Until recently, most GCs have been of the horizontal flow, velocity-controlled type
- These chambers have been designed so as to maintain a velocity as close to 1 fps as practical.
- Such velocity will:
  - Carry most organic particles through the chamber and
  - Tend to resuspend any that settle but
  - Permit the heavier grit to settle out.

Controlling velocity

- Plants designed in the 1920s and 1930s contained up to 12 long narrow grit channels,
- Which were cut in and out of service to control the velocity as the flow varied.
- Later, the number of channels was reduced,
- And the velocity was maintained constant by installing proportional or Sutro-type weirs at the outlet of the channels

Weirs

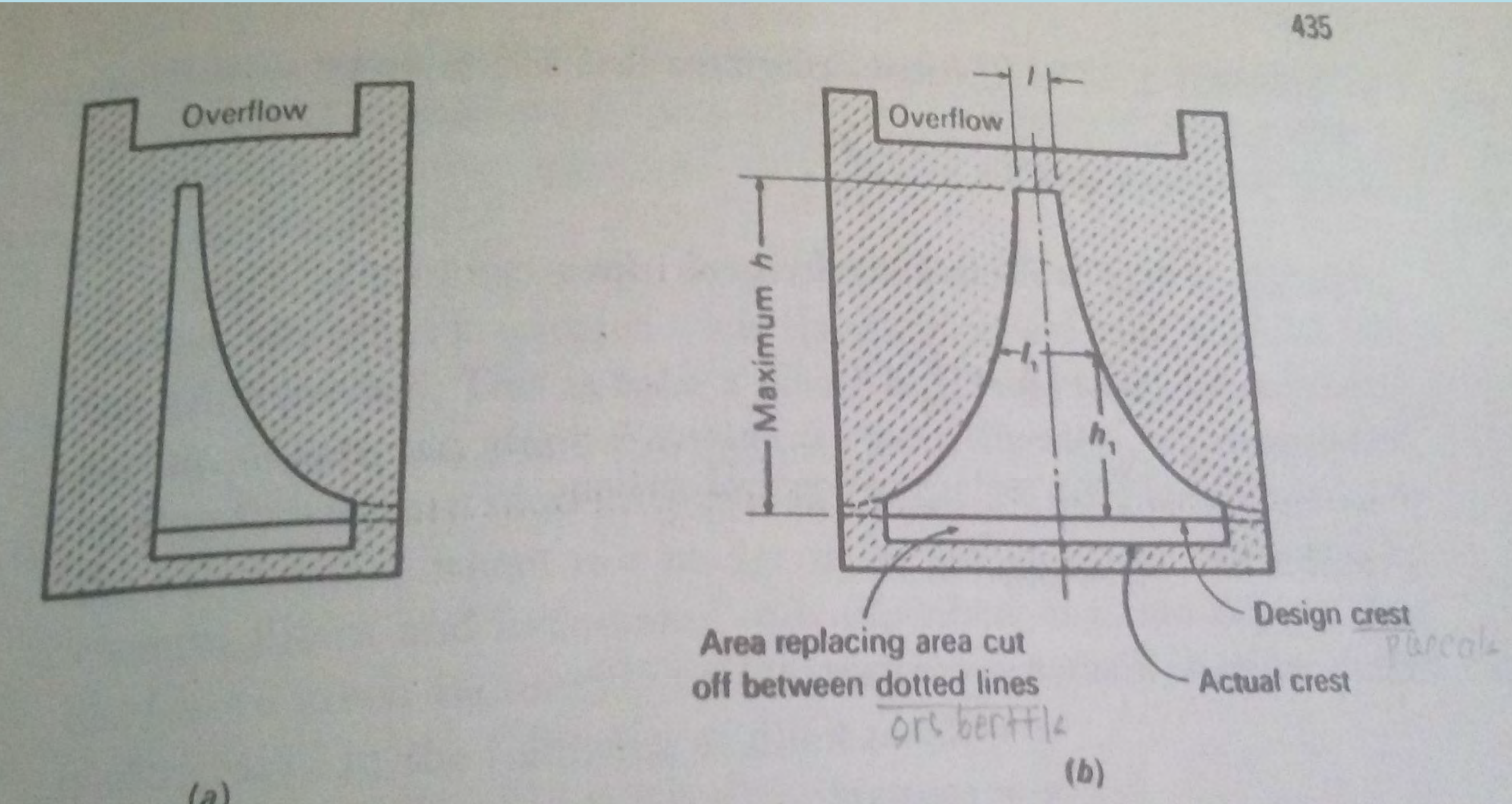
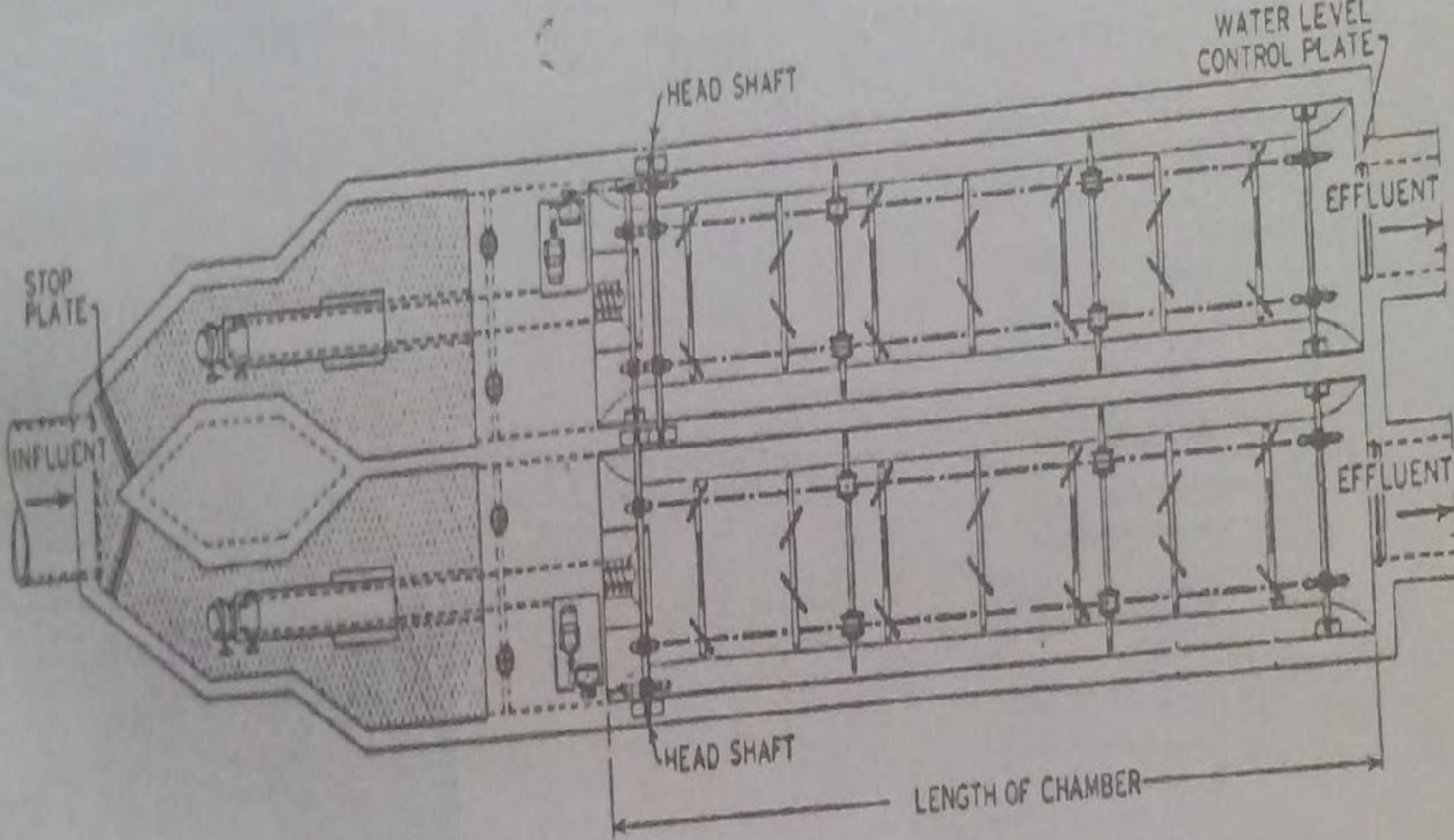
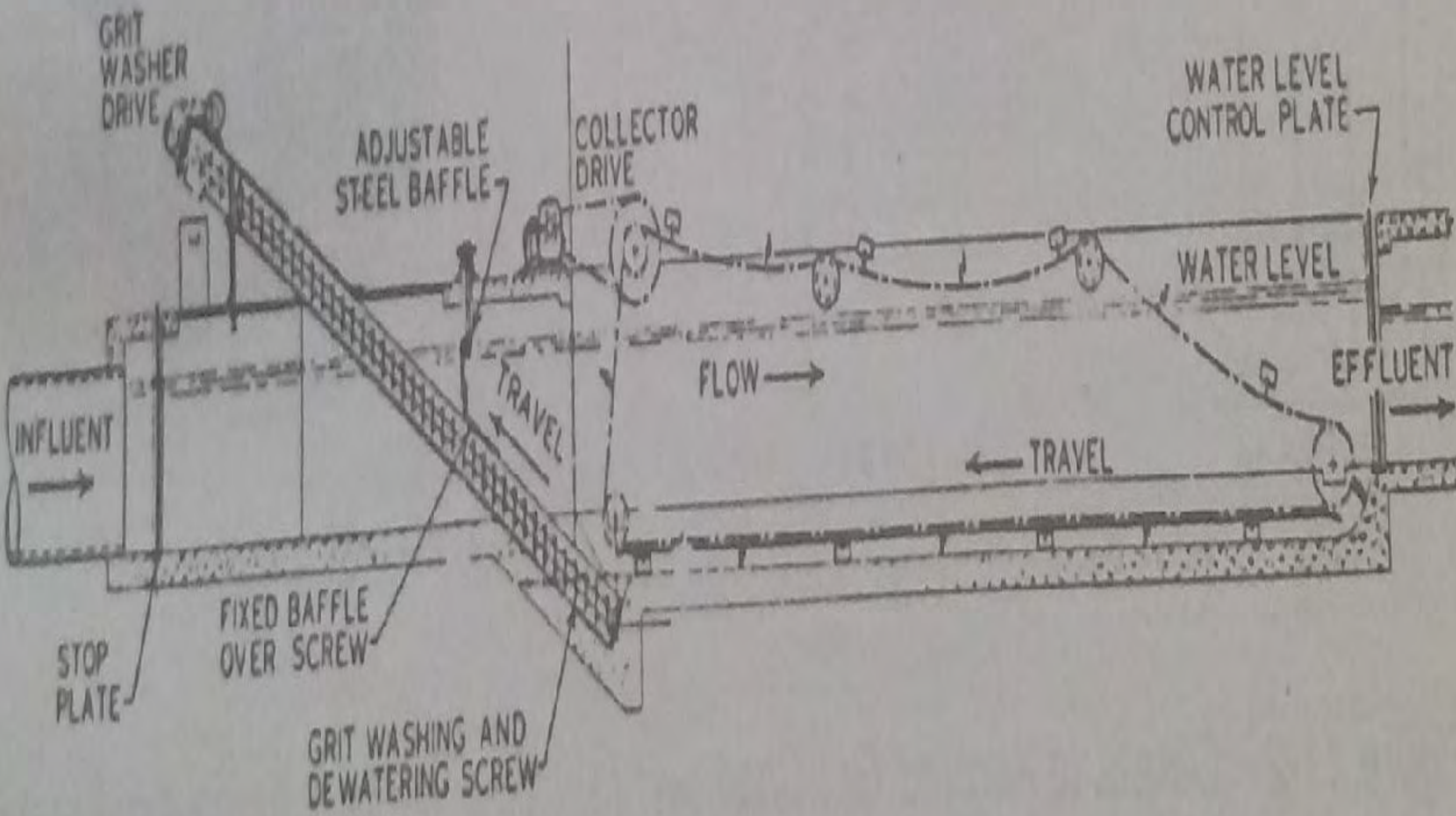


FIG. 11·6 Weirs for grit-chamber control channel. (a) Sutro and (b) proportional.

Plan of double channel grit collector



Longitudinal section of double channel grit collector



weirs

- Such weirs maintain a constant velocity in a rectangular channel as the depth varies
- (if the grit storage or space for grit-collecting equipment in the bottom of the channel is neglected),
- But they:
  - must have a free discharge and
  - Are wasteful of hydraulic head

Control sections

- Control sections with parallel vertical sides, which dissipate less of the depth as lost head, were also used.
- Theoritically, these require a GC of parabolic cross section for constant velocity with varying depth,
- But this can be satisfactorily approximated by a trapezoidal cross section (Example 11.2).

Control section

- If desired, the control section may be narrower at the top than at the bottom to obtain a more desirable trapezoidal cross section.
- If the GCs are followed immediately by a Parshal Flume, the flume may be designed to control the velocity.

Head loss

- The head loss in the control section at any particular rate of flow amounts to about 36% of the depth of the flow in the GC.
- This amount is = 1.1 times the velocity head in a control section with a well-rounded entrance.
- In addition, there is a considerable variation in the water level in the GC and in the control section between minimum and maximum flow.

A meter

- Every plant should have a meter for measuring the flow.
- If the meter is located between the GC and the sedimentation tanks,
- The difference in head can be utilized by the meter;
- Otherwise it may be wasted.
- The effect of the control-section geometry on the geometry of the GC is seen in Example 11.1

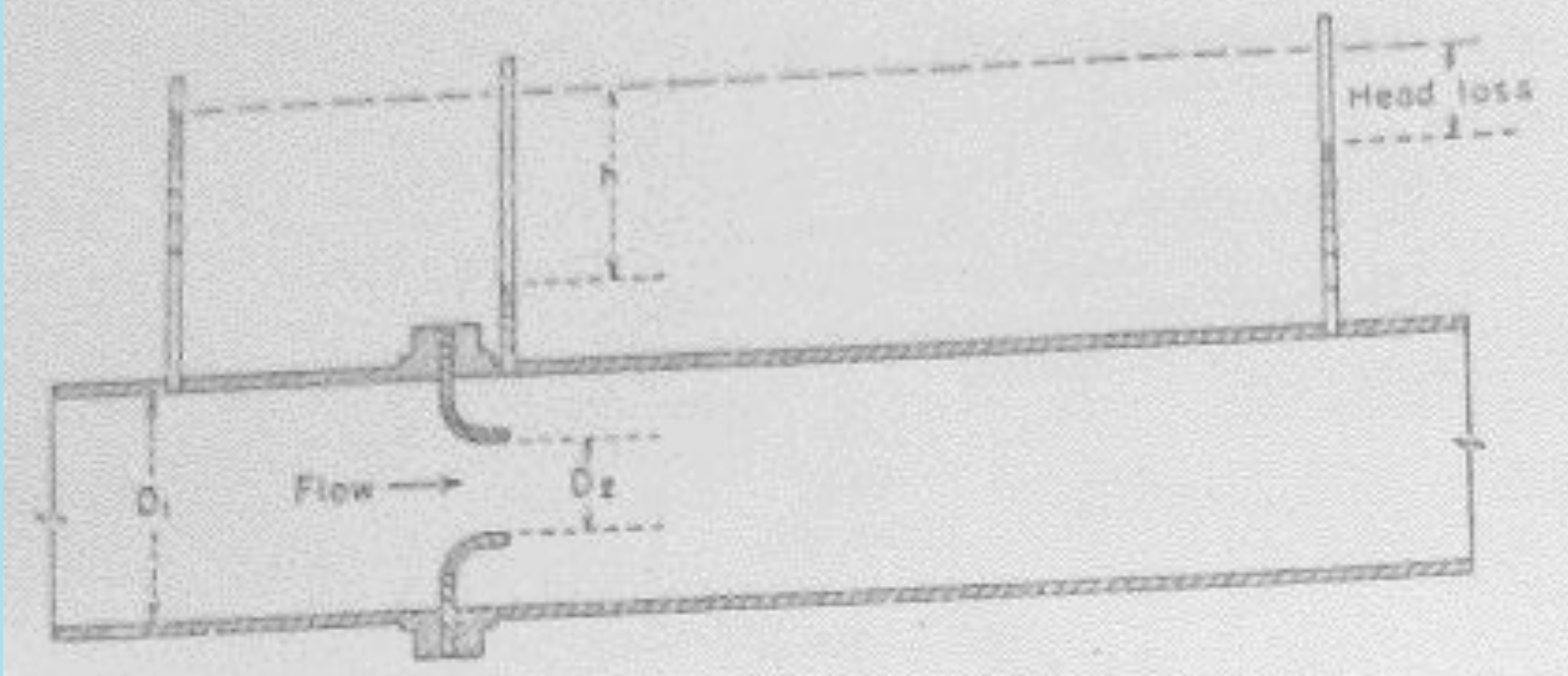
FLOW MEASUREMENT DEVICES

TABLE 10-2 Types of Flow Measurement Devices Available for Determining Liquid Discharges

Flow Measurement Devices	Principle of Flow Measurement
1. For pressure pipes	
a. Venturi meter[a]	The differential pressure is measured
b. Flow nozzle meter[a]	The differential pressure is measured
c. Orifice meter[a]	The differential pressure is measured
d. Pitot tube	The differential pressure is measured
e. Electromagnetic meter[a]	Magnetic field is induced and voltage is measured
f. Rotameter	The rise of float in a tapered tube is measured
g. Turbine meter[a]	Uses a velocity driven rotational element (turbine, vane, wheel)
h. Acoustic meter[a]	The sound waves are used to measure the velocity and liquid level
i. Elbow meter	The differential pressure is measured around a bend
2. For open channels	
a. Flumes (Parshall, Palmer-Bowlus)[a]	Critical depth is measured at the flume
b. Weirs[a]	Head is measured over a barrier (weir)
c. Current meter	Rotational element is used to measure velocity
d. Pitot tube	The differential pressure is measured
e. Depth measurement[a]	Float is used to obtain the depth of flow
f. Acoustic meter[a]	Uses sound waves to measure velocity and depth

Flow measurement devices applicable to pressure pipes and open channels

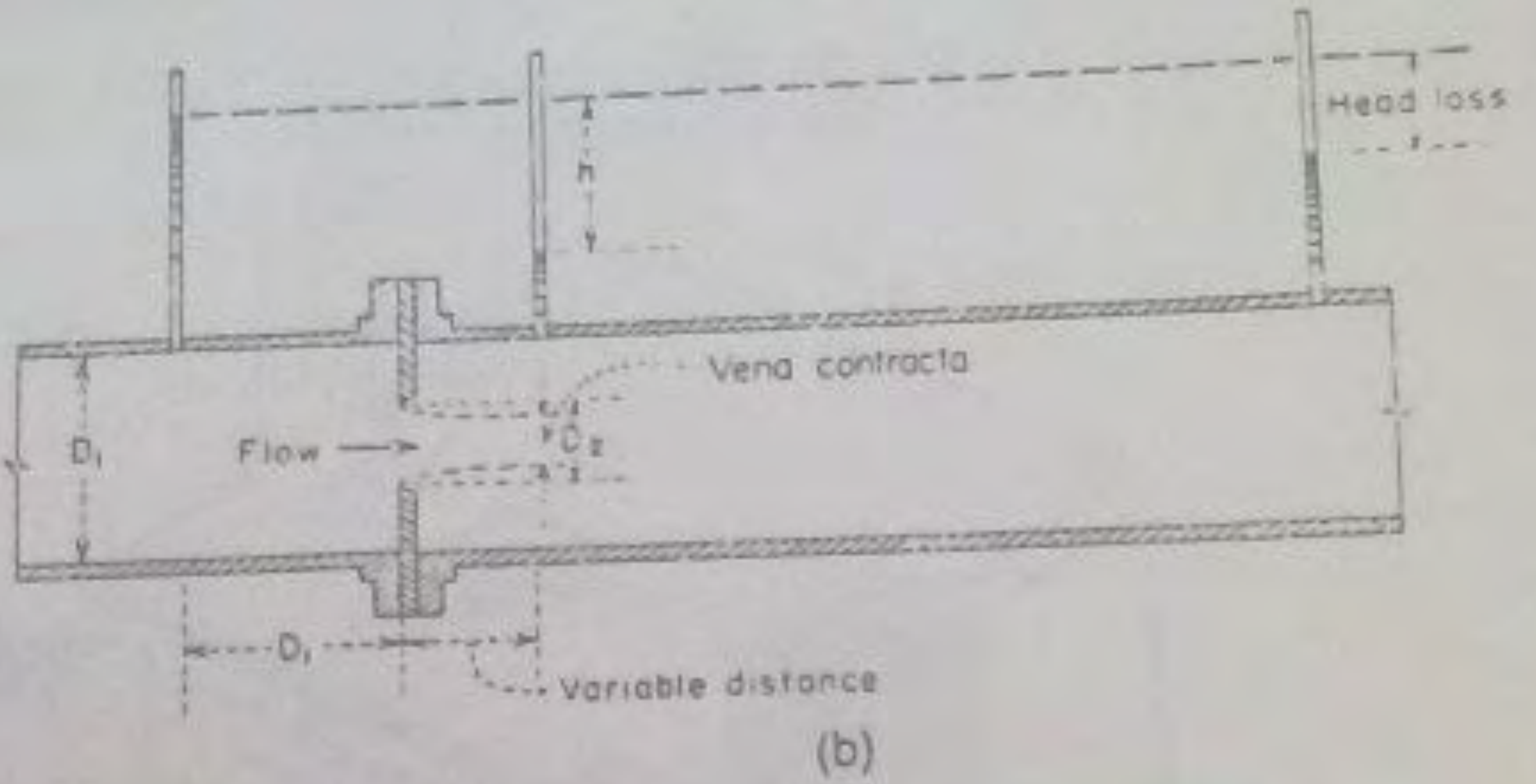
Flow nozzle



(a)

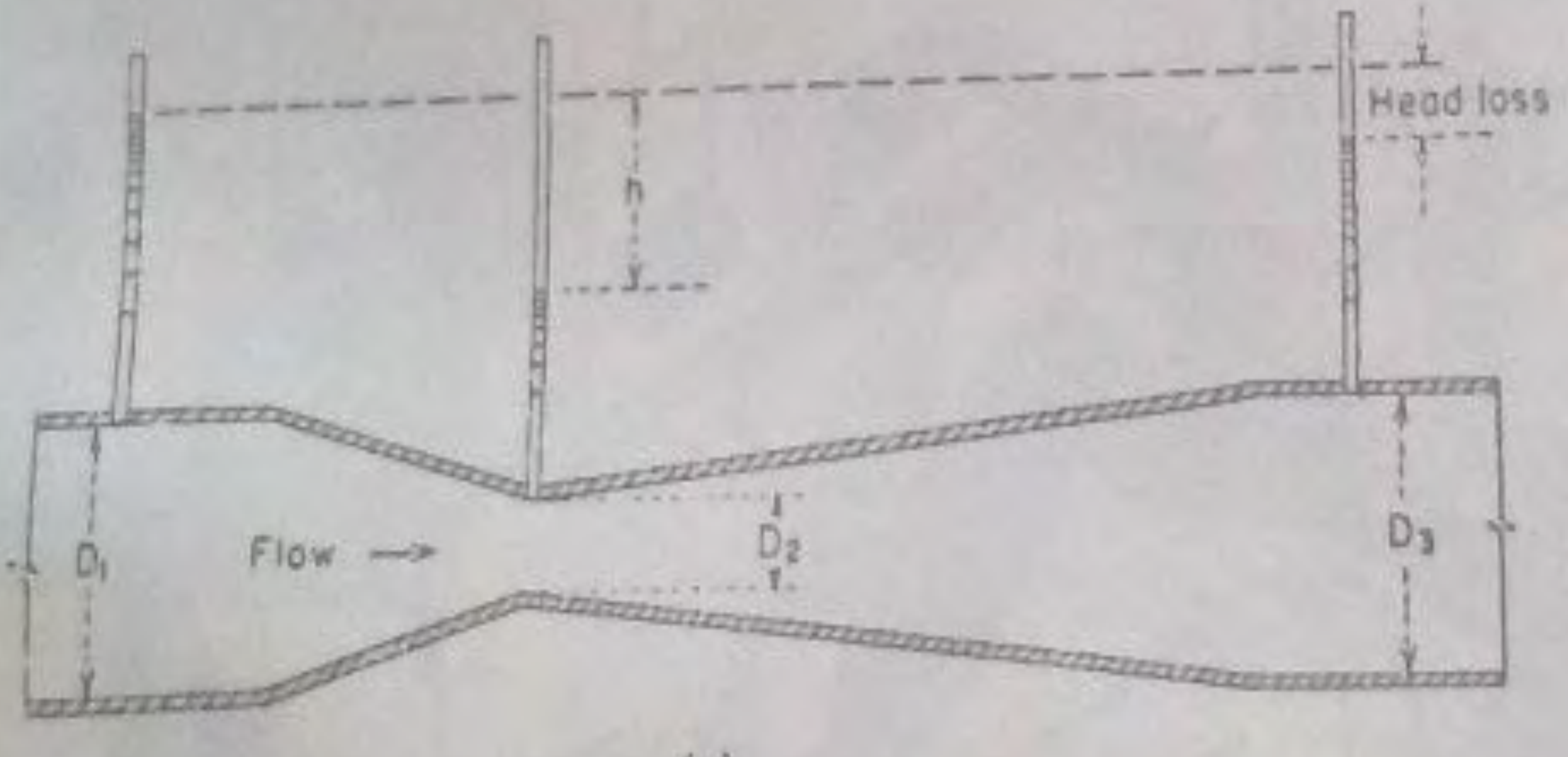
Flow measurement devices applicable to pressure pipes and open channels

Orifice meter



Flow measurement devices applicable to pressure pipes and open channels

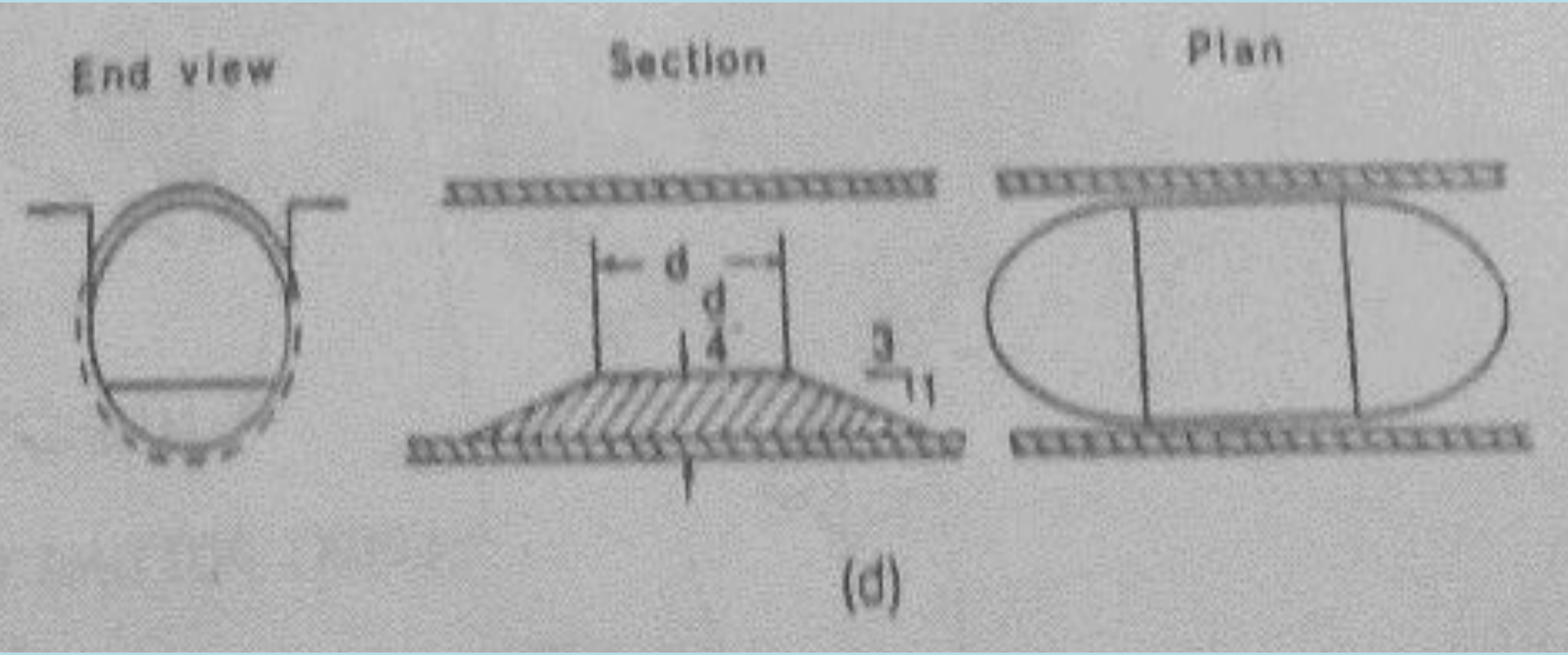
Venturi meter



(c)

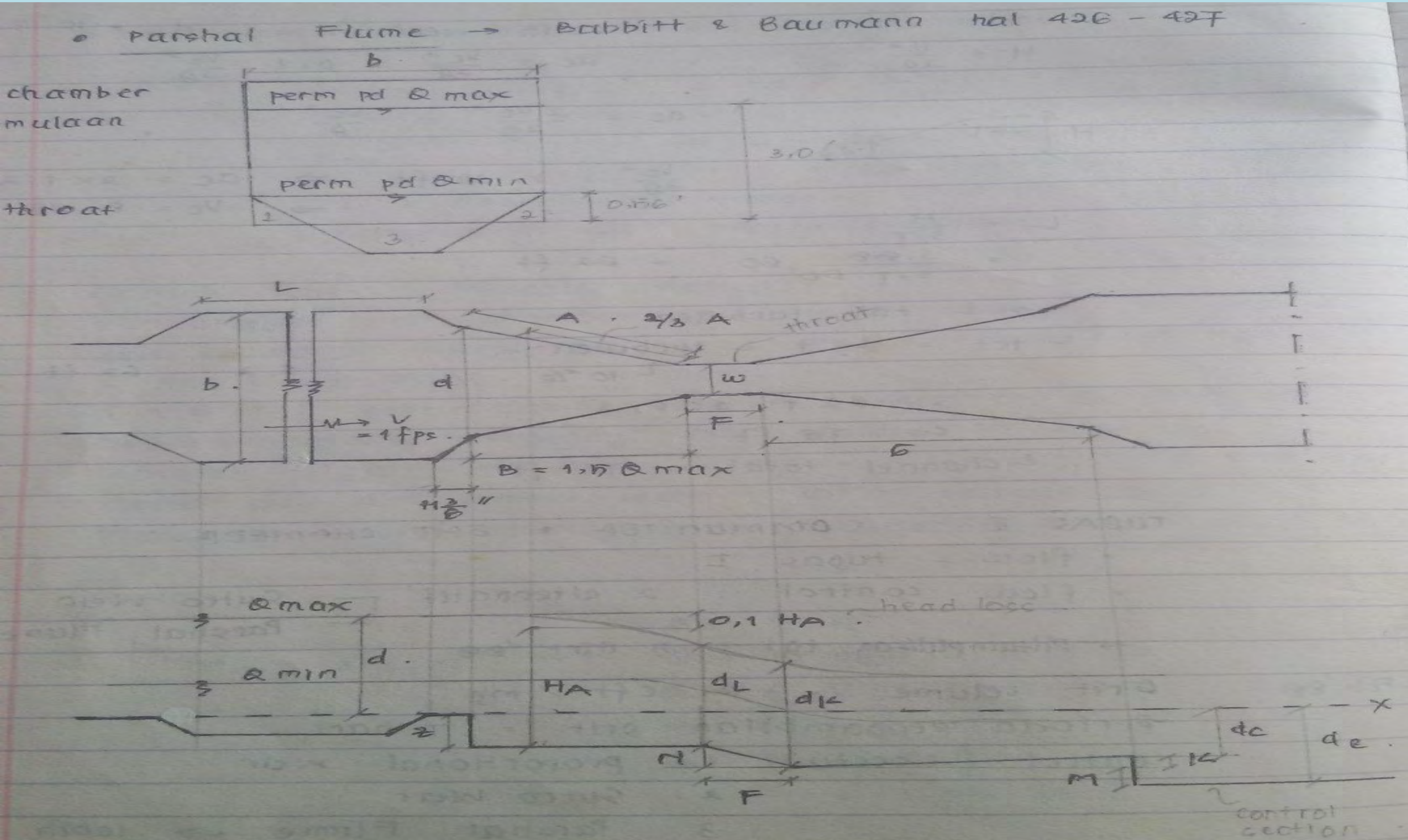
Flow measurement devices applicable to pressure pipes and open channels

Palmer-Bowlus flume



(d)

Parshal flume



Example 11.1 Effect of control-section geometry on GC geometry

- Demonstrate that the use of a rectangular control section requires an approach channel with a parabolic cross section to maintain constant velocity with varying rates of flow.

solution

1. For a prismatic channel:

- A = $\int_0^h t\ dh$
- Where:
- t = channel width at depth h

2. The discharge through the channel is given by:

Q=A V = V$\int_0^h t\ dh$

solution

3. For a constant velocity of 1 fps

Q=A $= \int_0^h t\, dh$

4. For a rectangular control section

Q = $c\ w\ h^{\,n}$

Where:

c = constant

w = throat width

n = constant

solution

5. Equating the two expressions (steps 3 and 4) for discharge yields

$$\int_0^h t\, dh = c\, w\, h^{\,n}$$

6. Differentiating the foregoing expression gives

t dh = $n\, c\, w\, h^{\,n-1}$dh

solution

7. Because n = 3/2 for a rectangular section, the height of the chamber is given by

$$h = \left(\frac{2}{3\,c\,w}\right)^2 t^2 = k\,t^2$$

8. therefore, the cross section of the GC must be parabolic

design of horizontal-flow GCs

- The design of horizontal-flow GCs should be such that, under the most adverse conditions, the lightest particle of grit will reach the bed of the channel prior to its outlet end.
- Normally, GCs are designed to remove all grit particles that will be retained on a 65-mesh screen (0.21 mm diameter),
- Although many chambers have been designed o remove grit particles retained on a 100-mesh screen (0.15 mm diameter)

design of horizontal-flow GCs

- Good practice to use:

 Vs = 3.7 fpm to remove 65 mesh material

 Vs = 2.5 fpm to remove 100 mesh material

- Where the specific gravity of grit < 2.65, due to local conditions:
- use lower velocities

design of horizontal-flow GCs

- Length of channel governed by:
  - The depth required by:
    - the settling velocity, and
    - The control section
  - Cross sectional area governed by:
    - The rate of flow
    - The number of channels

design of horizontal-flow GCs

- Allowance should be made for inlet & outlet turbulence
- Minimum: 2x maximum depth of flow
- Maximum: 50% of length

Problem Set: Horizontal-Flow-Grit-Chamber Design

- Design a grit chamber with three channels with a flow-through velocity of 1.0 fps for a plant with a maximum design flow of 30 mgd, an average flow of 15 mgd, and a minimum flow of 6 mgd.
- Assume that the maximum width of each channel is 6 ft and design each channel for a maximum emergency flow of 15 mgd, a normal maximum flow of 10 mgd, an average flow of 5 mgd, and a minimum flow of 2 mgd.

Problem Set: Horizontal-Flow-Grit-Chamber Design

- Use a fixed-width control section with vertical sides and a well-rounded and smooth approach, so that the head loss may be assumed equal to 10 percent of the velocity head.
- The flow in the control section will be at critical depth and the critical-depth equations will apply.

solution

1. For the control section selected, a parabolic GC cross section is required for a constant velocity.

For a parabola $A = 2/3\ HT$,

Where:

H= height

T = top width

In the final design, the parabolic section will be approximated by the straight lines.

solution

- Determine the velocity head and depth for the control section.
- Equating the upstream specific energy to that in the control section yields
- $H + \frac{V^2}{2g} = d_c + 1.1\,\frac{Vc^2}{2g}$
- $d_c = 2\,\frac{Vc^2}{2g}$

Grit chamber

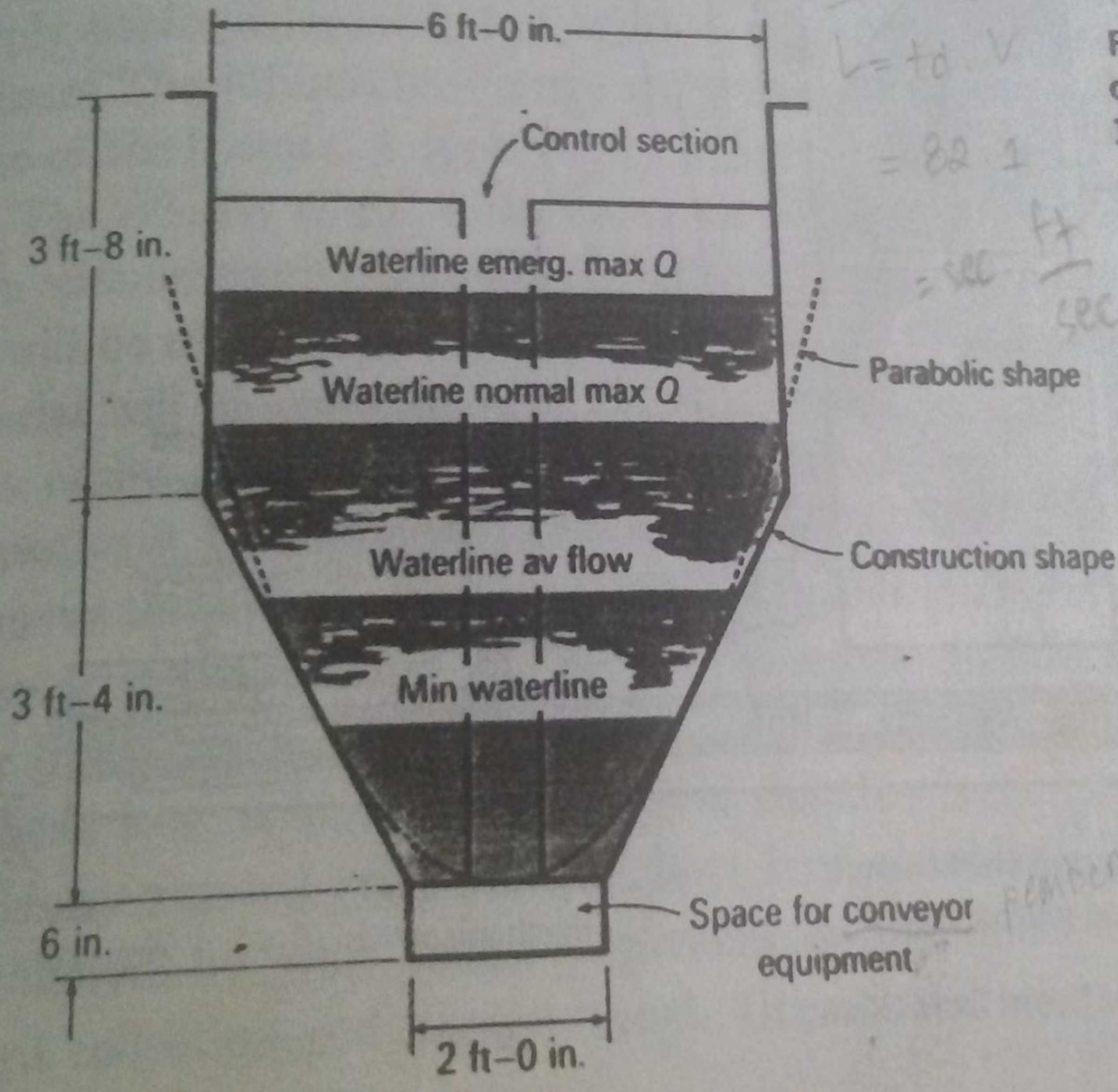


FIG. 11-7 Section through grit chamber designed in Example 11-2.

Grit chamber

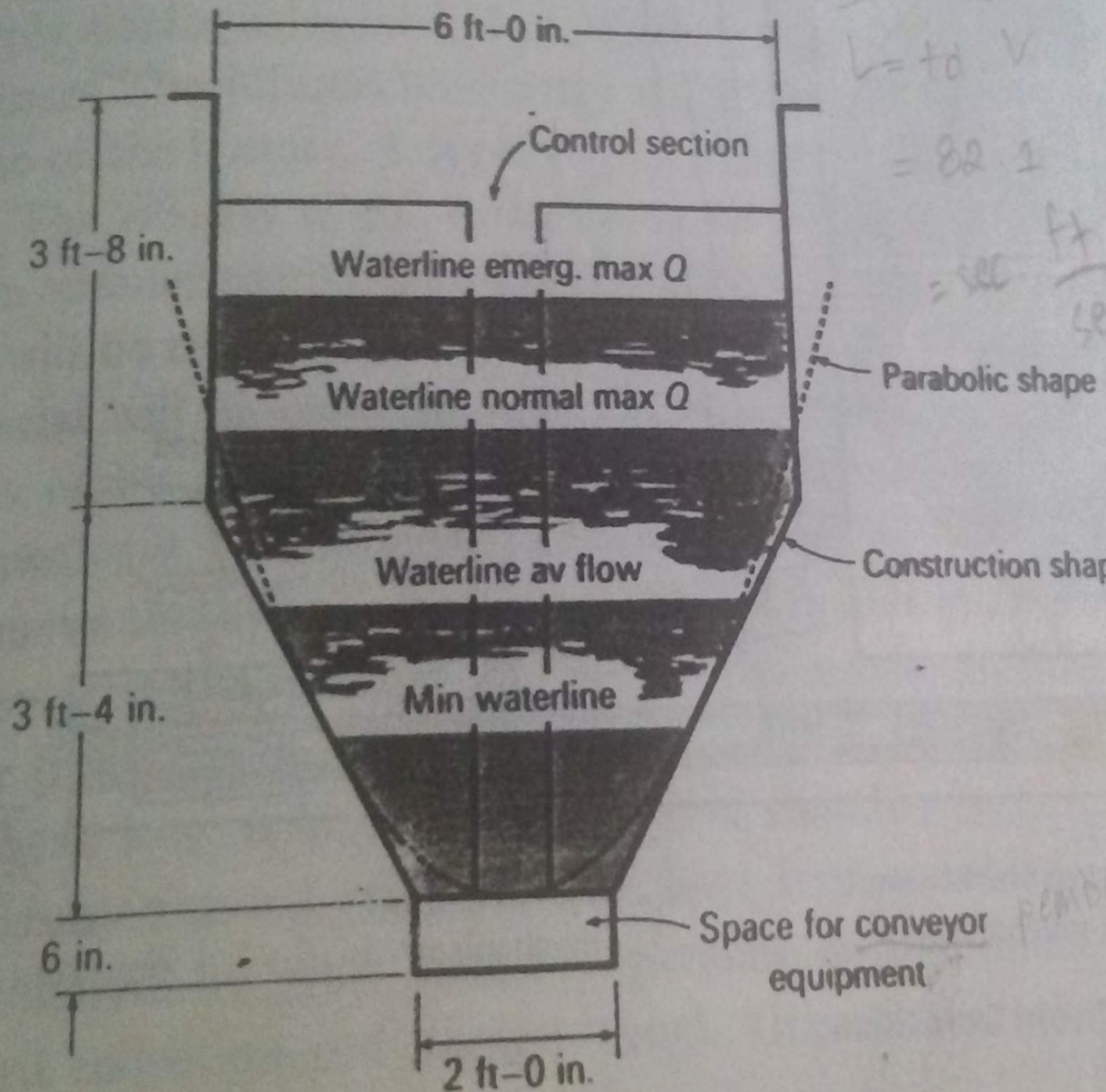
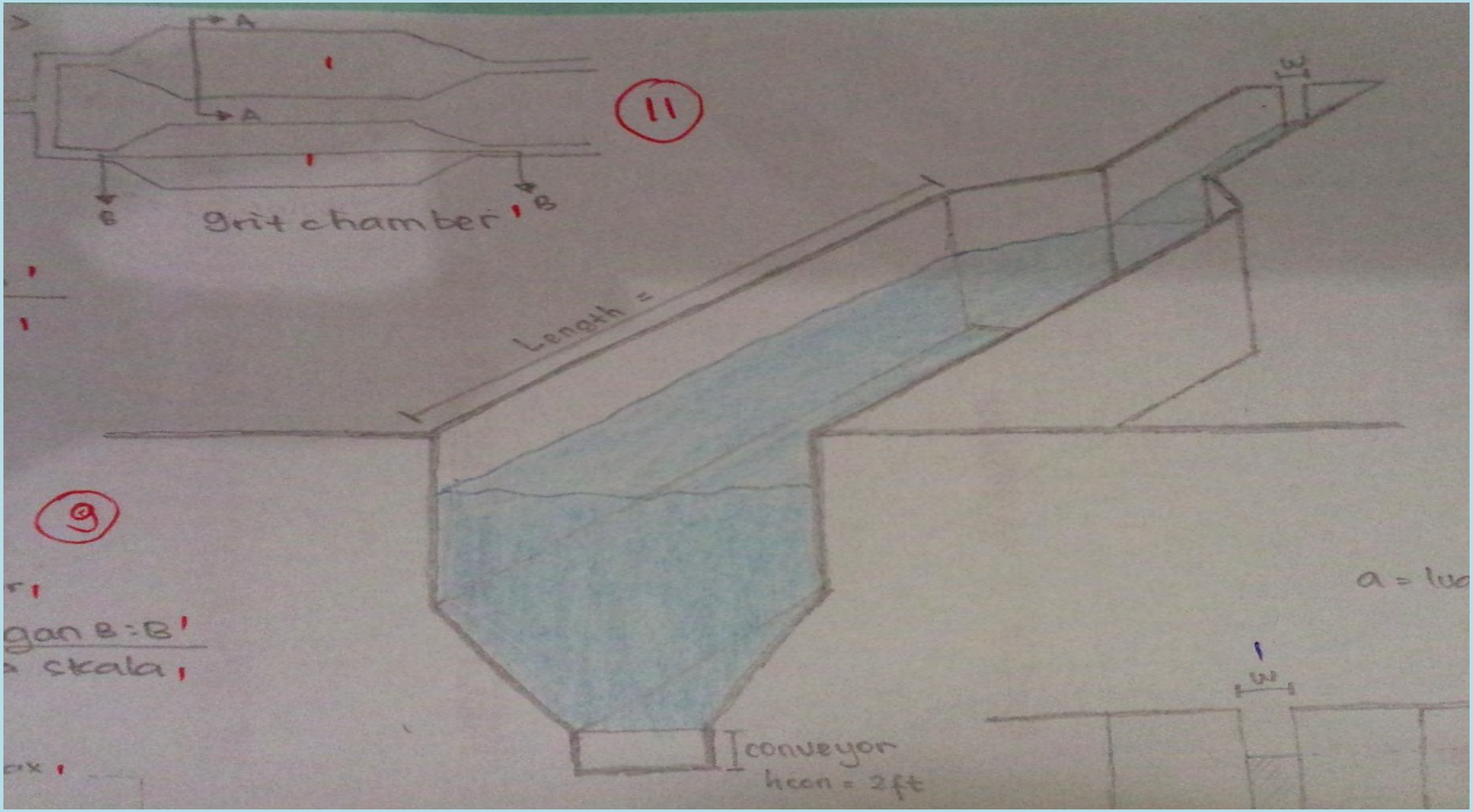


FIG. 11-7 Section through grit chamber designed in Example 11-2.

Denah & 3 dimensi




Terimakasih

TLB 314 PDIPAM

Dosen: Rachmawati S. Dj.

Week 8

Sedimentasi

Genap 2025/2026

Sub CP MK *Week 8-10*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]); Metode Pembelajaran[8]); Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5])	Teknik[6])	Luring	
1	2	3	4	5	6	9
8-10	6.3	Mahasiswa mampu menjelaskan primary treatment; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat	Ketepatan dalam menjelaskan primary treatment; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat	Tugas, PRA-UAS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 3*50 menit/minggu ▪ Primary treatment, prasedimentasi, sedimentasi dan filtrasi: 3 ▪ *3*50 menit	10%
11	PRA-UAS					

Source

Prof.dr.ir. L. Huisman, Sedimentation and flotation, September 2004, Delft University of Technology

Design of the settling zone

For discrete particles:

- Q
- Settling characteristics of the suspension
- Desired removal ratio

→ Surface loading, s_o

$As = Q/s_o$

H is decided for circular tank → Mechanical sludge removal: small H

Preliminary design: circular tank: $H = 0.17\ As^{1/3}$; H (m); A (m^2)

Manual cleaning: add 1 m for sludge storage depending on local circumstances

Design of the settling zone

Rectangular tank → Decide: → Depth and Length : Width

To stimulate quiescent settling conditions

Short, wide, deep

Long, narrow, shallow

To prevent reduction in basin efficiency by

turbulence & bottom scour

Basin instability & short circuiting

$$Re = \frac{v_o R}{\nu} < 2000$$

$$Fr = \frac{v_o^2}{gR} > 10^{-5}$$

temperature of 10 ^{0}C, $\nu = (1.31)10^{-6}$ m^2/sec

$v_o = (6.4)10^{-3}$ m/sec, $R < 0.41$ m

Overcoming reduction in basin efficiency

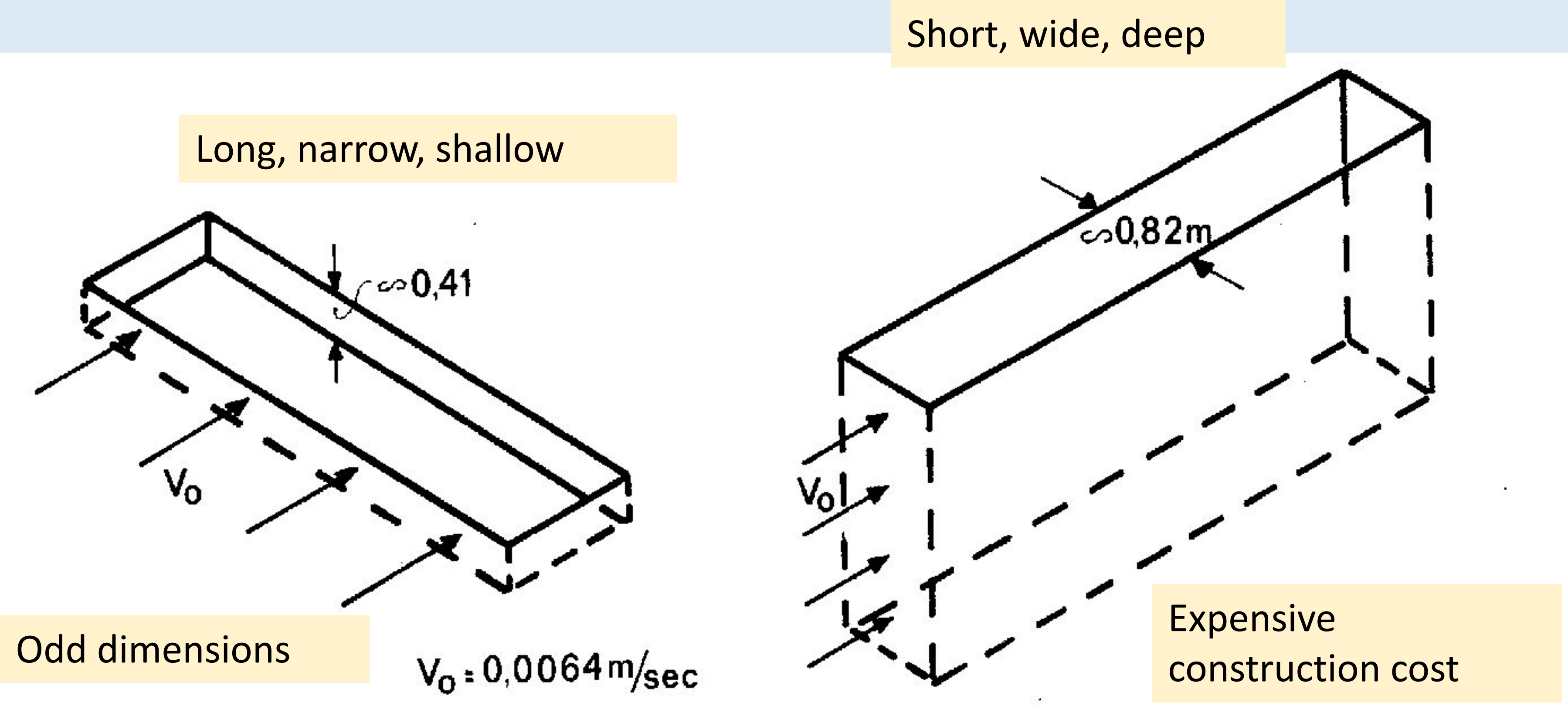
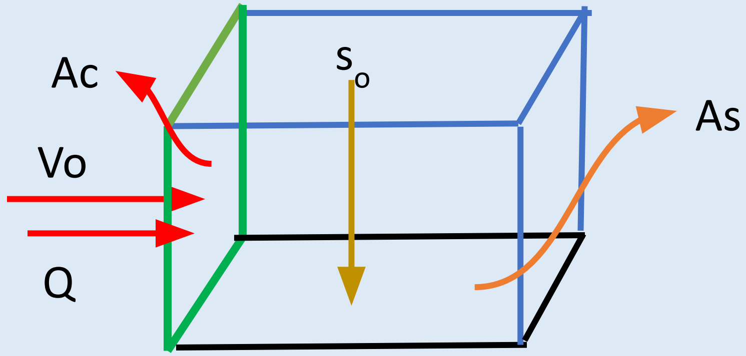


Fig. 3-31 Rectangular settling tanks with laminar and stable flow.

$v_o = (6.4)10^{-3}$ m/sec,

So small

No bottom scour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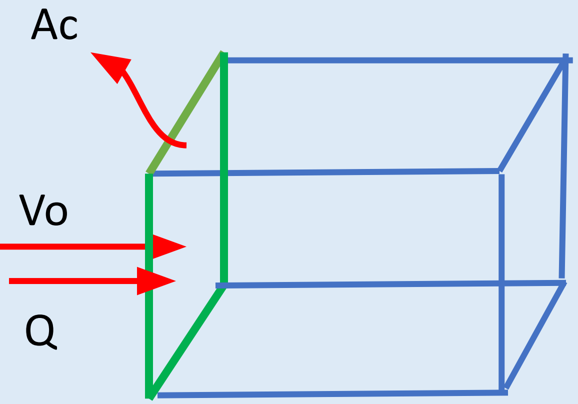
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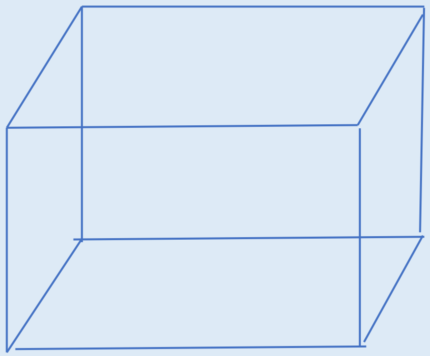

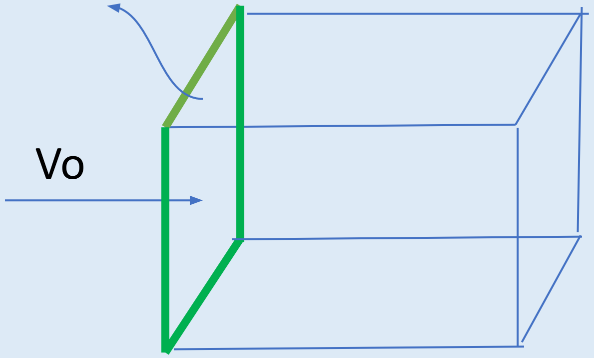
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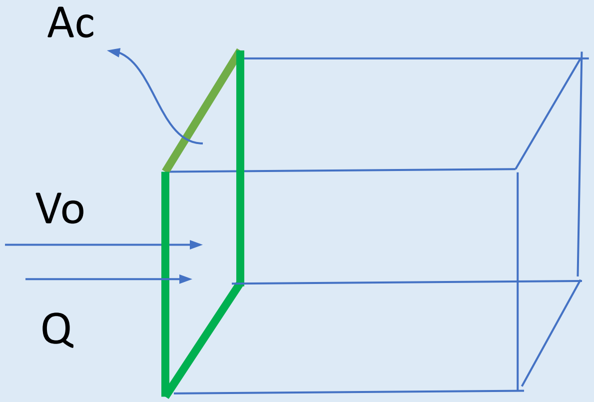
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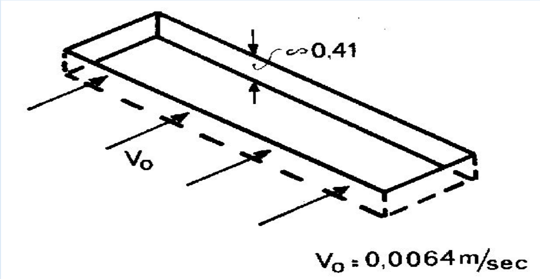
Vo
Q

Dimensionering



Defining width (B)

Q = 0.5 m3/s

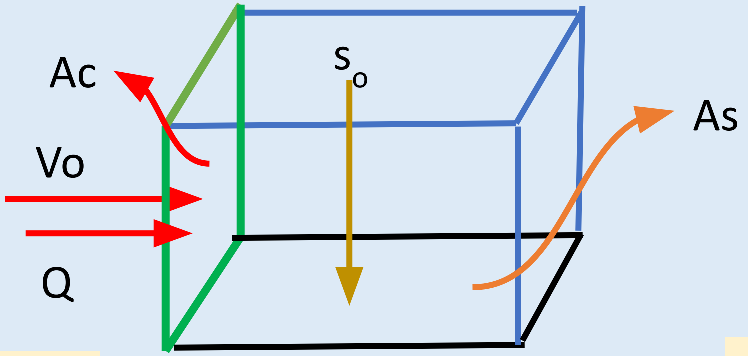
Vo = 0.0064 m/s

Ac = Q/Vo
Ac = 0.5 m3/s : 0.0064 m/s

H = 0.41 m

B = Ac/H
B = 0.5 m3/s : 0.0064 m/s / 0.41 m
B = 190 m

Odd dimensions



Defining length (L)

Q = 0.5 m3/s

s_o = 0.0037 m3/m2/s

As = Q/s_o
Ac = 0.5 m3/s : 0.0037 m3/m2/s

B = 190 m

L = As/B
L = 0.5 m3/s : 0.0037 m3/m2/s / 190 m
L = 7.1 m

Extremely expensive sludge removal

In practice, the shape of the settling zone

Is a compromise between:

- The hydrodynamics requirements:
  - a high Fr number
  - A low Re number
- Economic considerations:
  - A limited ratio of length & width
  - A shallow depth

$$H = \frac{1}{12} L^{0.8}$$

Enough for installation & proper functioning of sludge collecting mechanism

- H & L in m
- Length : width = 6-10

With a capacity of 0.5 m^3/sec and an overflow rate of $(0.37)10^{-3}$ m/sec as mentioned above, the required surface area equals

$$A = \frac{0.5}{(0.37)10^{-3}} = 1350 \text{ m}^2$$

giving with for instance $L = 6B$

$$B^2 = \frac{1350}{6} = 225, \quad B = 15 \text{ m} \quad \text{and}$$

$$L = \frac{1350}{15} = 90 \text{ m} \quad H = \frac{1}{12}(90)^{0.8} = 3 \text{ m}$$

$$R = \frac{(3)(15)}{21} = 2.14 \text{ m}, \quad v_o = \frac{0.5}{(3)(15)} = 0.0111 \text{ m/sec}$$

Week 8

TLB 314 PDIPAM

Genap 2025/2026

Dosen: Rachmawati S. Dj.

Sedimentation

Huismann, 1977

Inlet & outlet construction

- Ideal condition:

 Settling zone precede by an inlet zone:

   Divide incoming water & suspended particle equally over Ac
  Mix incoming water with part of the tank content prevent the occurrence of density currents due to differences in:
    Temp
     Suspended matter content

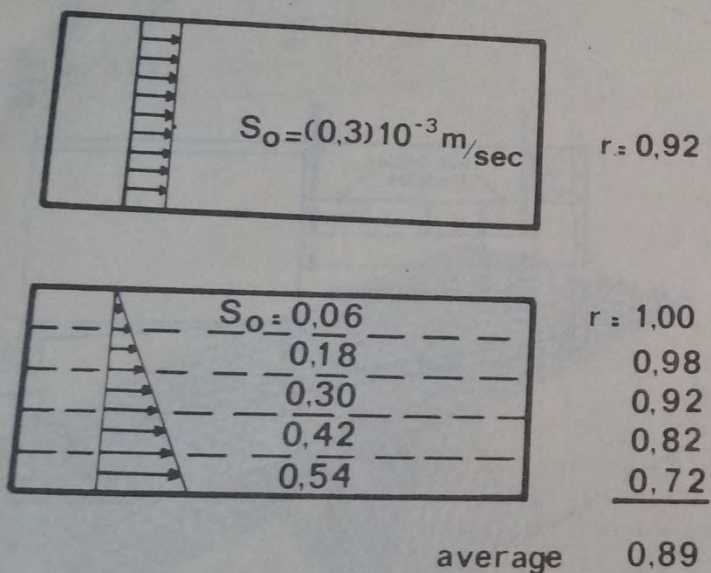


Fig. 3-42 Plan of tanks with different efficiencies. (according to fig. 3-21)

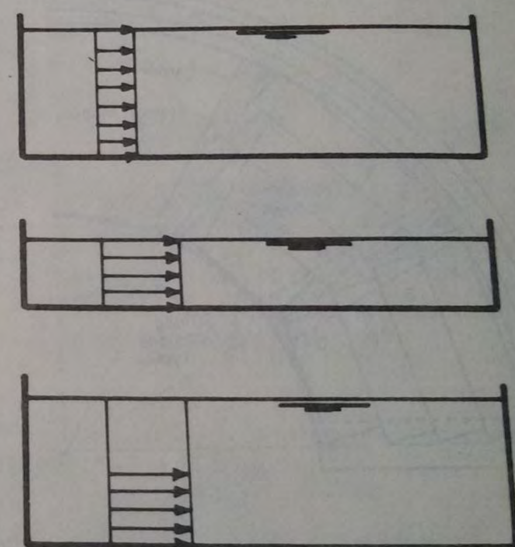


Fig. 3-43 Longitudinal section over tanks with equal efficiency.

Turbulence & jets of water

Not creating:

- turbulence
- Concentrated jets of water
  - Disturb the settling process

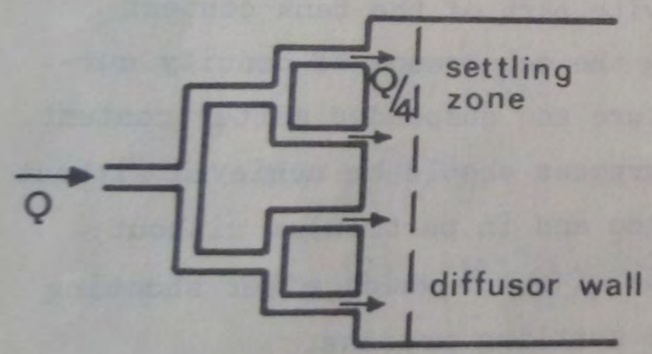
Equal division of water

- Equal division of water width of the tank
- Depth --> Has no influent on:
  - clarification efficiency
  - Unequal division of the inflow
- Equal division of incoming water over the tank width:

 subjecting the incoming water to equal losses of head

 subjecting the water to head losses which >>> variation in piezometric level over the length of the inlet channel

- principle of equal head losses Fig. 3.44



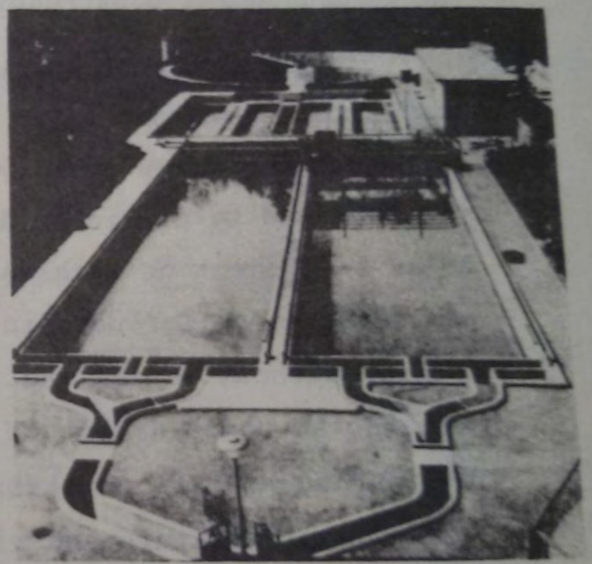


Fig. 3-44 Inletconstruction with equal losses of head.

diffusor wall

- Due to the cost of pipes & channels

□ number of inlets <<

□ requiring a diffusor wall (Fig. 3.45)

  □ a finer sub-division over the full width & depth of the settling zone

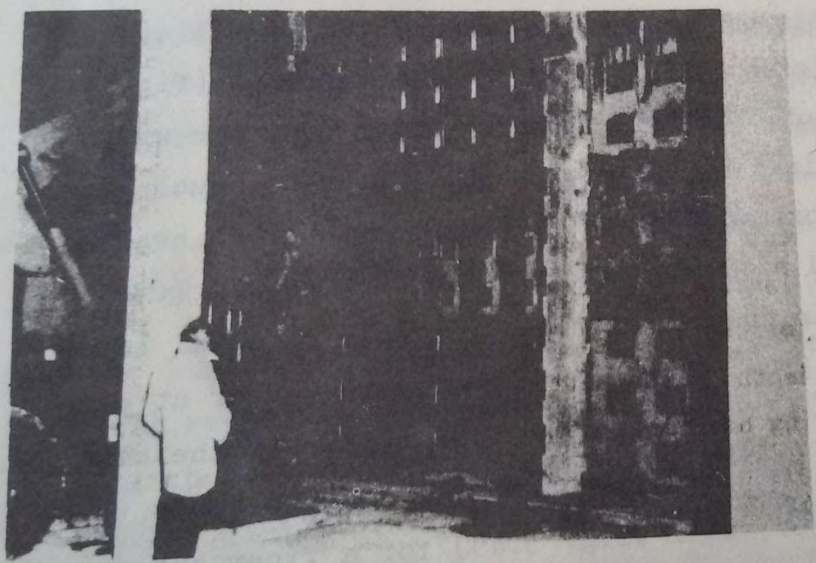


Fig. 3-45 Diffusor wall.

Controlling head losses

- Fig 3.46: the use of controlling head losses large compare to variation in piezometric level ahead of the various inlet openings
- Over the length B of the inlet channel:
  - The energy level drops by losses of fraction & turbulence
  - The piezometric level (water level) rises due to recovery of velocity head

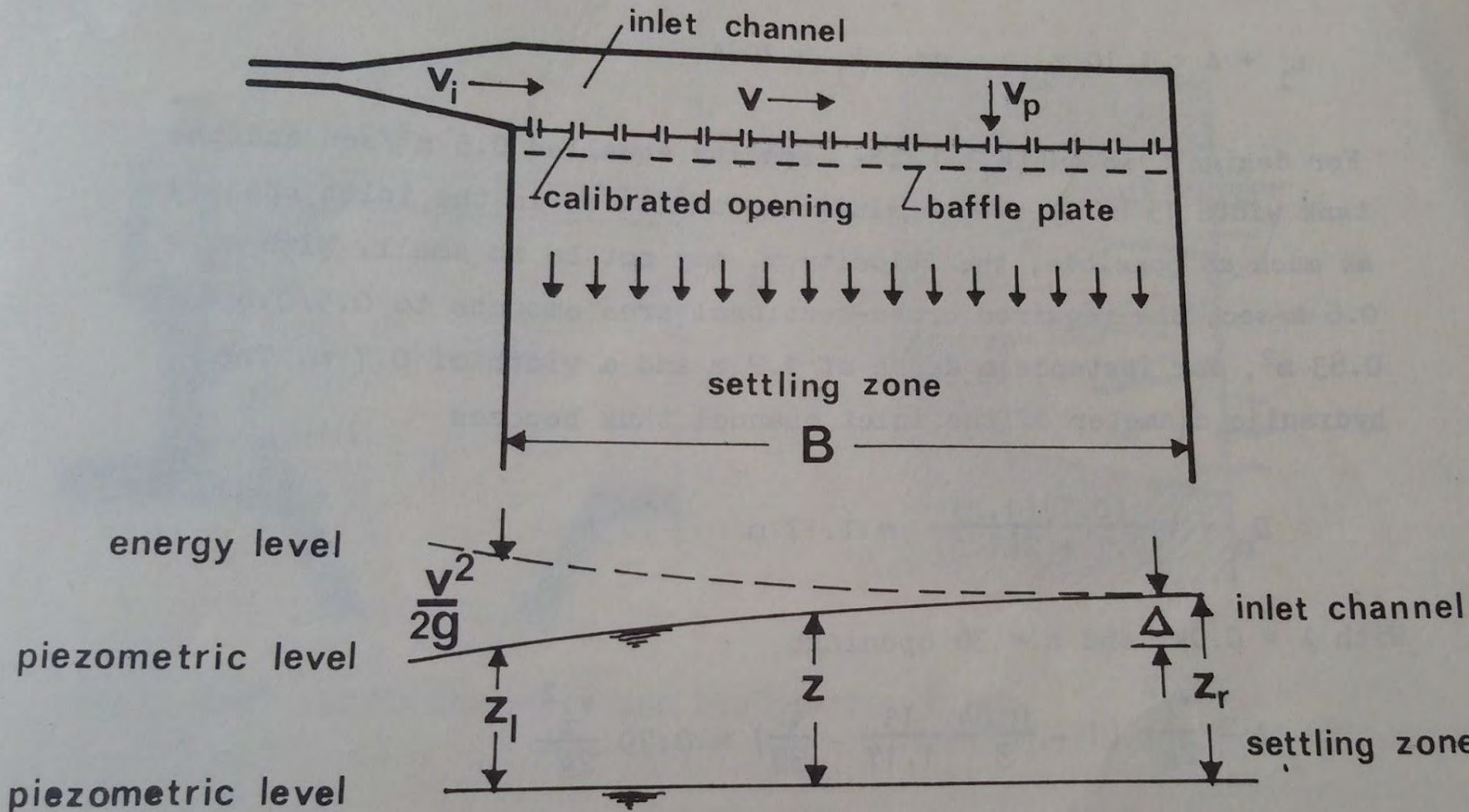


Fig. 3-46 Inletconstruction with calibrated openings.

piezometric level rise

$$\Delta = \frac{v_i^2}{2g} - \frac{\lambda}{3}\frac{B}{D_h}\frac{v_i^2}{2g} - n\,\frac{\left(\frac{v_i}{n}\right)^2}{2g}$$

- ʎ = friction coefficient
- Dh = hydraulic diameter of the inlet channel
- N = number of calibrated openings

Variation in discharge

- From the first to the last opening

$$Q_p = \mu F \sqrt{2 g z_1}$$

$$Q_p = \mu F \sqrt{2 g z_r} = \mu F \sqrt{2 g (z_1 + \Delta)}$$

- μ = discharge coefficient
- F = area of the opening

Allowable controlling head loss

- Discharge variation limited to 5%
- Allowable controlling head loss = 10%:

  $Z_1 + \Delta < 1.10\, Z_1$

  or $Z_1 > 10\, \Delta$
- For Q = 0.5 m3/sec, W = 15 m
- To reduce sludge accumulation in the inlet channel v_i may not be too small

Hydraulic diameter

- Inlet:
- V_i = 0.6 m/sec □ Ac = …m2
- H = 1.2 m, W = 0.7 m
- Dh = … m
- With ʎ = 0.04 , n = 30
- Δ =
- Vi =
- $V_i^2/2g$ =

- Δ = ….m
- Z> ….m
- With 30 openings
- Qp = …..m3/sec
- μF = ….. m2
- μ = 0.3-0.7 circular openings
- D = 0.135-0.205
- Vp = ….m/sec

Baffle plates & Inlet constructions

- Vp > □ baffle plates
- □ to prevent jet water shooting
- Various constructions can be applied
- Not too small
- Allow easy cleaning (Fig. 3.47 left)
- Fig. 3.47 right □ finer distribution of water can be obtained
- □ doesn’t need a diffusor wall

Fig. 3.47

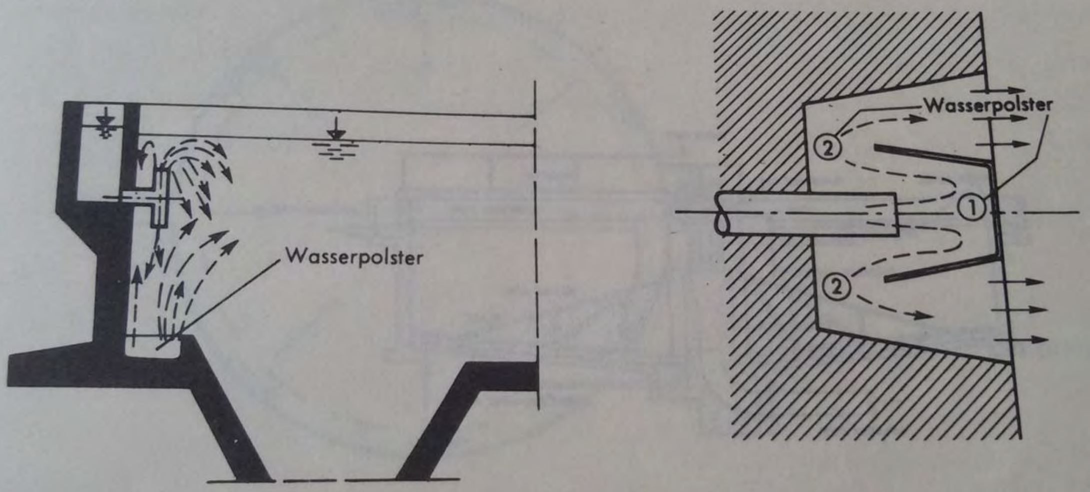


Fig. 3-47 Clifford inlet and Stuttgarter inlet.

Air blow

- V_i near the end of the inlet channel will always be low
- blow air to prevent sludge accumulation
- (Fig. 3.48)

Fig. 3.48

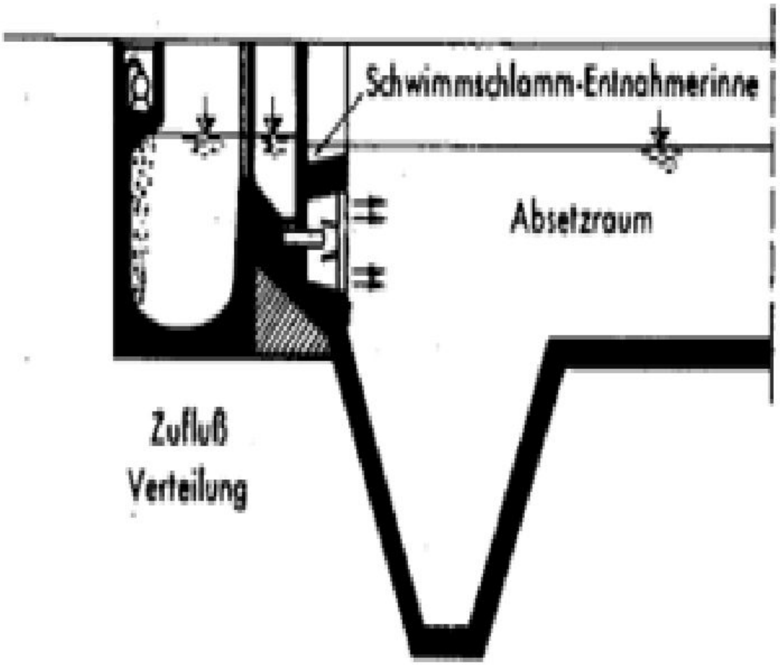


Fig. 3-48 Aerated inlet channel.

Circular tanks

- Circular & centre feed
- All inlets at the same distance from the point of supply
- Relatively large openings & small outflow velocities are allowable
- Simple baffle construction will suffice (Fig. 3.49)

Fig. 3.49

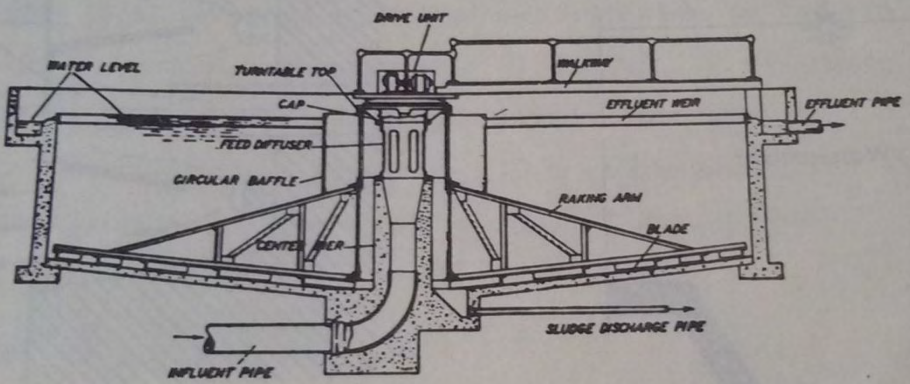


Fig. 3-49 Feed well with simple inlet construction.

Stuttgarter inlet

- Centre well has a larger diameter
- To avoid turbulent flow in the settling zone
- equal distribution can be obtained by:
- a tangential inlet
  - increasing the Froude number
  - stabilizing the flow
- Smaller openings with a larger controlling loss of head
  - require a more complicated baffle construction (Fig. 3.50)

Fig. 3.50

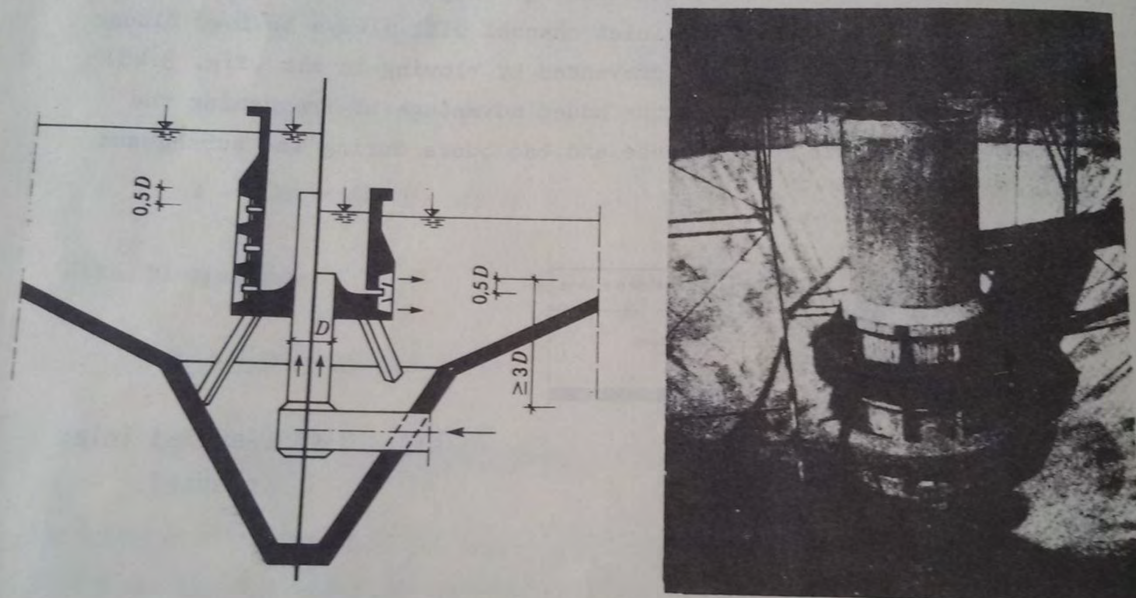


Fig. 3-50 Feed well with Stuttgarter inlet.

Peripheral feed

- The distance travelled by the raw eater from the point of supply to the various inlet openings will vary strongly (Fig. 3.15)
- Equal distribution of inflow over the full length of tank can be obtained by:
  - Small inlet openings
  - A large controlling loss of head

  □ concentrated jets of water

  □ the energy of jet water must be dissipated by baffles □ to prevent a disturbance of the settling process

Fig. 3.51

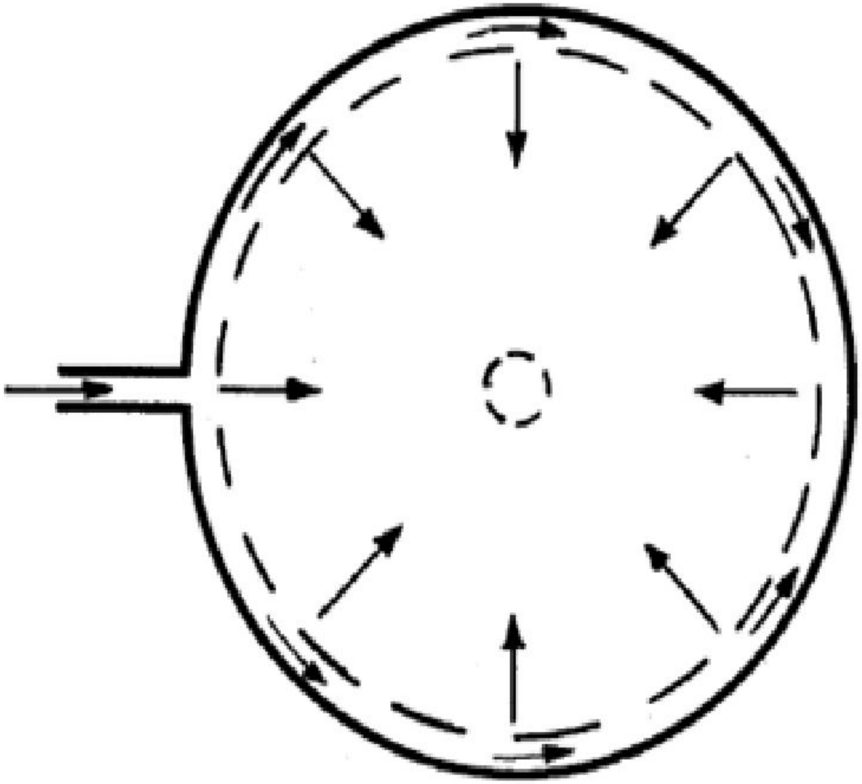


Fig. 3-51 Peripheral feed.

Outlet zone

- To collect the clarified liquid evenly over the full Ac of the basin
- Water will be accelerated
- □ flow will be quite stable
- □ even with concentrated outlets □ good results can be obtained

Outlet of rectangular tanks – single weir

- Weirs over the full width of the tank
- Single weir (fig. 3.52)

 statisfy all requirements hydrodynamically

 The weir loading (discharge per unit length) may not be too high

 As the settling of suspended matter near the end of the tank will be disturbed

Fig. 3.52

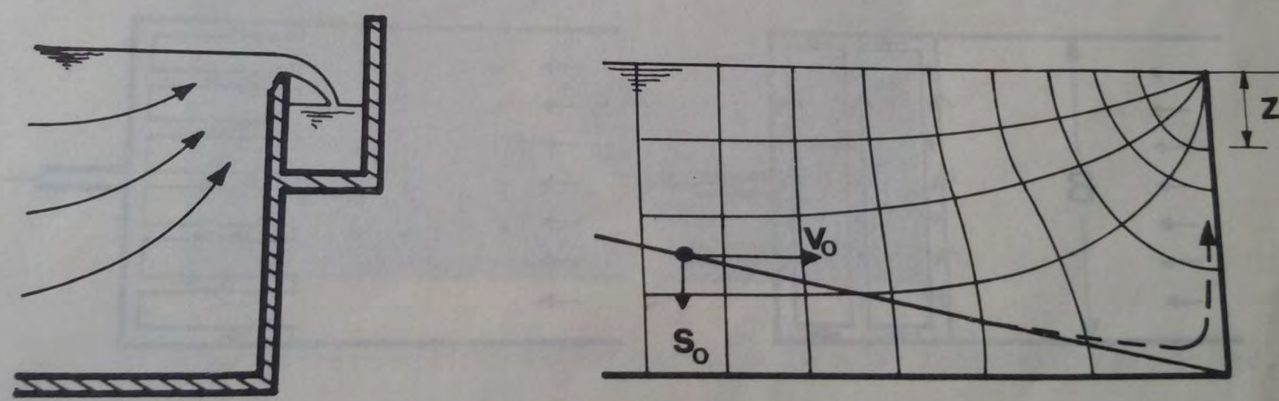


Fig. 3-52 Outlet weir over full width of tank.

S_o vs v_z

- $S_o < v_z$
- □Disturbance of the settling of suspended matter near the end of the tank
- S_o = settling velocity, downward movement
- v_z = updraft velocity created by the weir discharge

updraft velocity

- At a small distance z from the weir crest (Fig. 3.52 right):

$$v_z = \frac{Q}{B\,\frac{\pi}{2}\,z}$$

- Near the bottom of the tank, vz < the formula, with an estimated reduction factor 3

$$v_H = \frac{1}{3}\frac{Q}{B\,\frac{\pi}{2}\,H} = \frac{1}{5}\frac{Q}{BH}$$

Allowable weir loading

- $V_H < S_o$
- Allowable weir loading:
- with $\frac{Q}{B} < 5HS_0$

$$S_0 = \frac{Q}{BL}$$

- This requiremebt is automatiically fulfilled in case

$$\frac{L}{H} < 5$$

Additional weirs for rectangular tanks

$$\frac{L}{H} \; is \; mostly \; > 5$$

- (Except of turbulent settling in grit chambers)
- □ a smaller weir loading is now required
- □ can be easily obtained by installing additional weirs (Fig. 3.53)

Additional weirs for rectangular tanks

- With a total length nB:

$$\frac{Q}{nB} < 5HS_0$$

- For Q= 0.5 $^{m3/sec}$, B = 15 m, H = 2m, S_o = 0.37. 10^{-3} m/sec
- n > 9
- □ a total weir length of …m
- □ a weir loading of …. m/sec

Fig. 3.53

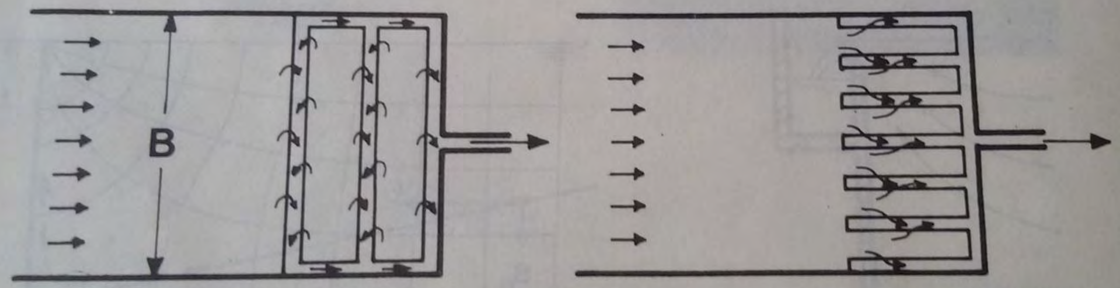


Fig. 3-53 Multiple outlet weirs, combined length nB.

Additional weirs for circular tanks – centre feed

- Single weir will be adequate once:

$$\frac{Q}{\pi D} < 5HS_0$$

- Or

$$\frac{D}{H} < 20$$

- most case
- If not multiple weirs Fig. 3.54

Fig. 3.54

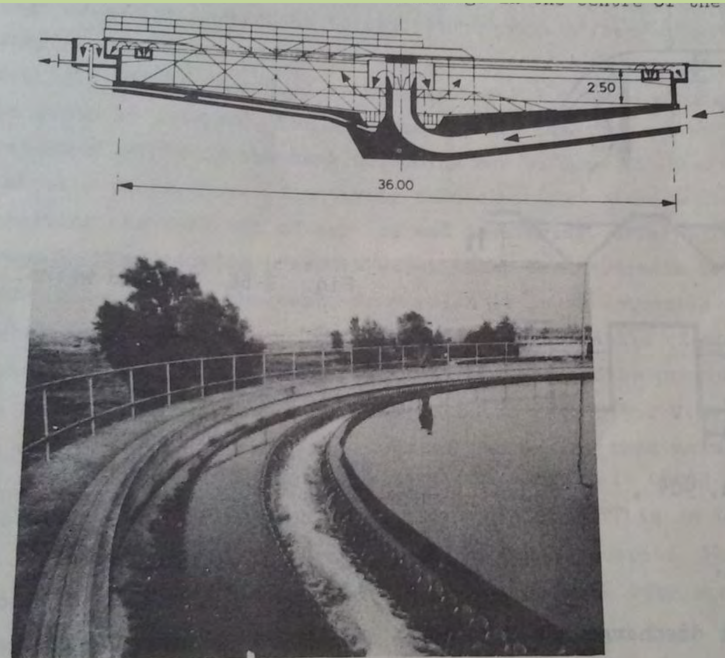


Fig. 3-54 Multiple outlet weirs in circular tanks with centre feed.

Peripheral feed

- V_z near the point of the discharge in the centre of the tank will be so high□ disturbance of the settling process
- □ disturbance can be activated by
  - □ choosing a low surface loading
  - □ near the centre of the tank
    - □ Settling process has been completed
    - □ No further deposition occur

Straight weirs

- Common weir loadings, q = (2-3). 10^{-3} m3/m/sec
- Straight weirs
  - very small overflow heights h (Fig. 3.55) = 10-14 mm
  - a deviation by 1mm from the horizontal
  - unequality in discharge = 10-15%
  - notched weirs applied in common

Notched weirs

- Steel
- Fastened to the concrete tank structure
- □ accurate adjustment of the horizontal position is possible
- V notches□ most popular □ self-cleaning
- Rectangular openings □ deviation in the vertical position has less influence on the discharge

Fig. 3.55

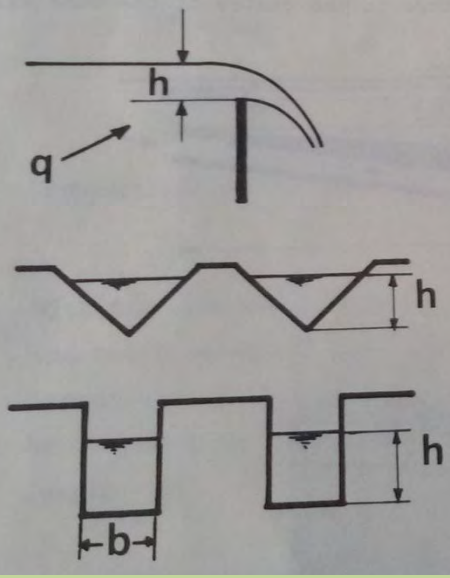


Fig. 3-55 Notched weirs.

Discharge per opening, q_0

- V-notch, 900

TLB 314 PDIPAM

Week 9

Dosen: Rachmawati S. Dj.

Genap 2025/2026

Sub CP MK *Week 8-10*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]; Metode Pembelajaran[8]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian [10] (%)
			Indikator[5]	Teknik[6]	Luring	
1	2	3	4	5	6	9
8-10	6.3	Mahasiswa mampu menjelaskan primary treatment; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat	Ketepatan dalam menjelaskan primary treatment; menganalisis dan merancang prasedimentasi, sedimentasi dan filtrasi secara tepat	Tugas, PRA-UAS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 3*50 menit/minggu ▪ Primary treatment, prasedimentasi, sedimentasi dan filtrasi: 3 ▪ *3*50 menit	10%
11	PRA-UAS					

FILTRATION

- Is a solid-liquid separation in which the liquid passes through a porous medium or other porous material to remove as much fine suspended solids as possible.

In WTP:

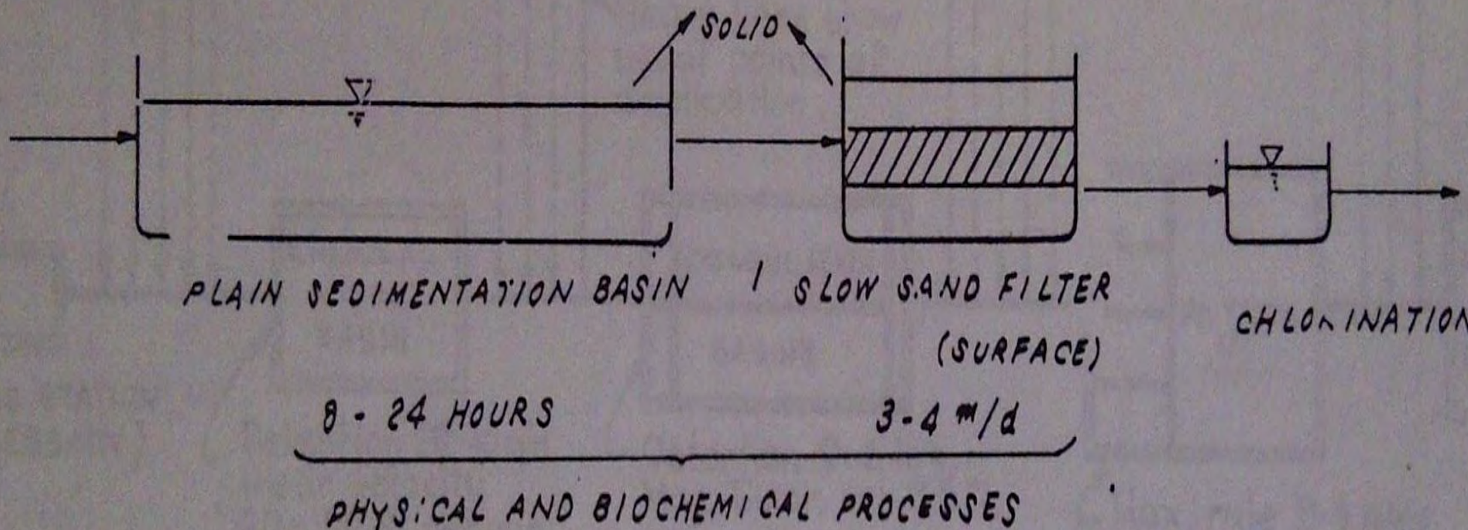
- To filter chemically coagulated and settled waters to produce a high-quality drinking water

In WWTP:

- To filter:
  - Untreated secondary effluent
  - Chemically treated secondary effluent
  - Chemically treated raw wastewaters

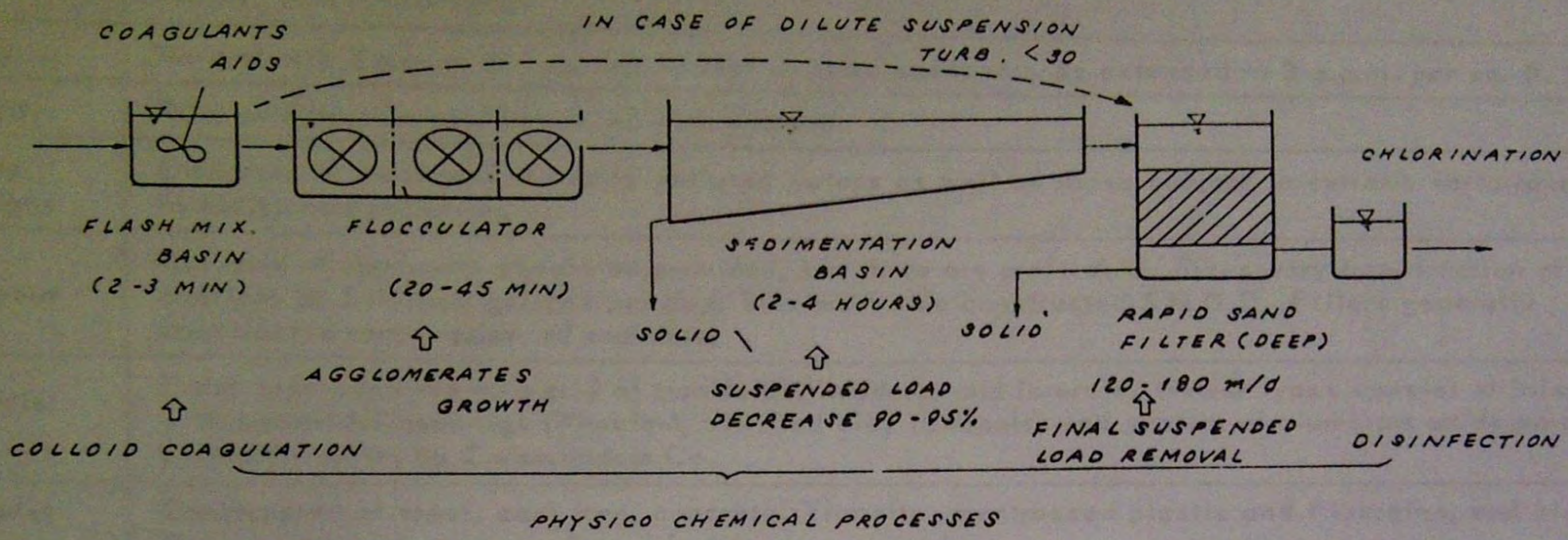
-□ to produce a high quality effluent

Slow sand filtration system ....



* Mechanism : Coarse suspended matter is removed in the plain sedimentation basin and colloidal (organic and inorganic) matters are arrested on the biological surface filter layer (Schmutzdecke).

Rapid sand filtration system . . . .



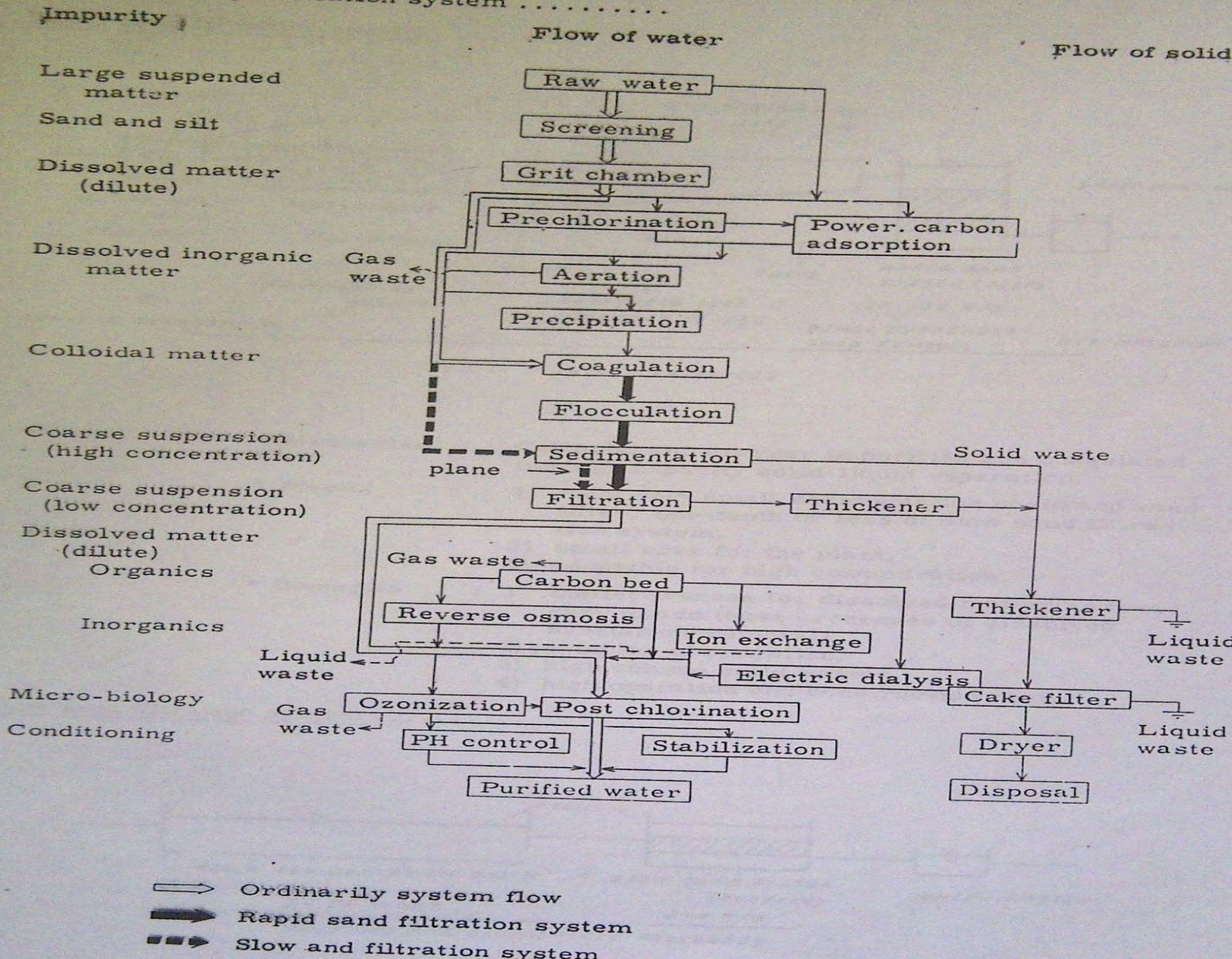
* Mechanism : Colloidal and coarser impurities are coagulated for high capacity solid-liquid separation.

* Merits : 1) relatively small sedimentation basin and sand filter, one-tenth or less of slow sand filtration system.
2) small area for the plant,
3) adoptable for high concentration.

* Demerits : 1\` ineffectiveness for dissolved matter(however, easy to add those processes of dissolved substances removal),
2) complex of operation,
3) high volume solid wastes,
4) high operation and construction cost.

Slow sand filtration system

A flow sheet of purification system ....



classification

- Single-medium filters:

 One type medium:
  - Sand, or
  - Crushed anthracite coal
- Dual media filters:

 two types of media:
  - Crushed anthracite and sand
- Multimedia filters:

 three types of media:
  - Crushed anthracite, sand and garnet

In WTP:

- All three types are used
- Popular: dual & multi media filters

In advanced & tertiary WWTP:

 Dual or multi media types

Both in WTP & WWTP:

- The principles
- Filter structures, equipment, accessories & method of operation

-□ similar

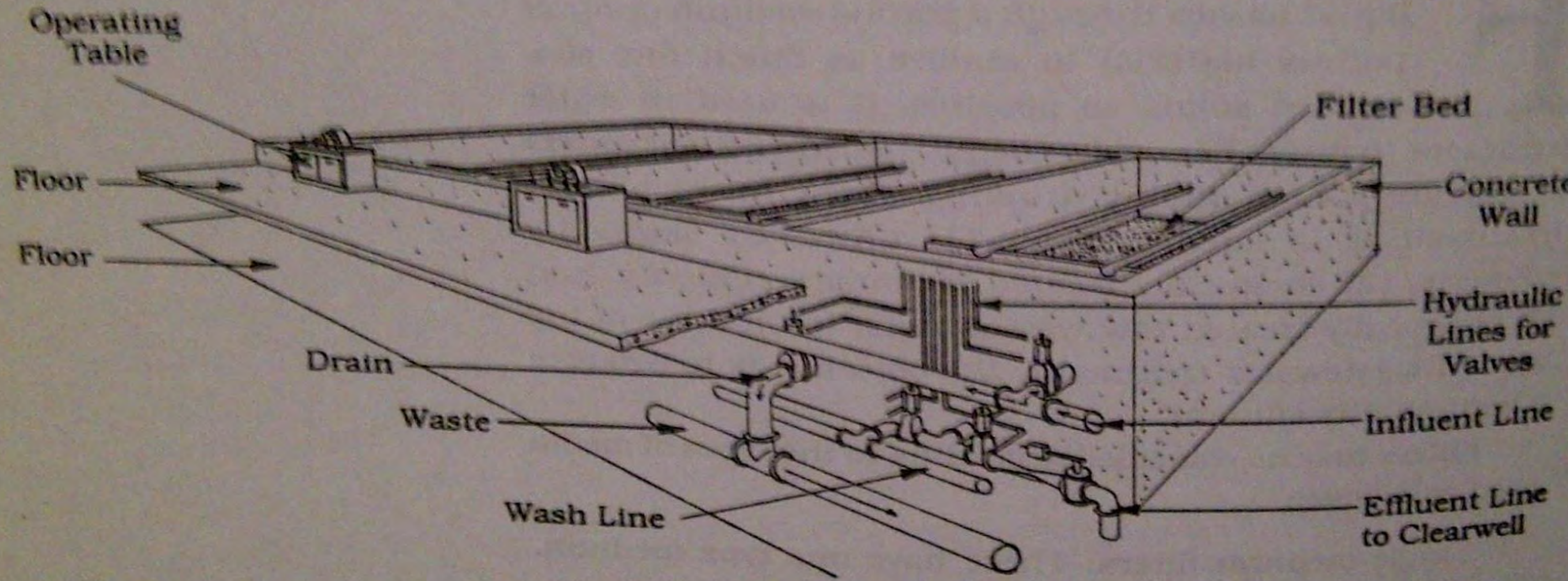
Single medium filter

RSF in WTP:

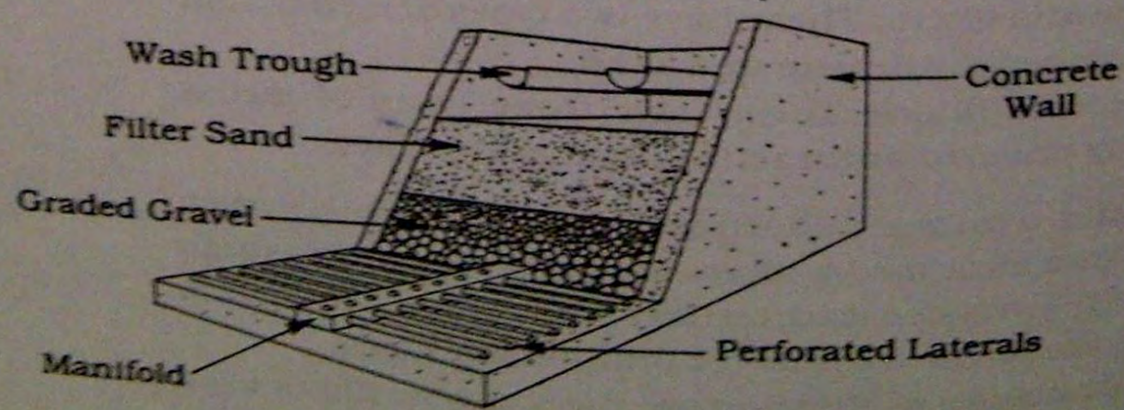
- Gravity type
- Housed in open concrete basins

- Fig 4.1 – 4.8
- The most common: open gravity filters
- pressured filters are also used (Fig 4.5 -4.7)

Figure 4.1. Gravity Filters and Accessories
Courtesy of the National Lime Association.



(a) Perspective of a Battery of Filters



(b) Perspective through a Filter

Figure 4.2. **Section through a Rapid Sand Filter**

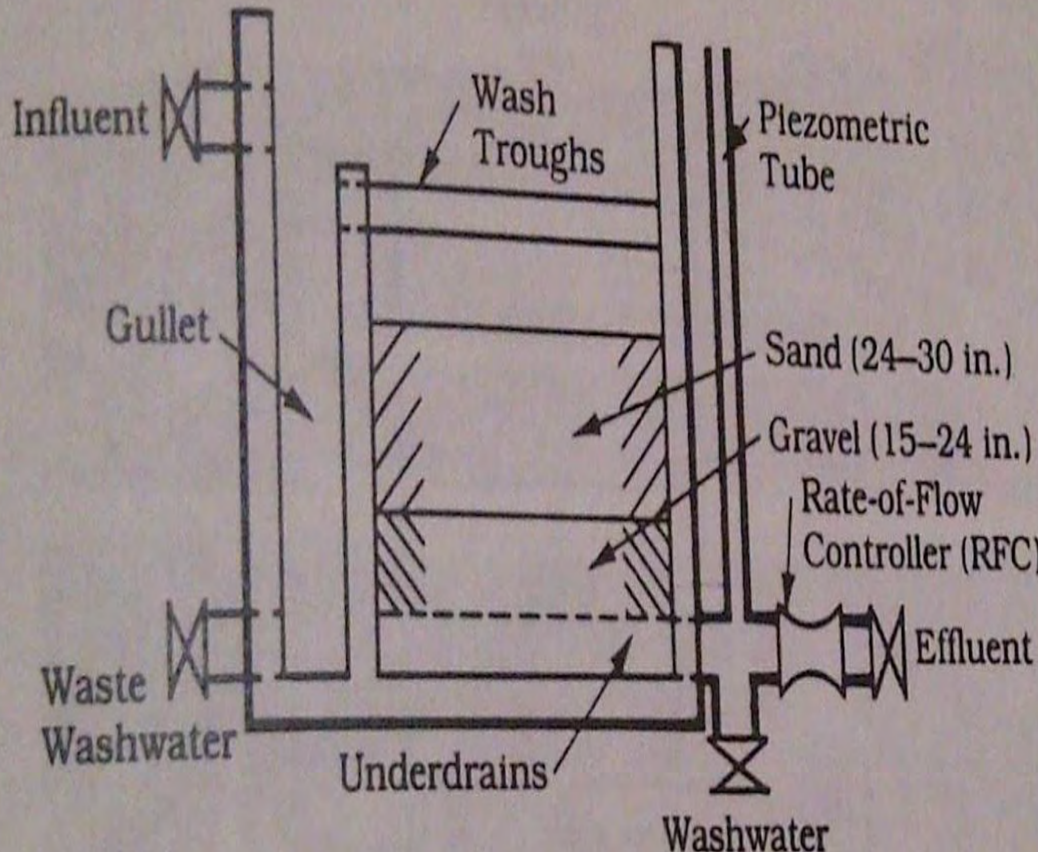


Figure 4.3. Wash System Layout

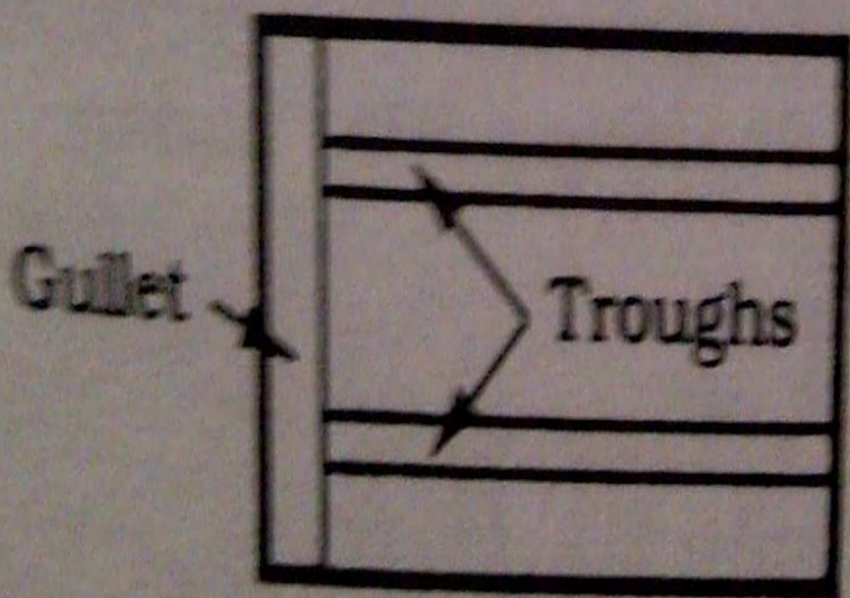


Figure 4.4. Filter Piping Layout

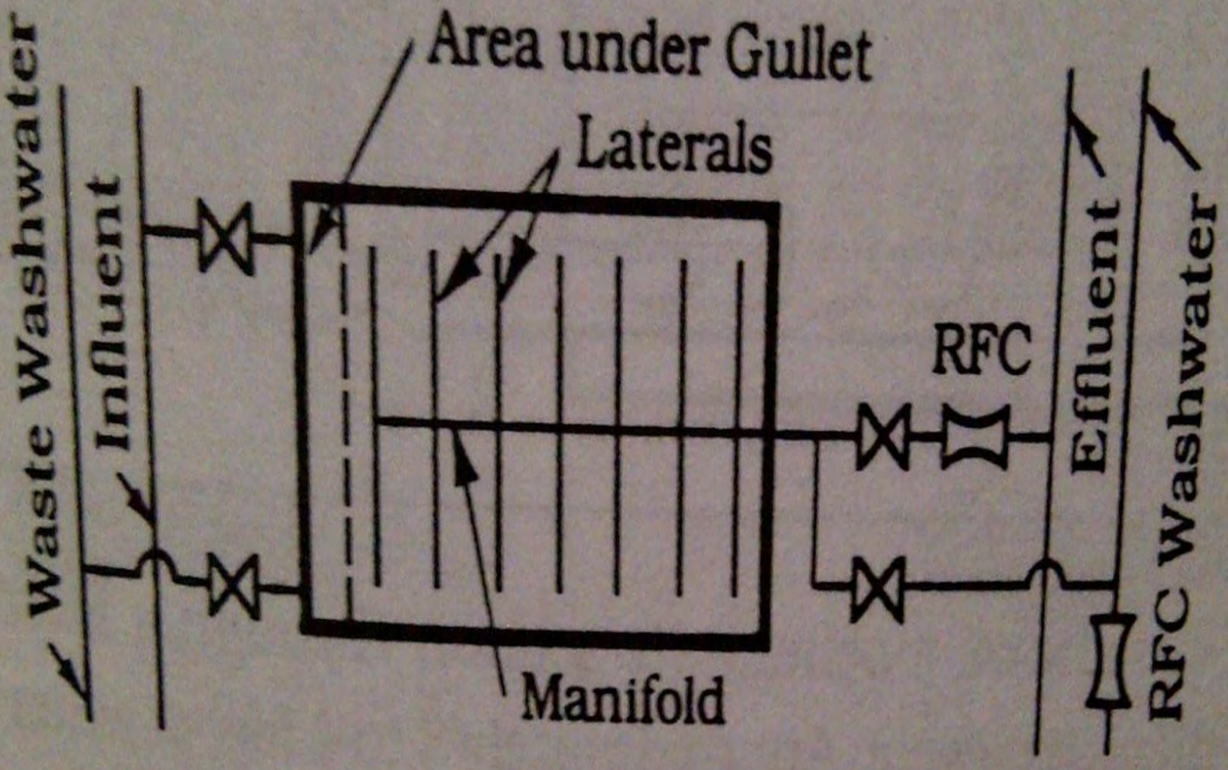


Figure 4.5. *Profile through a Horizontal Pressure Filter*

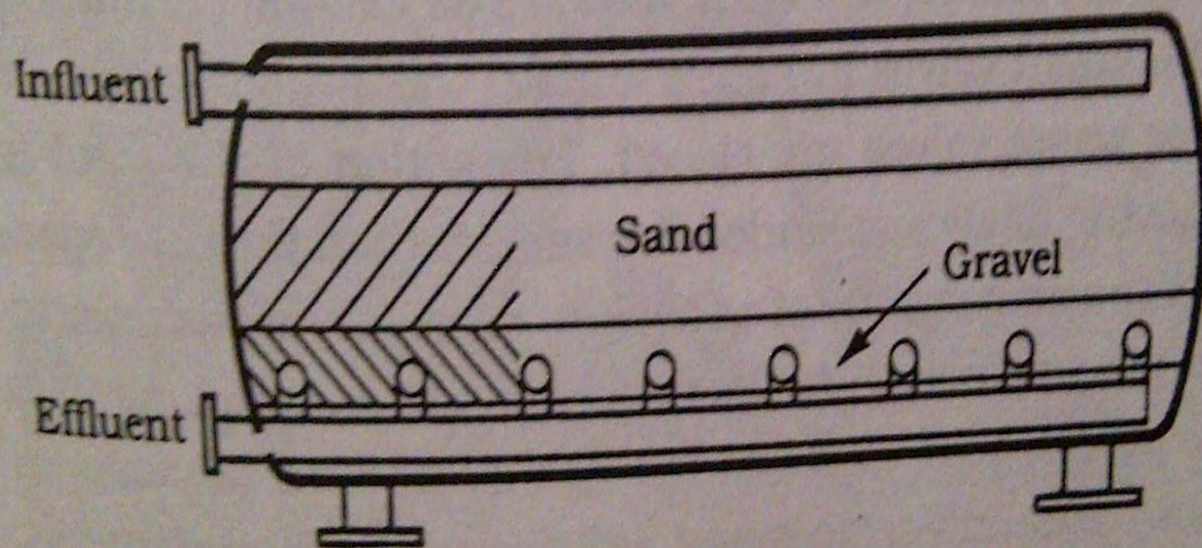


Figure 4.6. Cross Section through a Horizontal Pressure Filter

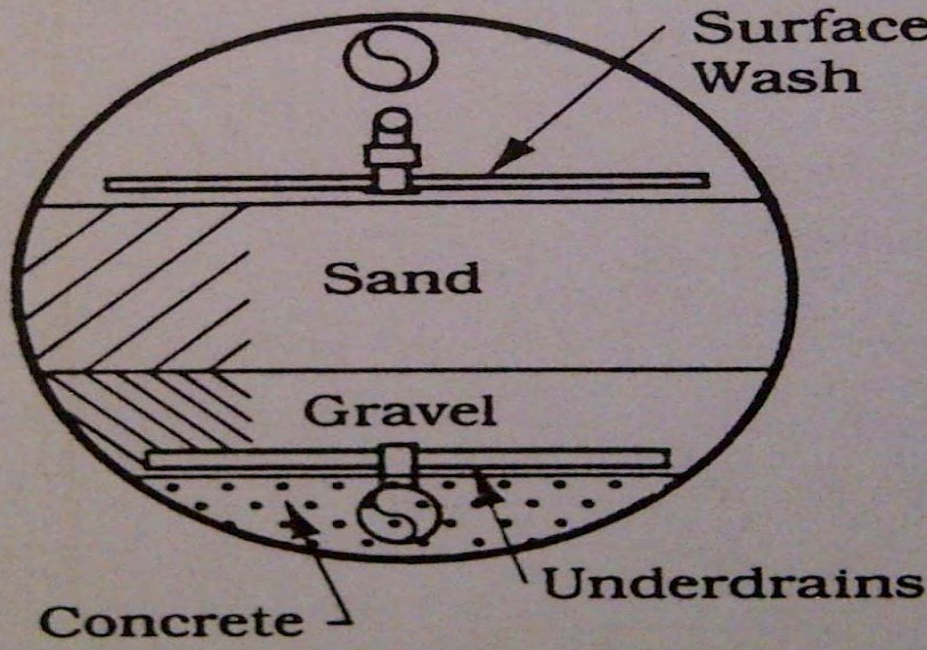
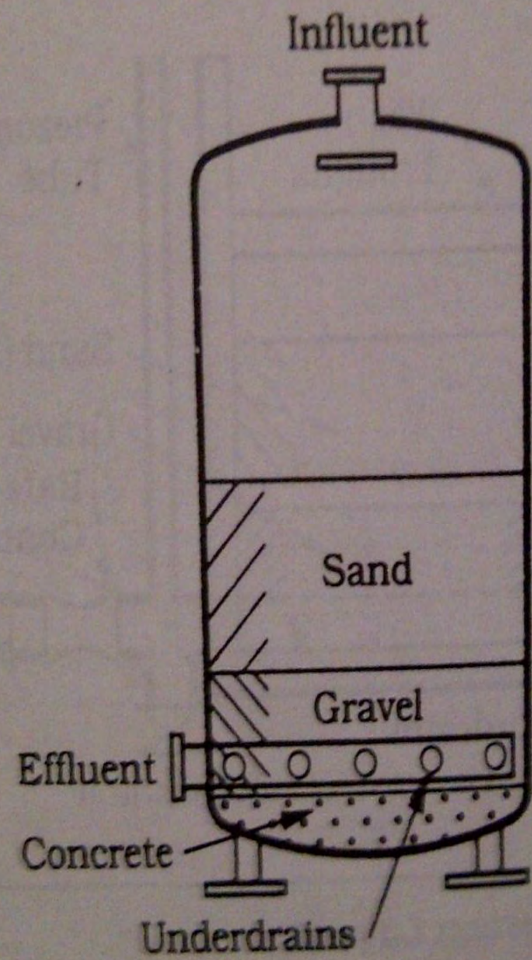


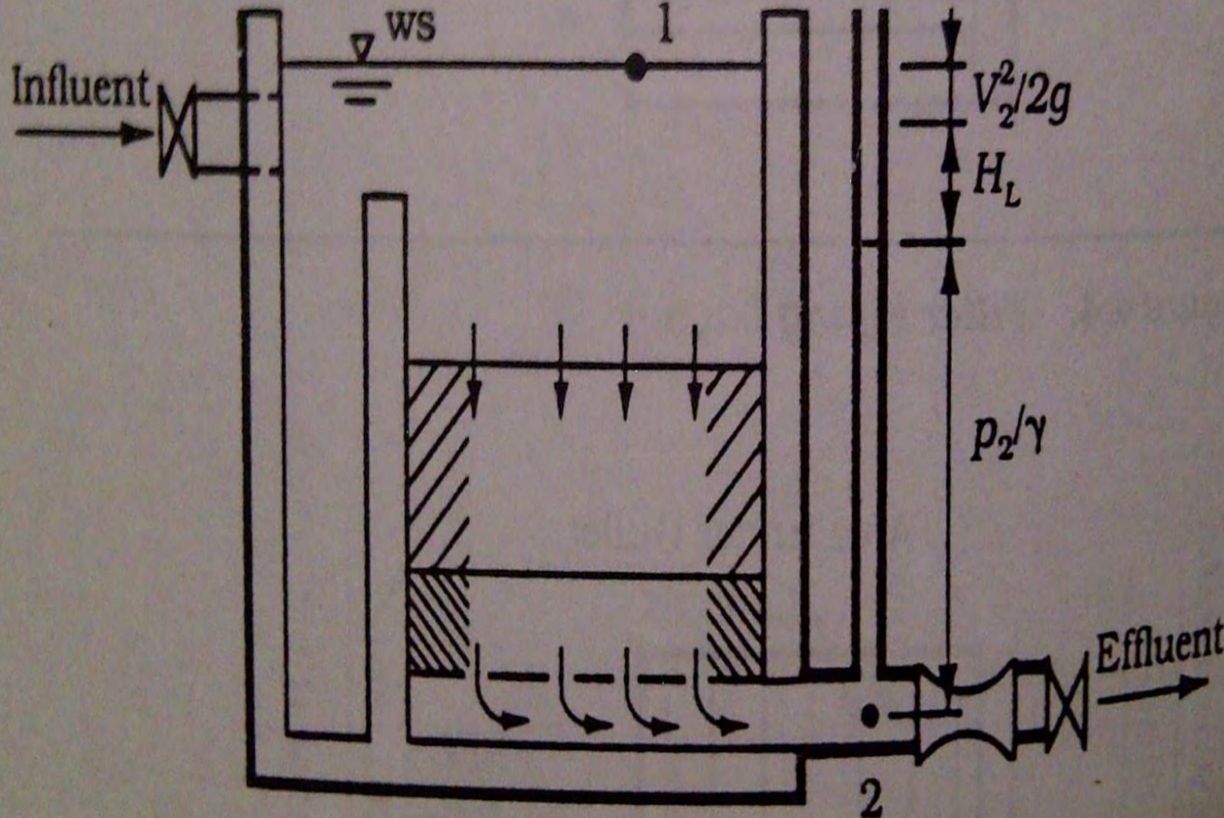
Figure 4.7. Cross Section through a Vertical Pressure Filter



- Frequently crushed anthracite coal is used
- Sand bed depth: 24-30 inches
- Underlaying gravel: 15-24 inches

- Fig 4.8: filtration cycle

Figure 4.8. Schematic Section Showing a Filter during Filtration



During filtration cycle

- Approximately 3-4 ft of water is above the sand.
- The water passes downward through the media into the underdrain system.
- Then it flows through the rate of flow controller which controls the rate at which the water is filtered.

During filtration cycle

The valves position (Fig 4.4):

- Influent & effluent valves are open
- Wash water & wash water waste valves are closed

The action of the sand in removing finely suspended floc smaller than the pore openings consists mainly of:

- Adhesion
- Flocculation
- Sedimentation
- Straining

- As the water moves downward through the pore spaces, some of the fine suspended flocs collides with the sand surfaces and **adheres** to the sand particles.
- As the water passes through pore constrictions, some of the fine floc is brought together, **flocculation** occurs, and the enlarged floc **settles** on the top of the sand particles immediately below the constrictions.

- The build up of floc that has been removed in the filter creates a straining action and some of the incoming floc is removed by **straining**.

- During a filter run:
  - The accumulated floc causes the pore spaces to become smaller
  - The velocities to increase
  - Some of the removed floc to be carried deeper within the filter bed.

- Straining may also occur at the surface of the filter if large particles of floc are strained and form a compressible cake that assists in filtering smaller particles.

To sum up:

- The removal of SS is by:
  - Surface removal at the top of the bed
  - And depth removal within the filter bed itself

- For WTP:
- RSF □ depth removal is the most important

When a clean filter is put into operation:

- The floc accumulation is in the first few inches of the sand

As the time of operation increases

- The floc accumulation extends deeper into the filter bed.

- The accumulated floc causes an increase in the hydraulic head loss.
- The magnitude of the head loss, HL is illustrated by writing Bernoulli’s energy equation between point 1 on the water surface (Fig 4.8) and point 2 at the center of the effluent line.

Bernoulli's energy equation

- (4.1):

$$\frac{V_1^2}{2g} + \frac{p_1}{\gamma} + z_1 = \frac{V_2^2}{2g} + \frac{p_2}{\gamma} + z_2 + H_L$$

- V1, V2 = respective velocities
- P1,P2 = respective pressures
- Z1, z2 = respective elevation heads
- γ = specific weight of water
- g = acceleration due to gravity
- HL = head loss in ft

- If the relative pressure is used, p1 = 0.
- Also v1 = 0, and
- The datumn may be selected so that z2 = 0.
- Incorporating these values in Eq 4.1 and rearranging gives (4.2)

$$\frac{p_2}{\gamma} = z_1 - \frac{V_2^2}{2g} - H_L$$

Since it is common to have:

- 4 ft of water over the sand
- 2 ft 6 inch of sand
- 1 ft 6 inch of gravel
- 1 ft depth for the underdrains

-□ $z1 = 4 + 2.5 + 1.5 + 1 = 9$ ft

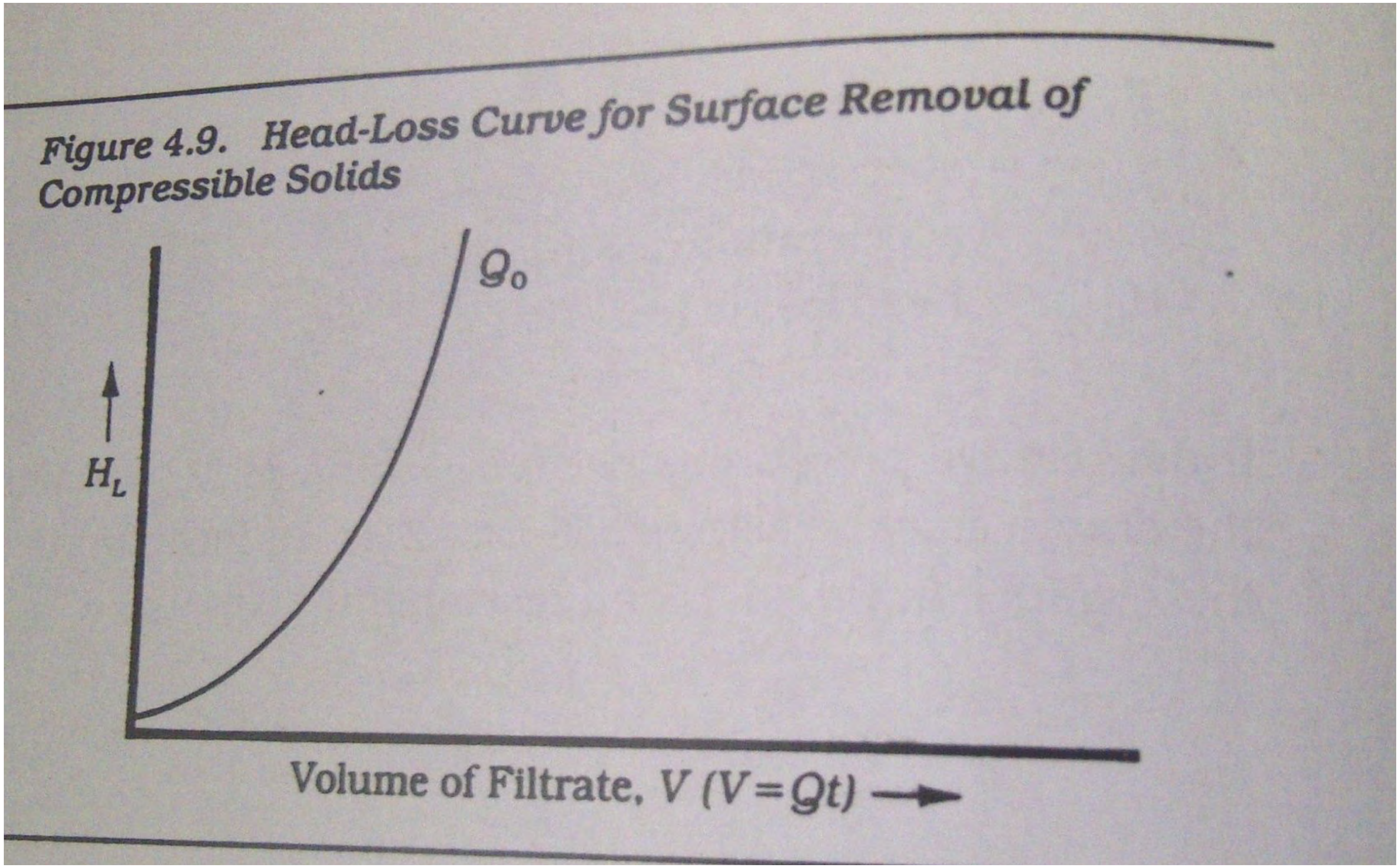
- And pipes are usually designed for= 4 fps

- Thus Eq 4.2 yields an expression for the gauge pressure head at point 2 (4.3):

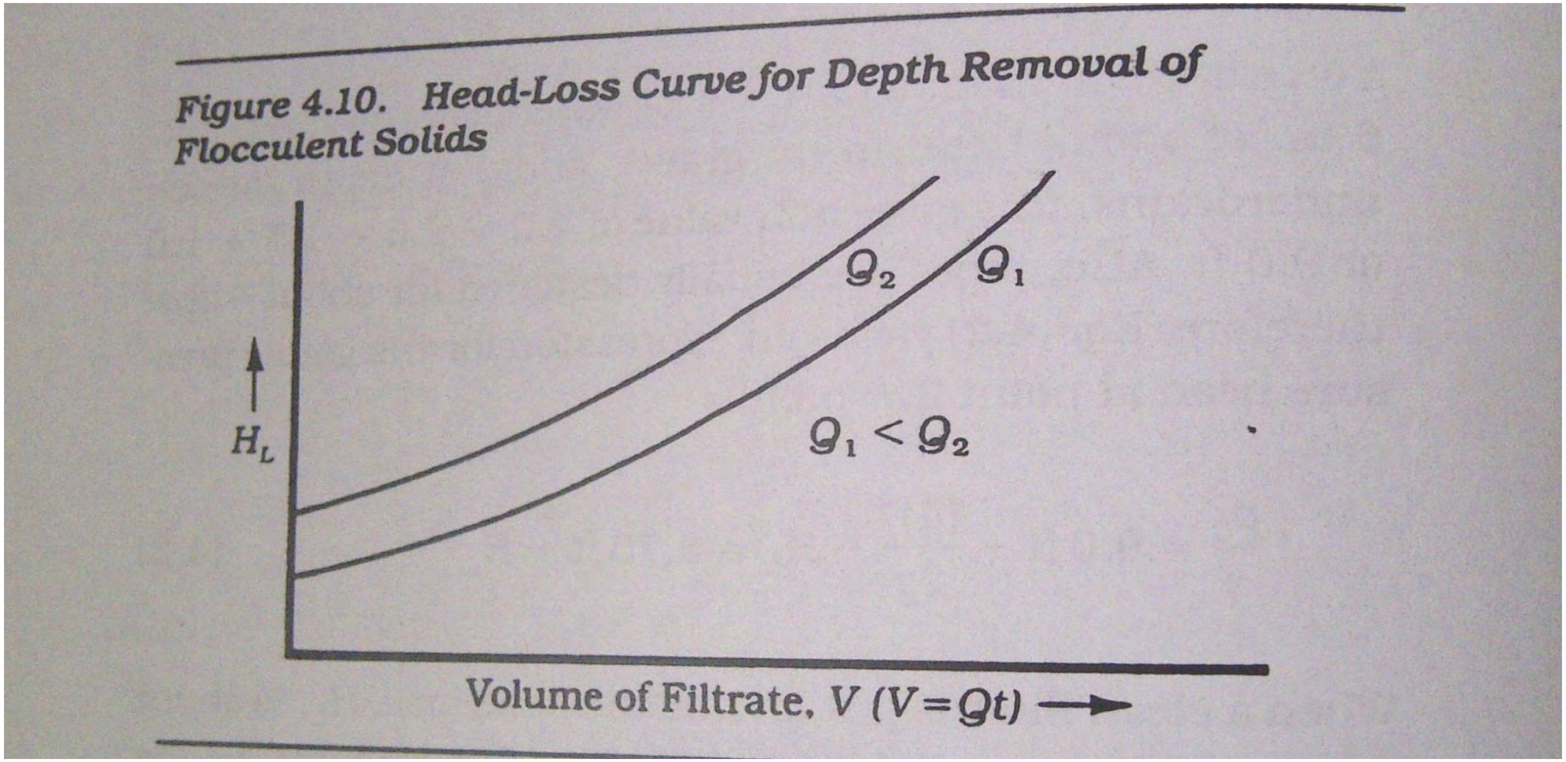
$$\frac{p_2}{\gamma} = 9\,ft - \frac{4^2}{2g} - H_L = 8.75\,ft - H_L$$

- When a clean filter is put on line, the HL = 0.5 -1.5 ft depending upon the filtration rate,
- But as the filter run progresses, the HL increases.
- Eq 4.3:
- Once the HL = 8.75 ft -□ P2 = 0
- HL >>> -□ a negative pressure -□ undesirable

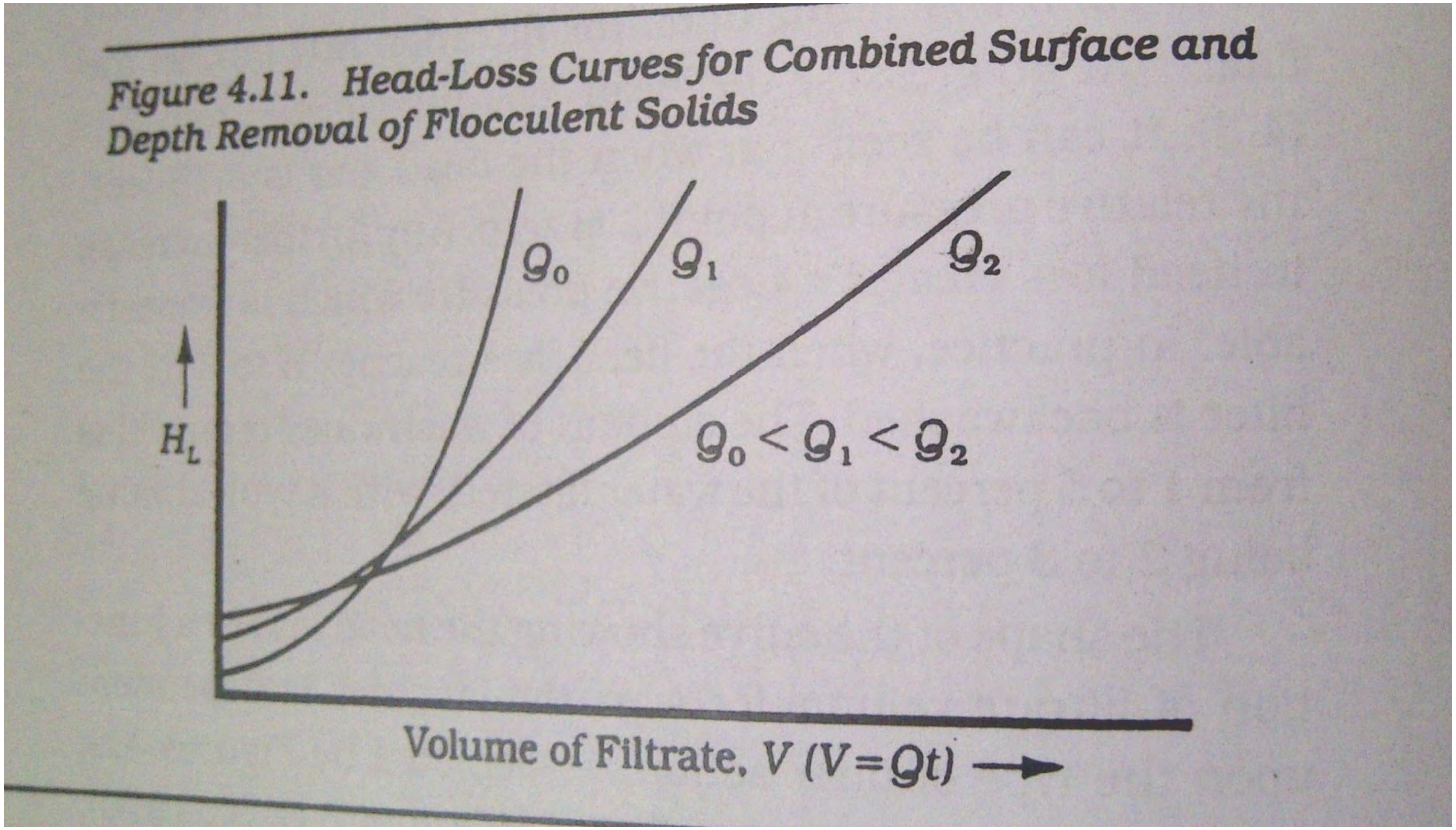
- In practice: once HL = 6-8 ft - back washed
- Brp pun kriteria (tinggi air di atas filter, h sand, gravel n underdrain), backwash hrs dilakukan ktk HLnya = 75%
- The amount of washwater= 1-5% of the filtered water (typical value=2-3%)
- The shape of the curve showing the HL as a function of filtrate volume for a particular filter is dependent upon the type of filter action (Fig 4.9-4.11)



If the filter action is by surface removal of compressible solids, the HL curve will be exponential.
For: fine grained media and low filtration rates
Ex: micro screens and diatomaceous earth filters



If the filter action is depth removal of flocculated suspended solids, the HL curve will be rather flat.
For: deep granular filters at relatively high filtration rate



If the filter action is by surface removal and depth removal of flocculated suspended solids, the HL curves will be as shown above.

- At low filtration rates, surface removal is predominant, the curve is similar to Fig 4.9.
- At higher filtration rates, the solids penetrate deep within the filter. The principal action is depth removal, the curves are similar to Fig 4.10.

- In RSF, at usual filtration rates:
  - □ depth removal □the main filter action
  - □ a flat HL curve

Surface removal

Will result when the feed water contains:

- Large floc, and
- High turbidity

The top pores will rapidly become clogged

- short filter runs

Depth removal

Will result when the feed water contains:

- small floc, and
- low turbidity

Deeper penetration within the filter bed

- long filter runs

Characterization of filter sand

1. The ES:

The sieve size in mm that will pass 10% (by weight) of the sand

2. The UC:

The sieve size passing 60% of the sand divided by that size passing 10%

UC & ES

- Most RSF have sand with an ES = 0.35-50 mm.
- Some have sand with an ES = 0.70 mm
- The UC (= a measure of gradation) = 1.3 <UC< 1.7.

gravel

- Serves to support the sand bed
- Usually is placed in several layers
- Total depth = 6-24 inches (typical=18 inches)
- The size of :
  - the top layer of gravel depends on the sand size
  - The bottom gravel depends on the type of the underdrain system

Underdrain system

- Serves to:
  - collect the filtered water from the bed during the filtration cycle.
  - Distribute the backwash water during the washing cycle
- The rate of flow of the backwash >> the filtration time □ The rate of flow of the backwash governs the hydraulic design of the filter

Underdrain system

- Two types:

1. A manifold with perforated lateral pipes
2. A false bottom

the manifold with perforated lateral pipe system

- the perforations are directed downward
- so that the high velocity of the backwash water is dissipated by:
  - the filter water bottom and
  - the surrounding gravel.

The false bottom

- Consists of a perforated bottom
- With a water way underneath:
  - that removes the filtered water
  - And permits the backwash to enter the filter bed

The standard rate of filtration

- 2 gal/min-ft2 of filter bed area
- This is a common rate at which the first RSF were operated
- Present coagulation & sedimentation practice allows the use of higher filtration rates
- Frequently, plants are rated at 2 gal/min-ft2
- But, provisions are made for operation at rates up to 5 gal/min-ft2

- Most filters are operated at a constant filtration rate
- But a declining rate of filtration is sometimes employed

a declining rate of filtration

- The rate of filtration is decreased:
  - as the filter run progresses
  - And the degree of clogging increases
- Result in:

 longer filtration runs

 Better effluent quality

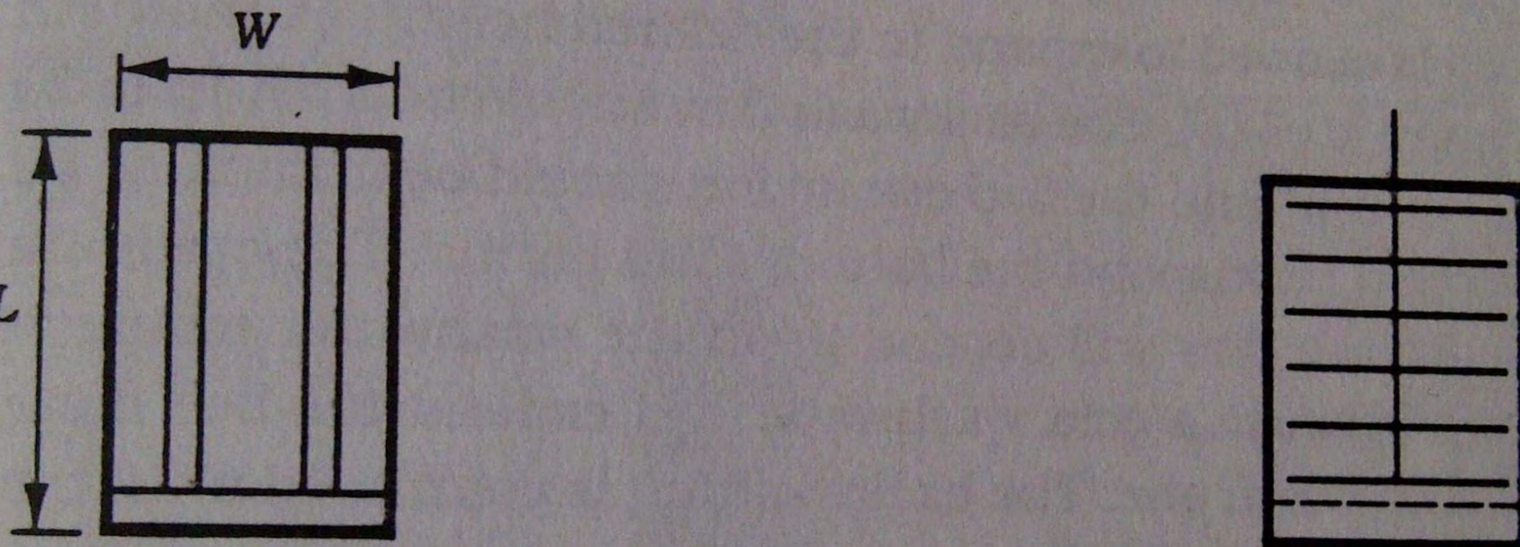
- It is limited to medium to large plants because the filters must be staggered in the degree of clogging to permit a constant rate in the total water production from the plant.

Gravity filters

- A single filter (fig 4.12) or
- A double filter within each concrete basin

(Fig 4.13)

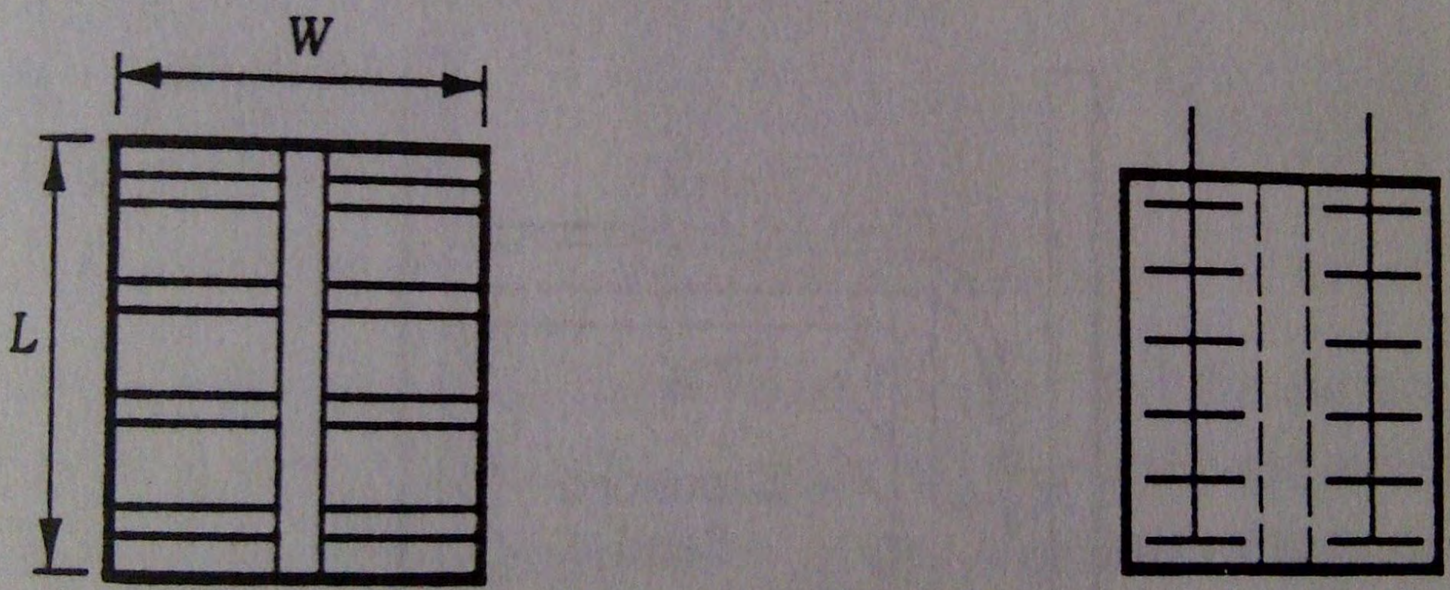
Figure 4.12. Layout and Underdrains for a Single Filter



most popular

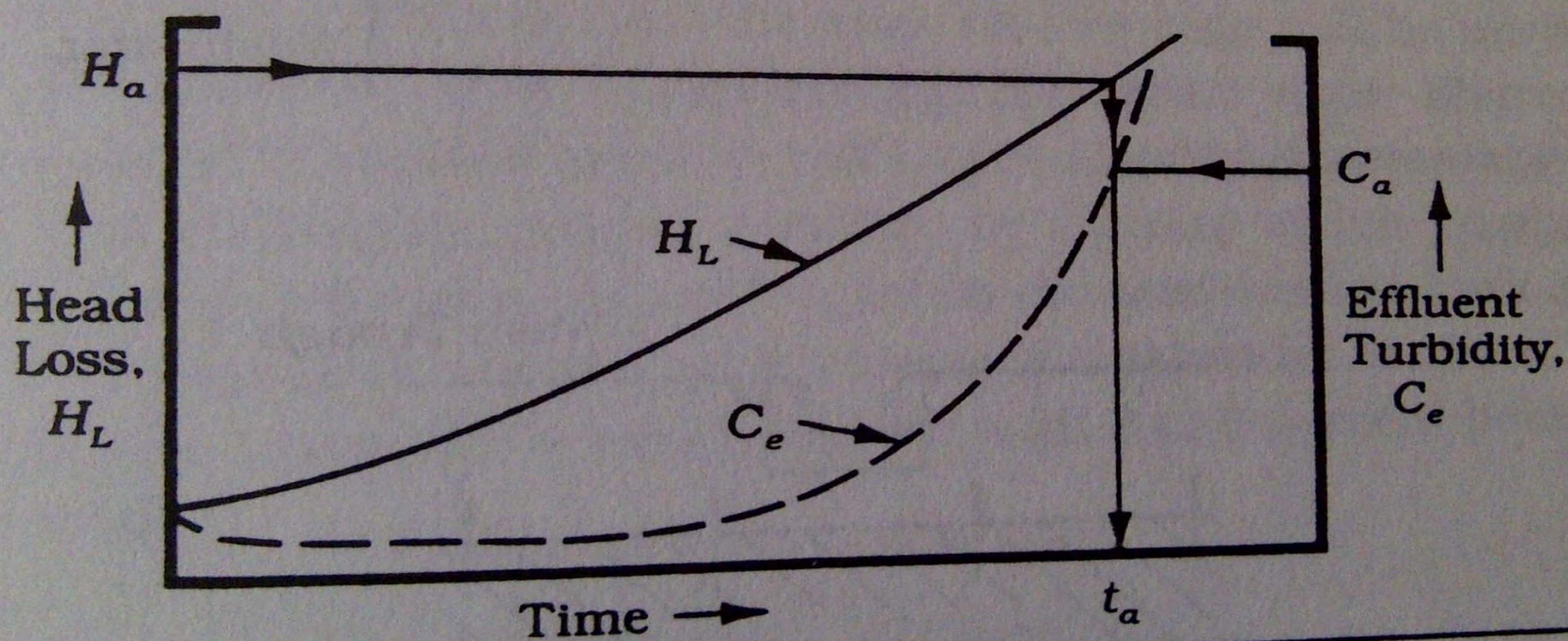
The length to width ratio = 1:1.5 to 1:2

Figure 4.13. Layout and Underdrains for a Double Filter



Almost square
Length to width ratio = 1:1

Figure 4.14. Head Loss and Effluent Turbidity versus Filter Run Time for Optimum Performance



If the filter operation is optimum:

The maximum allowable Ha

Occurs simultaneously with

The maximum allowable effluent turbidity Ca

Filter run

- In may cases, this does not occur and the termination of the filter run is controlled by whichever occurs first, Ha or Ca.
- The length of the filter run:
  - Will depend on the quality of the feed water
  - May range from less than a day to several days

backwashing

- Removes the floc that has accumulated upon and within the filter bed.
- A surface wash or
- Air scour system
- Is considered essential for high filter performance

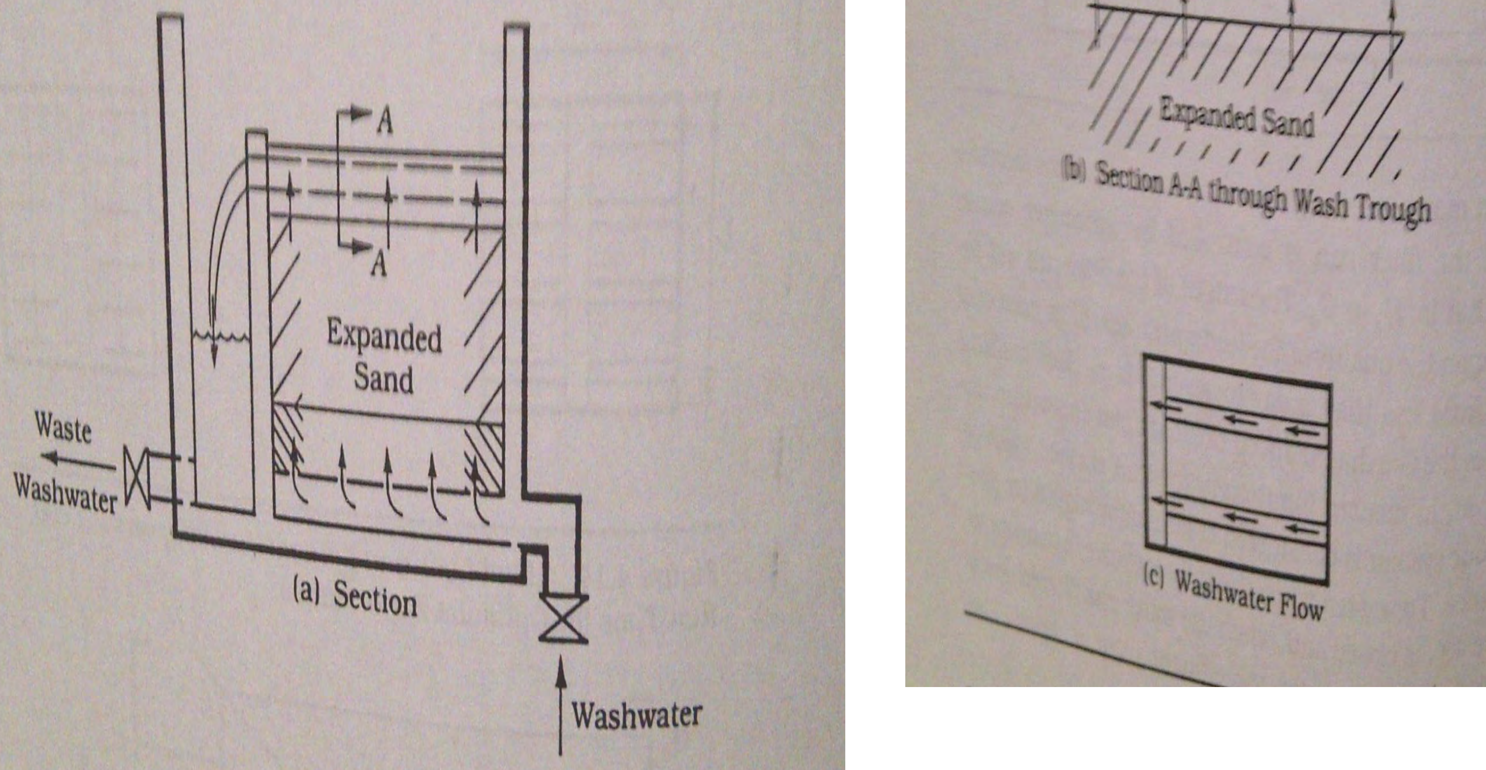
backwashing

- To wash a filter (Fig 4.4):
- The influent pipe is closed
- And once the water is filtered down below the wash troughs,
- The effluent valve is closed.
- The waste washwater is opened and
- The surface wash is started at a rate= 0.5 gal/min-ft2.

backwashing

- After about 1 min of surface washing
- The backwash flow is initiated by gradually opening the washwater influent valve and
- The bed is allowed to expand to the desired height (Fig 4.15 (a)).
- The backwash flow should be: 15-20 gal/min-ft2
- And the bed expansion should be: 20-50%
- To suspend the bottom sand grains

Figure 4.15. Schematic Showing Filter during Backwashing



(a) Section

(b) Section A-A through Wash Trough

(c) Washwater Flow

backwashing

- The optimum backwash flow will depend on the washwater temperature because a cold washwater will expand the bed more than a warm one.
- The backwashing is continued till the wastewash water appears relatively clear, and
- The surface wash is terminated at 1-2 min prior to the end of the backwash.

backwashing

Surface wash:

- Washes the filter surface prior to the backwashing
- Scours the expanded bed during the backwash

□ An auxiliary scour system

Complete washing: 3-10 min of backwash flow

Total off-line time: up to 20min

backwashing

- After backwashing: the initial water filtered should be wasted until the effluent turbidity is acceptable.
- Washwater supply:
- A pump
- An elevated storage tank
- The volume of washwater=1-5% of the water filtered (2-3% typically)

Hydraulics of filtration

- The HL through a clean bed of porous media having a relatively uniform diameter, as given by the Carman-Kozeny equation,maybe developed starting with the Darcy-Weisbach equation (4.4):

$$h_L = f \frac{LV^2}{D_c 2g}$$

h_L = frictional head loss

f = dimensionless friction factor

L = conduit length

D_c= conduit diameter

V= mean conduit velocity

g = acceleration due to gravity

- The flow channels in a porous bed are irregular, thus the diameter Dc may be replaced by the term 4r, where r is the hydraulic radius for a conduit diameter.
- If D=the bed depth, substituting this an Dc=4r into Eq 4.4 gives (4.5):
- $$h_L = f\frac{DV^2}{8rg}$$

- If there are n particles in the bed, and
- The particle volume = v_p,

□ The total volume of particle = nv_p.

- If the porosity = ε,

□ The total bed volume = $nv_p / (1- ε)$

- The total channel volume = the void space = $ε\, nv_p / (1- ε)$

- If the wetted surface is considered as the total surface of the particles = ns_p,
- where s_p=the surface area per particle.
- The hydraulic radius r = the total channel volume divided by the wetted surface or (4.6):

$$r = \left(\frac{\varepsilon}{1-\varepsilon} \right) \frac{v_p}{s_p}$$

- For spherical particles (4.7):

$$\frac{v_p}{s_p} = \frac{\pi d^3 / 6}{\pi d^2} = \frac{d}{6}$$

- For irregularly shaped particles (4.8):

$$\frac{v_p}{s_p} = \phi \frac{d}{6}$$

- Where φ = the shape factor

Shape factors

- Spheres = 1
- Crushed coal and angular sand = 0.73
- Rounded sand = 0.82
- Average sand = 0.75

- The approach velocity, Va = the flow Q divided by the filter surface A.
- Thus, the velocity through the pore spaces (4.9):

$$V = \frac{V_a}{\varepsilon}$$

- Substituting Eq (4.6), (4.8), (4.9) into (4.5), gives (4.10):

$$h_L = f' \frac{D}{\phi d} \frac{1-\varepsilon}{\varepsilon^3} \frac{V_a^2}{g}$$

- □ Carman-Kozeny relationship
- Where: f’ = dimensionless friction factor

- The friction factor f'(4.11):

$$f' = 150\left(\frac{1-\varepsilon}{N_{\text{Re}}}\right) + 1.75$$

- The Reynolds number (4.12):

$$N_{\text{Re}} = \frac{\phi d V_a}{\nu} = \frac{\phi \rho d V_a}{\mu}$$

- Where:
- ρ= mass density
- μ= dynamic viscosity
- ν=kinematic viscosity

- The HL through a clean bed of porous media having a relatively uniform diameter is also given by the Rose equation (4.13):

$$h_L = \frac{1.067}{\phi}\frac{C_D}{g}D\frac{V_a^2}{\varepsilon^4}\frac{1}{d}$$

- Where C_D = the coefficient of drag

- For $N_{Re} < 1$ (4.14):

$$C_D = \frac{24}{N_{\mathrm{Re}}}$$

- For $10^4 > N_{Re} > 1$ (4.15):

$$C_D = \frac{24}{N_{\mathrm{Re}}} + \frac{3}{\sqrt{N_{\mathrm{Re}}}} + 0.34$$

- For beds with varying particle size, the Rose equation (4.16):

$$h_L = \frac{1.067}{\phi}\frac{C_D}{g}D\frac{V_a^2}{\varepsilon^4}\sum\frac{x}{d}$$

- Where:

x =the weight fractions for particle sizes, d

- For stratified beds with uniform porosity, the Rose equation (4.17):

$$h_L = \frac{1.067}{\phi}\frac{D}{g}\frac{V_a^2}{\varepsilon^4}\sum\frac{C_D x}{d}$$

- In both equations, the summation terms maybe obtained from computation using sieve analysis.

- The HL through the underdrain system is usually negligible compared to the HL through the bed.
- The Carman-Kozeny & Rose equation are limited to clean filter beds, but they also illustrate the relationship between the HL and the degree of clogging.
- As a filter bed cloggs, the effective porosity ε decreases the HL increases.

example

A RSF has a sand bed 24 inch in depth. Specific gravity of the sand = 2.65, shape factor φ = 0.82, porosity ε = 0.45, filtration rate = 2.5 gpm/ft2, and operating temperature 50^0F (10^0C). The sieve analysis of the sand is shown in the table below. Determine the H_L for the clean filter bed using the Rose equation for a stratified bed.

Soal 1

Suatu saringan pasir cepat mempunyai ketebalan 25 inch. Specific gravity pasir = 2.65, shape factor φ = 0.82, porosity ε = 0.45, filtration rate = 2.6 gpm/ft^2, temperatur pada saat beroperasi = 50^{0}F (10^{0}C). Sieve analysis untuk pasir diperlihatkan pada tabel di bawah ini. Tentukan H_L untuk media filter yang masih bersih dengan menggunakan persamaan Rose untuk suatu media yang terstratifikasi.

Table. Sieve analysis

(1) Sieve Size	(2) Weight Retained (%)
14–20	0.87
20–28	8.63
28–32	26.30
32–35	30.10
35–42	20.64
42–48	7.09
48–60	3.19
60–65	2.16
65–100	1.02

Sieve size

Sieve size	d (ft)
14-20	0.003283
20-28	0.002333
28-32	0.001779
32-35	0.001500
35-42	0.001258
42-48	0.001058
48-60	0.000888
60-65	0.000746
65-100	0.000583

No ayakan	Ukuran bukaan (mm)	% kumulatif lolos
140	0,105	0,4
100	0,149	1,2
70	0,210	3,6
50	0,297	9,2
40	0,420	20,8
30	0,590	38,4
20	0,840	58,6
18	1,00	66,2
16	1,19	78,4
12	1,68	92,8
8	2,38	96,2
6	3,36	100,0

No ayakan	Kumulatif Berat Tertahan (%)
40-50	2,4
30-40	37,1
20-30	44,3
18-20	92,9
16-18	100,0

At 10^0C:

- v = 1.3101 centistokes
- 1 centistoke = 10^{-2} cm^2/sec
- 1 centistoke = 1* 1.075 x 10^{-5} sqft/sec

1 cuft = 7.481 gall

1 ft = 12 inch

Hydraulics of expanded bed

- May be analyzed for:
  - Uniform
  - Stratified beds

For a uniform bed

- For a uniform bed of depth, D,
- Backwashing will expand the bed to expanded depth D_e.
- During backwashing, the frictional resistance of the particles equals the head loss of the liquid expanding the bed.
- thus (4.18):

$$h_L \rho g = (\rho_s - \rho)(1 - \varepsilon_e)(D_e) g$$

- ρ_s = mass density of the particles
- ε_e = porosity of the expanded bed

- Cancelling g and rearranging Eq 4.18 gives (4.19):

$$h_L = \left(\frac{\rho_s - \rho}{\rho}\right)(1 - \varepsilon_e)(D_e)$$

- The value of ε (4.20):

$$\varepsilon_e = \left(\frac{V_b}{V_s}\right)^{0.22}$$

- V_b = upflow velocity of the backwash water
- V_S = settling velocity of the particles

- Consequently, a bed of uniform particles will expand when (4.21):

$$V_b = V_s \varepsilon_e^{4.5}$$

- The volume of the sand in an unexpanded bed will equal the volume of sand in an expanded bed (4.22):

$$(1-\varepsilon)AD = (1-\varepsilon_e)AD_e$$

- A = bed area

- Rearranging gives (4.23):

$$D_e = \left(\frac{1-\varepsilon}{1-\varepsilon_e} \right) D$$

- Substituting Eq (4.20) for ε_e in Eq (4.23) gives (4.24):

$$D_e = \left[\frac{1-\varepsilon}{1-\left(V_b / V_s\right)^{0.22}} \right] D$$

For stratified beds

- The smaller particles in the upper layer expand first.
- Once V_b is sufficient to fluidize the largest particles, the entire bed will be expanded.
- The expansion of the bed is illustrated by a modification of Eq 4.23 (4.25):

$$D_e = (1-\varepsilon)D\sum\frac{x}{1-\varepsilon_e}$$

- X = the weight fraction of the particles with an expanded porosity, ε_e.

Example

A RSF having the same sand analysis as in the previous example is to be backwashed. Determine:

1. The backwash velocity required to expand the bed.
2. The backwash flow required to expand the bed.
3. The headloss at the beginning of the backwash.
4. The depth of the expanded sand bed.

-
- $V_s = \left[\frac{4}{3}\,\frac{g}{C_D}\,(S_s - 1)\,d\right]^{1/2}$

Operational problems

- Mud accumulation or mudballs
- Bed shrinkage
- Air binding

Mud accumulation or mudballs

- May occur when:
  - the filter feed contains a muddy floc and
  - The filter is not adequately backwashed
- The muddy floc will accumulate on the surface of the sand bed forming a muddy mat that will penetrate any craks in the top of the sand.
- If a surface wash is not used, some of the mud may be pressed together to form small muddy balls during the backwash.

mudballs

- With subsequent cycles of filtration & backwashing these balls enlarge and become caked with sand and may eventually settle to the gravel layer.
- They interfere with uniform filtration and cause inadequate backwashing.
- May be minimized by the use of surface wash that breaks up any muddy mat formation.

Bed shrinkage

- May occur if the sand grains become covered with a soft slime coating.
- Causes the bed to compact as the filter run progresses, and
- Results in cracks in the bed surface & along the side walls of the filter.
- These cracks are undesirable:
- They may allow improperly filtered water to pass through the bed, and
- Fine muddy floc may accumulate in them to start mudball formation.
- May be minimized by the used of a surface wash system.

Air binding

- Caused by the release of air gases dissolved in the water, i.e. nitrogen & oxygen
- Creating air bubbles in the sand bed
- Results when a filter is operated under a negative head.
- May interfere with the rate of filtration.
- At the beginning of the backwash, the violent agitation due to the rising air bubbles may cause a loss of sand.
- To control avoid negative head or pressures

Multi media filters

- Maybe:
  - Open gravity filters (Fig 4.1) or
  - Pressure filters (Fig 4.5 & 4.7)
- In WTP become more popular
- Dual media:
  - Usually employ Anthracite & sand
  - others Activated carbon & sand

Multi media filters

- Generally use □Anthracite, sand & garnet
- Others □ activated carbon, sand & garnet
- Or dual & multi media filters □ IE resin as one of the media.
- The media may have additional characteristics other than removing particulates.
- Ex: activated carbon removes dissolved organic substances.

Main advantages of multi media filters

- Compared to single medium filters:
  - Longer filter runs
  - Higher filtration rates
  - The ability to filter a water with high turbidity and SS.
- These advantages are due to:
  - The media particle size
  - The different specific gravities of the media
  - The media gradation
- These result in: a filter with a larger percent of the pore volume being available for solid storage.

The pore available for solids storage

- In the single medium filter: in the top portion of the bed.
- In the multi media filters: is extended deep within the filter bed.
- Due to the deep penetration of accumulated floc deep bed filters.

usage

- Single medium filter are rarely used in WWTP or advanced WWTP due to short filter runs
- Due to the large volume being available for floc storage, multi media filters can be used in advanced or tertiary WWTP and still have a reasonable filter run.

Dual media filters

- Consisting of :
  - A layer of coarse anthracite coal above
  - A layer of fine sand

 To increase the pore volume of a filter.

Pore size profile

- The available pore volume of the dual media filter > the single-medium filter
- The available pore volume, won’t be as large as the total pore volume due to the fine to coarse gradation within each layer.
- Ideally, the available pore volume would be maximum at the top of the filter, and gradually decrease to a minimum at the bottom of the filter.

A dual media filter

- Consists of:
  - An 18-24 inch layer of crushed anthracite coal overlaying
  - A 6-12 inch layer of sand.
- Specific gravity:
  - Coal = 1.2 -1.6
  - Sand = 2.65

A dual media filter

- During the first backwash:

 The sand layer remains below the coal due to:
  - Its higher specific gravity and
  - Its grain size relative to the coal particles

- After the first backwash:

 There won't be a distinct interface between the two layers, but instead

 There will be a blended region of both coal particles & sand grains.

A dual media filter

- The size & characteristics of the anthracite & sand media, and
- The thickness of the layers depend on:
- The usage of the filter:
  - o WTP
  - o WWTP

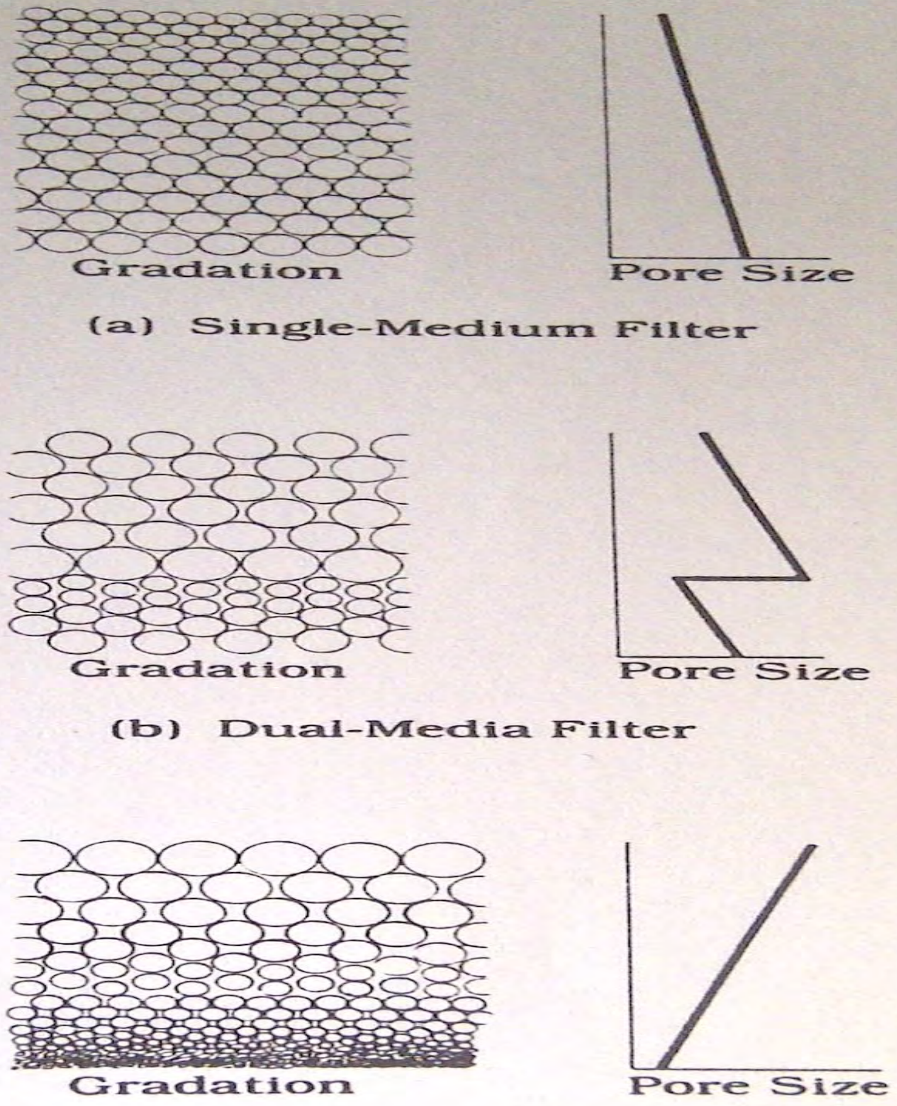
Filtration rate:

- o 2 -10 gpm/ft2 or
- o 3-6 gpm/ft2

Mixed media filter

- The ideal filter has a pore size and gradation as Fig 4.16 (c).
- The pore size is:
  - greatest at the top of the bed,
  - And gradually decreases to a minimum at the bottom.
- The available pore volume (pore space) is:
  - maximum at the top of the bed, and
  - Decreases to a minimum at the bottom.

Figure 4.16. Gradation and Pore Size in Various Filters
Courtesy of Neptune Microfloc, Inc.



- The media have a gradation which is:
  - from coarse at the top to
  - Fine at the bottom.
- The ideal filter maybe approached by using:
- A dual-media filter of:
  - Crushed anthracite coal above sand, and
  - Placing a third very dense medium below the sand

A third medium

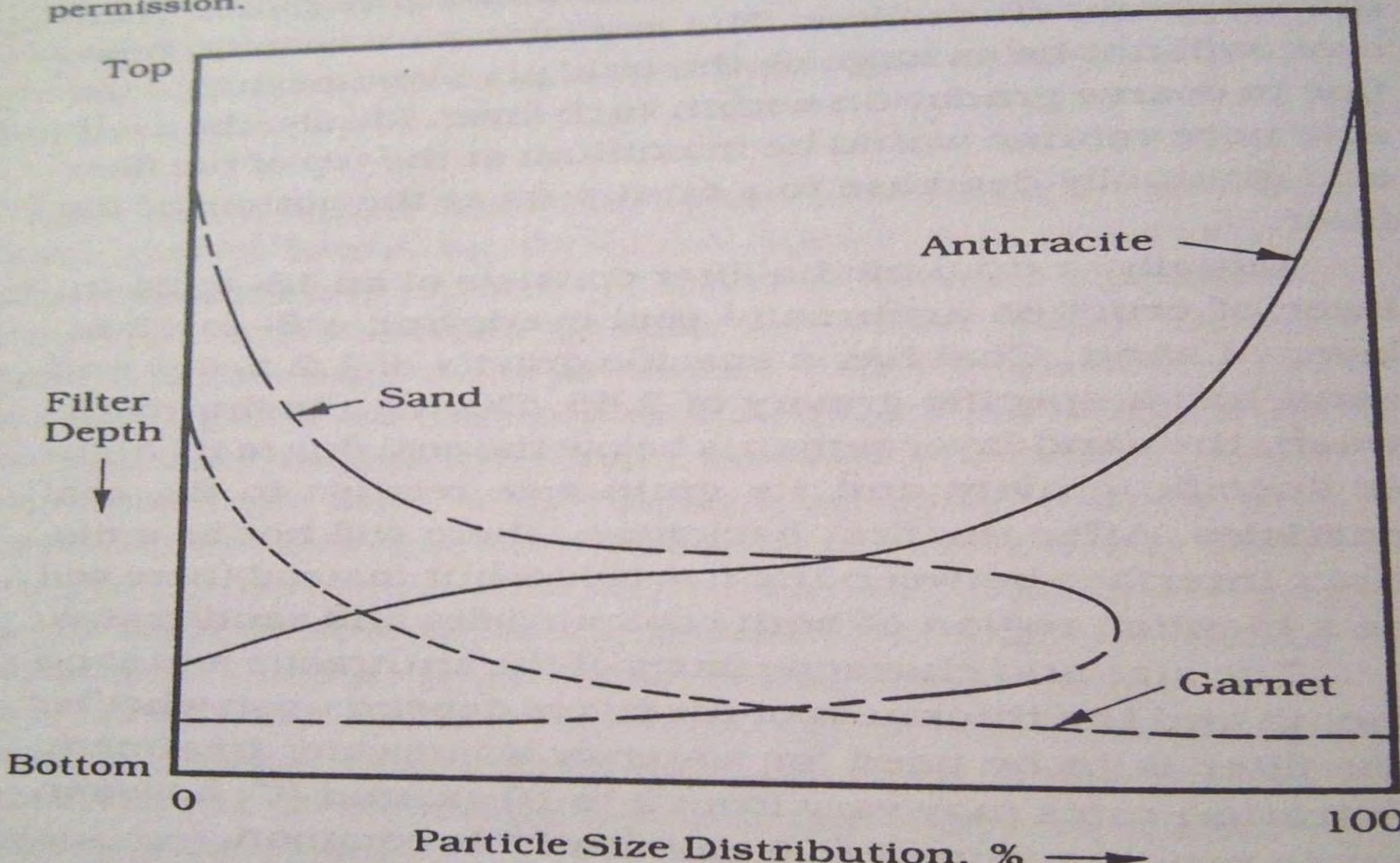
- This allows the third medium to be very fine and still remain in the lower depths during backwashing.
- The resulting filter is referred to as a mixed media filter since there is some intermixing between the layers during backwashing.

Third medium

- Garnet: Ss =4.2
- Illeminite: Ss= 4.5
- The anthracite, sand, and garnet or ilmenite are properly sized to allow some intermixing of the media during backwash.
- After backwash no distinct interface between media layers.
- The filter bed the ideal (Fig 4.16 c) a gradual decrease in pore size with increasing depth

- Since the pore size decreases from the top to the bottom of the filter the filter will have a large available pore volume (total) extending throughout the depth of the filter bed.
- Fig 4.17
- 3 inch of coarse garnet or ilmenite are placed under the third layer to prevent fine particles to enter the underlaying gravel.

Figure 4.17. ***Media Distribution in a Mixed-Media Filter***
Adapted from *Mixed Media*, Bulletin no. KL 4206, by Neptune Microfloc, Inc. Copyright 1975 by Neptune Microfloc, Inc. Reprinted by permission.



- Filter:
  - Size and
  - Characteristics of media
  - The thickness of the layers
- □ depend on the type of service for the filter
- □ WTP or WWTP?
- WTP or advanced WWTP: 2-12 gpm/ft2
- Sometimes: 3-6 gpm/ft2

Filter layout, appurtenances, details

- Gravity filters reinforced concrete.
- Min no. 2 4 are preferable
- Placed side by side in a row.
- Pipe gallery (contains all the necessary piping, valves etc) runs parallel to the filter row.
- Pipe gallery & operating floor always enclosed protect personnel & equipment.
- A dehumidified pipe gallery reduce maintenance on controls, valves etc.

Pressure filters

- Usually cylindrical
- Prefabricated of steel
- A max diameter = 10-12 ft
- Max length = 60 ft.
- Should be equipped with a sight glass observe the bed during backwashing
- Should have an access manhole for maintenance.

Control systems

- Manual or
- Fully automatic
- Equipment to measure effluent turbidity □ should be accurate & reliable:
  - For a continuous record of filter performance
  - Assists in filter operation

- Fully automatic systems a programmer activated by:
  - Effluent turbidity
  - Head loss
- Once the effluent turbidity or head loss preset level the progammer takes the filter off line backwash it place it back on line.

A rate of flow controller

- To control the flow of the filter.
- Maintains a uniform flow rate with a constant water depth over the filter depth.
- Uniform flow is maintained by varying the head loss between:
  - the filter bed surface and
  - The downstream side of the rate of flow controller.

A rate of flow controller

- Usually consists of a ventury
  - with a variable opening diaphgram or
  - A butterfly valve on the downstream side
- The valve is activated by the difference in pressure between:
  - The upstream side
  - And the throat of the venturi

A weir

- Another method to control the flow of the filter.
- Consists of:
  - A weir in the inlet to the filter
  - A weir in the effluent channel discharging into the clear well.

The weir

- The weir downstream:
- keeps a minimum water depth over the filter bed.
- The weir in the inlet:
- maintains a constant rate of flow to the filter
- The filter flow rate is independent of:
- the depth of water over the filter bed since the weir crest is above the water surface

The weir

- as the filter run progresses, the depth of water over the filter bed increases
- due to the increase in head loss.
- Disadvantage:
- The filter walls must be from 5-6 feet deeper than required when a rate of flow controller is used.

By pumps

- For pressure filter
- Pump at a relatively constant rate to the filters.

Air scouring

- For surface wash
- The water is filtered down to about 6 inches above the bed.
- Air is applied to the underdrain system at 2-5 cfm/ft2 for 3-10 min
- Then the backwash is initiated at 2-5 gpm/ft2

Air scouring

- Once the water level is about 1 feet below the washwater throughs:
- the air is stopped
- the backwash is operated at the normal rate for the usual period of time.

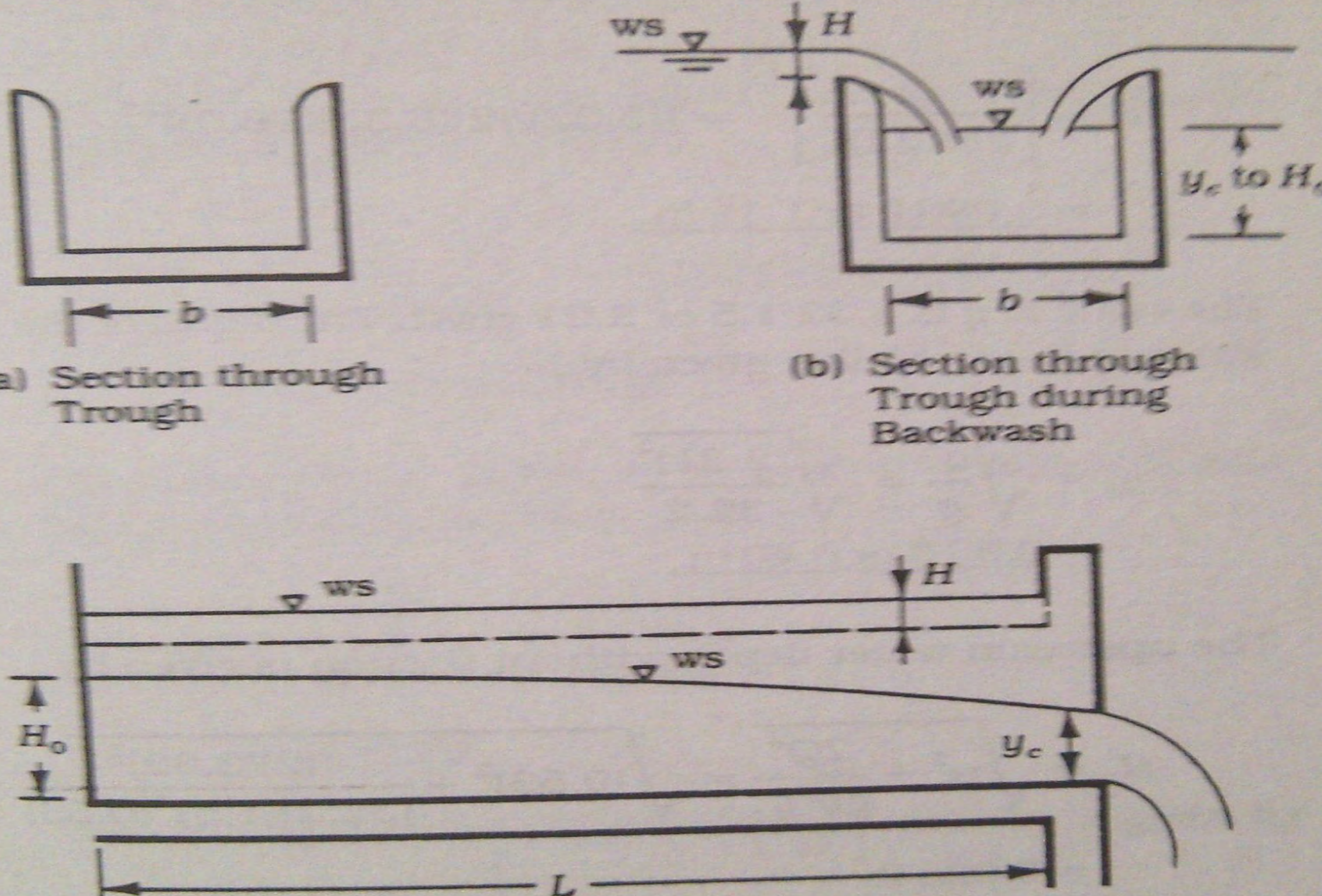
Washwater troughs

- Are usually placed at a clear distance of 5-6 ft from each other.
- Function:
  - To remove the backwash
  - To maintain a uniform backwash, since the distance from the top of all troughs to the underdrains is a constant value.

Washwater troughs

- Trough bottoms: min 6 inch above the expanded bed during backwashing.
- Material:
  - (precast) Reinforced concrete
  - Fiberglass
  - Enameled steel
- Rectangular cross section□ Fig 4.18
- Fig 4.18 b □ the washwater overflowing into a trough

Figure 4.18. Wash Trough Details



(a) Section through Trough

(b) Section through Trough during Backwash

(c) Profile of Trough during Backwash

Total discharge of washwater overflowing into a trough

- Is twice that of a supressed weir (4.26):

$$Q = 2(3.33)LH^{3/2}$$

- Q= total discharge, cfs
- L= trough length, ft
- H= head on weir, ft

Critical depth

- Fig 4.18 c profile of a trough during backwashing
- Shortly before the freefall into the gullet, the water is at the critical depth, y_c.
- Critical depth can be assumed at the freefall.

Critical depth

- For a rectangular channel the critical depth (4.27):

$$y_c = \sqrt[3]{\frac{q^2}{g}}$$

- y_c = critical depth, ft
- q = discharge per ft of width, q = Q/b, cfs/ft
- g = acceleration by gravity

Upstream depth

- The upstream depth, H_0, for a level, rectangular, lateral spillway with a freefall and no friction (4.28):

$$H_0 = \sqrt{y_c^2 + \frac{2Q^2}{gb^2 y_c}}$$

- H_0 = upstream depth, ft
- Q = total discharge,cfs
- b = trough width, ft

- The friction loss will increase H_0 by 6-16% of the water surface drawdown.
- A distance of min 3 inch should be provided from the maximum water depth to the top of the trough.

Example

A RSF has washwater troughs that are 16 ft long and spaced 6.20 ft from center to center. The precast concrete troughs are rectangular in cross section with an inside width of 18 inch. The backwash flow is 15 gpm/ft2. It is desired to determine the water depth over the trough sides, H, the depth at the freefall, y_c, the upstream water depth, H_0, and the trough depth if the top of the trough is min 3 inch above the maximum water surface in the trough. Assume the friction loss is 16% of the surface drawdown.

Soal 3

Suatu filter cepat mempunyai washwater troughs yang panjangnya 6.0 m, dan berjarak 2.0 m dari pusat ke pusat washwater troughs. Troughs ini terbuat dari beton, yang bentuknya rectangular jika dipotong secara melintang, dengan lebar dalam sebesar 0.5 m. Aliran backwash = 11 L/det-m^2. Tentukan ketinggian air di atas sisi trough (H), ketinggian air pada saat tinggi jatuh ($y_{c)}$, ketinggian air di hulu (H_0), dan ketinggian air di dalam trough, jika bagian teratas trough minimal sebesar 7.5 cm di atas ketinggian muka air maksimum di dalam trough. Asumsikan *friction loss* = 16% dari penurunan tinggi muka air.

Filtration in water treatment

- SSF first type used in WTP
- PS SSF
- Single medium filter
- ES = 0.2-0.4 mm
- V = 0.05-0.15 gal/min-ft2
- Cleaned manually usually every 4-6 weeks, by:
  - By scraping off the top layers of clogged sand
  - And cleaning the sand with a scouring device

SSF

- Disadvantages:
  - Large land area requirement
  - Manual labour involved
- replaced by RSF

RSF

- Always preceded by:
  - Coagulation
  - Flocculation
  - Sedimentation
- First RSF:
  - 2 gal/min-ft2
  - A quartz sand bed
  - Overlaying a gravel layer

RSF

- Turbidity removals= 90-98%
- Standard rate= 2gpm/ft2
- Most:
  - operated at 3-5 gpm/ft2
  - Coarse sand beds
- Primary action: depth removal
- Table 4.3

Table 4.3. Single-Medium Filter Characteristics for Water Treatment

Characteristic	Value	
	Range	Typical
Sand Medium:		
Depth, in.	24–30	27
Effective size, mm	0.35–0.70	0.60
Uniformity coefficient	<1.7	<1.7
Filtration rate, gpm/ft^2	2–5	4
Anthracite Medium:		
Depth, in.	24–30	27
Effective size, mm	0.70–0.75	0.75
Uniformity coefficient	<1.75	<1.75
Filtration rate, gpm/ft^2	2–5	4

Calcium carbonate encrustations

- May occur on the sand grains once lime-soda softening is used.
- Enlarge the sand grains -□ undesirable
- Controlled by:
  - Lowering the pH by carbonation prior to filtration to:
    - precipitate excess lime and
    - Stabilize the water
  - Stabilization using sodium hexametaphosphate or other such chemicals.

encrustations

- Crushed anthracite coal less susceptible to encrustation
- is used in many RSF
- Typical anthracite characteristics Table 4.3
- To support the anthracite bed:
  - – gravel or
  - – graded anthracite of 12 in thickness

Dual media & mixed media filters

- Used by most new plants
- Primary filter action □ depth removal
- Table 4.4 & 4.5
- Principal advantages over sand filters:
  - High filtration rates
  - Longer filter runs due to the increased volume for floc storage within the filter
  - Thus, less backwash water is required per unit volume of filtrate produced.

Table 4.4. Dual-Media Filter Characteristics for Water Treatment

Characteristic	Value	
	Range	Typical
Anthracite:		
Depth, in.	18–24	24
Effective size, mm	0.9–1.1	1.0
Uniformity coefficient	1.6–1.8	1.7
Sand:		
Depth, in.	6–8	6
Effective size, mm	0.45–0.55	0.5
Uniformity coefficient	1.5–1.7	1.6
Filtration rate, gpm/ft^2	3–8	5

Table 4.5. Mixed-Media Filter Characteristics for Water Treatment

Characteristic	Value	
	Range	Typical
Anthracite:		
Depth, in.	16.5–21	18
Effective size, mm	0.95–1.0	1.00
Uniformity coefficient	1.55–1.75	<1.75
Sand:		
Depth, in.	6–9	9
Effective size, mm	0.45–0.55	0.50
Uniformity coefficient	1.5–1.65	1.60
Garnet:		
Depth, in.	3–4.5	3
Effective size, mm	0.20–0.35	0.20
Uniformity coefficient	1.6–2.0	<1.6
Filtration rate, gpm/ft^2	4–10	6

Filtration in WWTP

- In advanced WWTP may be employed to filter:
  – Secondary effluents
  – Chemically treated secondary effluents
  – Chemically treated primary or raw wastewaters
- In advanced or tertiary WWTP are usually:
  – Dual media or
  – Mixed media
- Table 4.6 & 4.7

Table 4.6. Dual-Media Filter Characteristics for Advanced or Tertiary Wastewater Treatment

Characteristic	Value	
	Range	Typical
Anthracite:		
Depth, in.	12–24	18
Effective size, mm	0.8–2.0	1.2
Uniformity coefficient	1.3–1.8	1.6
Sand:		
Depth, in.	6–12	12
Effective size, mm	0.4–0.8	0.55
Uniformity coefficient	1.2–1.6	1.5
Filtration rate, gpm/ft^2	2–10	5

Table 4.7. Multimedia or Mixed-Media Filter Characteristics for Advanced or Tertiary Wastewater Treatment

Characteristic	Value	
	Range	Typical
Anthracite:		
Depth, in.	8–20	16
Effective size, mm	1.0–2.0	1.4
Uniformity coefficient	1.4–1.8	1.5
Sand:		
Depth, in.	8–16	10
Effective size, mm	0.4–0.8	0.5
Uniformity coefficient	1.3–1.8	1.6
Garnet:		
Depth, in.	2–6	4
Effective size, mm	0.2–0.6	0.3
Uniformity coefficient	1.5–1.8	1.6
Filtration rate, gpm/ft^2	2–10	5

Tables 4.6 and 4.7 adapted from *Wastewater Engineering, Treatment, Disposal and Reuse* by Metcalf and Eddy, Inc. Copyright © 1979 by McGraw-Hill Book Co., Inc. Reprinted by permission.

difference

- Principal difference between filters used in WTP & WWTP the size of media.

For WWTP:

- The granules must be larger
- the filter will have:
  - The desired flow rate capacity
  - And the required volume for the accumulated floc.

TLB 314 PDIPAM
Week 10

Dosen: Rachmawati S. Dj.

Genap 2025/2026

DISAIN FILTER

(Jurusan Teknik Lingkungan, Institut Teknologi Bandung, 1987)

Kriteria perencanaan:

- Q total (max + pengolahan) = 100 l/det
- Kec. Filtrasi, V_f = (4.000-5.000) L/m^2/jam = (1,11-1,39) L/m^2/dt
- Direncanakan: V_f = 1,37 l/det/m^2
- Cara pencucian backwash

Jumlah filter

$N = 12\sqrt{Q}$ Q dlm m^3/det

- Don't forget: back up system, 1 buah

Dimensi filter

Tentukan dimensi filter (panjang & lebar)

Jumlah & Dimensi filter

$N = 12\sqrt{0.1} = 3.79 \approx 4$ □ cadangan =1

A total = Q/V_f = (100 L/dt)/(1.37 L/dt/m^2)

= 73 m^2

A/bak= 73 m^2 /4 =18,25 $m^2 \approx$ 18 m^2

Panjang=4,5 m

Lebar= 4m

PERENCANAAN MEDIA PENYARING (dual media)

Direncanakan media penyaring tersusun dari:

- Antrasit di atas
- Pasir di bawah

a. Media Pasir

Kriteria:

ES = 0,45 mm

UC= 1,5

Distribusi Media Pasir

No ayakan	Ukuran bukaan (mm)	% kumulatif lolos
140	0,105	0,2
100	0,149	0,9
70	0,210	4,0
50	0,297	9,9
40	0,42	21,8
30	0,59	39,4
20	0,84	59,8

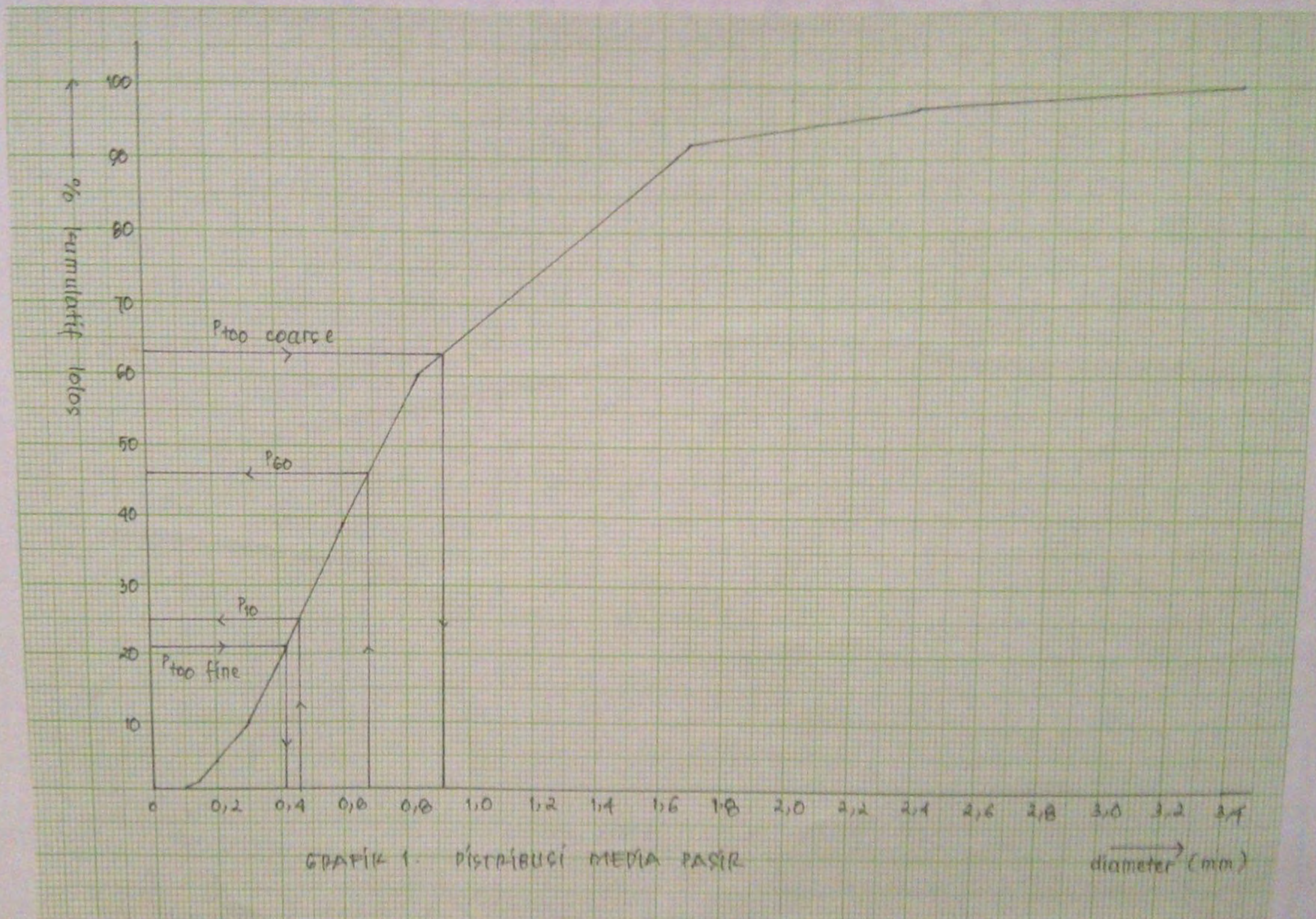
Distribusi Media Pasir

No ayakan	Ukuran bukaan (mm)	% kumulatif lolos
18	1,00	66,5
16	1,19	74,4
12	1,68	93,3
8	2,38	96,8
6	3,36	100,0

Pencarian media pasir usable

- Media pasir usable didapatkan dari distribusi media pasir.
- Caranya:
  - Gambarkan grafik distribusi media pasir
  - % kumulatif lolos (sb y) vs diameter (mm) (sb x)

Grafik distribusi media pasir



Pencarian media pasir usable

Cari:

- d_{10}
- P_{10}
- d_{60}
- P_{60}

Pencarian media pasir usable

- ES = 0,45 mm
- d_{10} = 0,45 mm
- P_{10} = 25%
- UC = 1,5
- UC = d_{60}/d_{10}
- d_{60} = 0,675 mm
- P_{60} = 46%

Pencarian media pasir usable

Cari:

- d_{tf} = d too fine
- d_{tc} = d too coarse
- $P_{usable} = 2\,(P_{60} - P_{10})$
- $P_{too\ fine} = P_{10} - 10\%usable$
- $P_{too\ coarse} = 100 – P_{usable} - P_{too\ fine}$

Pencarian media pasir usable

- P_{usable}=2 (P_{60}-P_{10})= 42%
- $P_{too\ fine}$=P_{10}-10%usable=20,8%
- □ d_{tf}=0,415 mm
- $P_{too\ coarse}$=100-P_{usable}-$P_{too\ fine}$=37,2%
- □ d_{tc}=0,92 mm

kehilangan tekanan ktk pengoperasian

- Kehilangan tekanan melalui media pasir dlm kondisi stratified

$$\frac{h}{l} = \frac{k}{g} \nu V_f \frac{(1-f)^2}{f^3} \left(\frac{6}{\psi} \right)^2 \sum_{i=1}^{i=n} \frac{p_i}{d_i^2}$$

Perencanaan media pasir

l = tebal media pasir = 40 cm

K = konstanta = 5

v= viskositas kinematis=$1.01.10^{-2} cm^2/dt$

f=porositas media =0,4

ψ=sperisitas media=0,8

V_f= kec.filtrasi = 1,37 $L/dt/m^2$

P_i=fraksi berat media

D_i = diameter rata-rata

Distribusi Media Pasir Usable

- Buat distribusi media pasir usable

Ukuran bukaan (mm)	% kumulatif tertahan	% tertahan (P_i)	D_i (mm)	$P_i/(D_i^*)^2$
				$\Sigma=$

Distribusi Media Pasir Usable

$$\%kumtertahan = \frac{\%kumlolos - P_{tf}}{P_{tc} - P_{tf}} x100$$

- D_i=akar dari perkalian ukuran saringan batas atas & bawah
- D_i*= dlm cm

Distribusi Media Pasir Usable

Ukuran bukaan (mm)	% kumulatif tertahan	% tertahan (Pi)	D_i (mm)	$P_i/(D_i^*)^2$
0,415-0,420	2,4	2,4	0,417	13, 802
0,420-0,590	44,3	41,9	0,498	168,949
0,590-0,840	92,9	48,6	0,704	98,060
0,840-0,920	100,0	7,1	0,879	9,189

RSD08

Hitung kehilangan tekanan ktk pengoperasian

- Kehilangan tekanan melalui media pasir dlm kondisi stratified

$$\frac{h}{l} = \frac{k}{g} \nu V_f \frac{(1-f)^2}{f^3} \left(\frac{6}{\psi} \right)^2 \sum_{i=1}^{i=n} \frac{p_i}{d_i^2}$$

kehilangan tekanan ktk pengoperasian

- Kehilangan tekanan melalui media pasir dlm kondisi stratified
- H = 26,26 cm

distribusi media antrasit

No ayakan	Ukuran bukaan (mm)	% kumulatif lolos
50	0.30	0
40	0.42	0,2
30	0.59	1,5
20	0.84	17,0
18	1.00	23,0
16	1.19	50,0
12	1.68	82,0
8	2.38	95,0
6	3.36	100,0

Buat distribusi media anthrasit usable

Kriteria:

- ES = 0,8
- UC=1,2
- S_{sa}=1.45
- l=30 cm
- Ψ=0,7
- f=0,48

- d_{10}=0,8 □P_{10}=14%
- d_{60}=0,96mm
- P_{60}=21%
- P_{usable}=14%
- $P_{too\ fine}$=12,6%
- $d_{too\ fine}$=0,79mm
- $P_{too\ coarse}$=73,4%
- $d_{too\ coarse}$=1,04mm

Distribusi media anthrasit usable

Ukuran bukaan (mm)	% kumulatif tertahan	% tertahan	Di (mm)	Pi/Di^2
0,79-0,84	31,4	31,4	0,815	47,273
0,84-1,00	74,3	42,9	0,917	51,017
1,00-1,04	100,0	25,7	1,020	24,702
			Σ	122,992

Hitung kehilangan tekanan ktk pengoperasian utk anthrasit

- Kehilangan tekanan melalui media anthrasit dlm kondisi stratified

$$\frac{h}{l} = \frac{k}{g} \nu V_f \frac{(1-f)^2}{f^3} \left(\frac{6}{\psi} \right)^2 \sum_{i=1}^{i=n} \frac{p_i}{d_i^2}$$

- Kehilangan tekanan melalui media anthrasit dlm kondisi stratified
- H = 4,74 cm

Perencanaan media gravel

- Lihat F&G: p 27-30, Fig.27-9(a)
- $L = k (\log d + 1.40)$

Distribusi media gravel, k=10

Diameter (inch)	Di (inch)	L (inch)	Xi=L/Σ L	$Xi/(Di)^2$
1/12-1/8		4		
1/8-1/4		3		
¼-½		2,5		
½-¾		3,5		
¾-1 ½		3,5		
1½-2½		6		
		Σ=…inch =…cm		$Σ=…/inch^2$ $=…/cm^2$

Distribusi media gravel, k=10

Diameter (inch)	Di (inch)	L (inch)	Xi= L/ΣL	$Xi/(Di)^2$
1/12-1/8	0,102	4	0,2	19,22
1/8-1/4	0,177	3	0,15	4,79
¼-½	0,354	2	0,10	0,80
½-¾	0,612	3	0,15	0,40
¾-1 ½	1,061	3	0,15	0,13
1½-2½	1,936	5	0,25	0,07
		Σ=20 inch =50 cm		$\Sigma=25,41/inch^2$ $=3,94/cm^2$

Hitung kehilangan tekanan ktk pengoperasian utk gravel

- Kehilangan tekanan melalui media penahan stratified

$$\frac{h}{l} = \frac{k}{g} \nu V_f \frac{(1-f)^2}{f^3} \left(\frac{6}{\psi} \right)^2 \sum_{i=1}^{i=n} \frac{p_i}{d_i^2}$$

Perencanaan media gravel

Kriteria:

- S_{sg}=2,65
- l=50 cm; stratified
- Ψ=0,8
- f=0,5

kehilangan tekanan ktk pengoperasian utk gravel

- Kehilangan tekanan melalui media penahan stratified
- H = 0,16 cm

Checking pencampuran

- Pemisahan campuran terjadi jika:
- V_s min anthrasit ≤ V_s max pasir

$$V_s = \left[\frac{4}{3} \frac{g}{C_D} (S_s - 1) \psi D_i \right]^{1/2}$$

$$C_D = \frac{18{,}5}{N_{RE}^{0{,}6}}$$

$$N_{RE} = \frac{\psi D_i V_s}{\upsilon}$$

V_s pasir & antrasit

- Cari V_s pasir & V_s anthrasit
- Cari $V_{s\ max}$ pasir & $V_{s\ min}$ anthrasit

V_s pasir & antrasit

- Pasir: $V_s = 166{,}306D^{1{,}143}$
- Anthrasit: $V_s = 56{,}439D^{1{,}143}$
- Pasir: $V_{s\ max} = 166{,}306(0{,}0417)^{1{,}143} = 4{,}403$ cm/dt
- Anthrasit: $V_{s\ min} = 56{,}439(0{,}102)^{1{,}143} = 4{,}153$ cm/dt
- $V_{s\ min\ anthrasit} \leq V_{s\ max\ pasir}$ □ terjadi pemisahan sempurna

Perencanaan sistem underdrain (Degremont, 1991)

- Kriteria:
  - Sistem: perforated pipe
  - Luas orifice total=(1,5-2)x 10^{-3}x luas filter
  - Diameter orifice=(0,25-0,5) inch
  - Jarak lateral=(20-30)cm

- Luas lateral total = (2-4) luas orifice total
- Luas manifold = (1,5 -3) luas lateral total
- Jarak orifice = (3-12 inch)
- Kec air wkt penyaringan:
- V manifold ≤0,2 m/dt
- V lateral ≤0,15m/det

Perencanaan orifice

- Luas orifice total =1,5x 10^{-3}x luas filter
- Diameter orifice=0,5 inch

Orifice

- L tiap ori = $1,27x\ 10^{-4}\ m^2$
- Jmlh ori= 213 buah

Perencanaan lateral

- Luas lateral total = 2 x luas orifice total

Lateral

- Luas lateral=2xluas orifice total= 0,054 m2
- Jmlh lateral = (panjang manifold/jrk lateral) + 1 (cek dg gbr!)=16
- Jmlh lateral tot = 32
- Luas tiap lateral= 1,7 x 10^{-3} m2
- D lat = 0,04 m
- Jmlh ori/lat = 7
- Jrk ori = 0,3 m

Perencanaan manifold

- Luas manifold = 1,5 x luas lateral total

Manifold

- Luas manifold=1,5xluas lateral total=0,081 m2
- D man= 13 inch

pengecekan

Orifice:

- Jmlh ori/lat = 7
- Jmlh ori total =
- Luas ori total = …m2
- Luas filter = …m2
- Luas orifice total = ….x luas filter ☐ ???
  Ok???

lateral

- Diam = 2 inc
- Luas tiap lateral =
- Jumlah lateral = 32
- Luas total lateral = ….m2
- Luas orifice total =….m2
- Luas lateral total = …..x luas orifice total
  □ ok???

manifold

- Diam = 13 inch
- Luas = …m2
- Luas manifold = ….x luas lateral -□ ok???
- Kriteria:
- Luas manifold = 1,5 x luas lateral
- = …m2
- Diameter manifold = …m =…inch -□ …inch

Check V manifold & V lateral

- Q tiap bak = …m3/det

V manifold

- V manifold = ….m/dt -□ ok???

V manifold

- V manifold = ….m/dt -□ ok???
- Jika tidak ok □ D man di> □ D = 16 inch
- A =…m2
- V =…..-□ ok???

V lateral

- V lateral = ….m/dt -□ ok???

V lateral

- V lateral = ….m/dt -□ ok???
- Jika tidak ok □ D lat di> □ D = 3 inch
- A =…m2
- V =…..-□ ok???

V lateral

- V lateral = ….m/dt -□ ok???
- Jika tidak ok □ jarak/lateral di< □ 25 cm
- Jumlah lateral =….
- Total lateral =…
- D = 3 inch □ A = …m2
- A total = …m2
- V = …m/dt □ ok???

Perencanaan sistem underdrain

- V = …m/dt ok???
- Jk ok Perencanaan sistem underdrain:
- Jumlah ori = ….dg D = … inch
- Jumlah lateral = ….dg D =…inch
- D manifold =…inch

Hitung kehilangan tekanan saat pengoperasian filter melalui sistem underdrain

- Manifold

$$H_0 = \left(\frac{Q}{0{,}2785 C_{HW} D^{2,63}} \right)^{1/0,54} L$$

- H_0 = kehilangan tekanan
- Q = debit air yang diolah
- C_{HW} = konstanta Hazen Williams = 100
- D = diameter manifold
- L = panjang manifold

manifold

- $H_f = 1/3\ H_0$

Kehilangan tek melalui Manifold-lateral, orifice:

- $h_f = (Q/CA)^2/2g$
- Hf = kehilangan tekanan
- Q = debit/lateral
- C= konstanta=0,6
- A = luas/lateral
- G = gravitasi

Kehilangan tekanan melalui perlengkapan pipa

- $Hf = k (V^2/2g)$
- K = konstanta
- V = kec aliran dlm pipa

Kehilangan tekanan mel lateral & orifice

- Lateral
- = perhit kehil tek pd manifold

- Orifice
- = perhit kehil tek pd manifold-lateral

Kehilangan tekanan melalui sistem underdrain

Manifold

- Ho =.... cm
- Hf = ...cm

Manifold-lateral

- Q/lat = ...m^3/dt
- A/lat = ...m^2
- Hf = ...cm

lateral

- Ho = ...cm
- Hf = ...cm

orifice

- Hf = ...cm

Kehilangan tek mel sistem underdrain

- Hf = hf man + hf man-lat + hf lat + hf ori

Kehilangan tek pd perpipaan outlet

- = pd manifold
- Direncanakan panjang pipa = 400 cm
- D pipa = ….inch
- Debit rata-rata melalui pipa outlet = …m3/dt
- Hf = ….cm

Kehil tek pd pipa outlet & perlengkapannya

D (inch)	Pipa/perlengkapan	Pjng (cm)/jmlh	C/k	Hf (cm)
	pipa	400	100	
	tee	2	1,25	
	Gate valve	2	0,19	
				Σ

Kehilangan tekanan pd saat filtrasi

- Kehil tek slm filtrasi = jumlahkan semua (pasir, antrasit, gravel, underdrain, outlet & perlengkapan)

Kehilangan tekanan air pd saat Backwash

Kriteria perencanaan:

Vbw = (25-37)m^3/m^2/jam = (6,94-10,28)x10^{-3} m/dt

Td = (3-10) mnt

Kehilangan tekanan air pd saat Backwash

$$H_f = L_e(1 - f_e)(S_s - 1)$$

- Le = tinggi ekspansi
- Fe = porositas
- Ss= berat jenis

Tinggi ekspansi

$$L_e = L(1 - f_e)\sum\left(\frac{p_i}{1 - f_{ei}}\right)$$

- L = tebal media
- p_i = fraksi berat
- f_{ei} = porositas pasir terekspansi

Porositas pasir terekspansi

$$f_{ei} = \left(\frac{V_{bw}}{V_{s-pasir}} \right)^{0,22}$$

- V_{bw} = kec backwash
- $V_{s\text{-}pasir}$ = kec mengendap pasir

Kec backwash

$$V_{bw} = V_{s\max}\left(f_e\right)^{4,5}$$

V_{smax} = kec mengendap butir pasir dengan diameter terbesar

Kec mengendap

$$V_s = \left[\frac{4}{3} \frac{g}{C_D} (S_s - 1) \psi D_i \right]^{1/2}$$

- Utk 1,9 ≤NRE≤500

$$C_D = \frac{18{,}5}{N_{RE}^{0{,}6}}$$

$$N_{RE} = \frac{\psi D_i V_s}{\upsilon}$$

Kec mengendap

- Utk v = 1,01 x 10-2 cm^2/dt:
- $V_{spasir} = 166,306D^{1,143}$
- $V_{santhrasit} = 56,439D^{1,143}$

Kehil tek mel pasir bw

- Syarat terjadinya ekspansi

  $V_{bw} \geq V_{smax}\ (f)^{4,5}$
- d terbesar, d=....mm
- V_{smax} = ... cm/dt
- V_{bw}= ..... cm/dt
- Diambil V_{bw}= ..... cm/dt

Tabel Distribusi pasir terekspansi

D_i(mm)	P_i(%)	V_s (cm/dt)	f_{ei}	$1-f_{ei}$	$P_i/(1-f_{ei})$
0,417	2,4				
0,498	41,9				
0,704	48,6				
0,879	7,1				
					Σ

Tabel Distribusi pasir terekspansi

D_i(mm)	P_i(%)	V_s (cm/dt)	f_{ei}	$1-f_{ei}$	$P_i/(1-f_{ei})$
0,417	2,4	4,443	0,66	0,33	0,07
0,498	41,9	5,395	0,64	0,36	1,164
0,704	48,6	8,011	0,58	0,41	1,157
0,879	7,1	10,325	0,55	0,41	0,159
					2,55

- Le= .... cm
- Hf= .... cm

- Le= 61,2 cm
- Hf= 60,588 cm

Tabel Distribusi antrasit terekspansi

Di(mm)	Pi(%)	Ut (cm/dt)	fei	1-fei	Pi/(1-fei)
0,815	31,4				
0,917	42,9				
1,020	25,7				

Tabel Distribusi antrasit terekspansi

Di(mm)	Pi(%)	Ut (cm/dt)	fei	1-fei	Pi/(1-fei)
0,815	31,4	3,214	0,714	0,286	1,09
0,917	42,9	3,673	0,693	0,307	1,39
1,020	25,7	4,149	0,675	0,325	0,79
					3,27

- Le= 51,012 cm
- Hf= 11,94 cm

Knp pasir & antrasit hrs terekspansi?

- Check gravel terekpansi?
  - D terkecil gravel = 0,102 inch = 0,259 cm
  - Ut, cd=0,44 utk 500< nre< 2000
  - Ut=31,88 cm/dt
  - Vbw>1,4 cm/dt

- Jd gravel tdk terekspansi, shg kehil tek pd saat bw=
  - Vbw= 0,694 cm/dt
  - Vfil=0,137 cm/dt
  - Hf= (vbw/vfil)x kehil tek saat op
  - =0,917 cm

Kehil tek pd underdrain pd saat bw

- Vbw=0,694 cm/dt
- Td= 5 mnt
- Q pencucian/bak = ...m3/dt
- Vol air pencuci = ...m3

Kehil tek pd underdrain pd saat bw

- Vbw=0,694 cm/dt
- Td= 5 mnt
- Q pencucian/bak = Vbw x A = 0,125 m3/dt
- Vol air pencuci = 37,99 m3

Manifold

- Ho=..... m
- Hf= ......m

Man-lat

- Q/lat =...... m^3/dt
- Hf = ...m

Manifold

- Ho=0,05 m
- Hf= 0,017 m

Man-lat

- Q/lat =3,9.10-3 m3/dt
- Hf = 0, 75 m (cek utk sy)

Lat

- Ho= ......m
- Hf= ......cm

Ori

- Q/or= m3/dt
- Hf= ......m
- Kehil tek underdrain pd saat bw=..... m (cek)

Lat

- Ho= 3,9.10-3: (0,2785. 100. (0,047)2,63)1/0,54 2= 0,428 m
- Hf= 14,27 cm

Ori

- Q/or= 5,869.10-4 m3/dt
- Hf= 3,023 m
- Kehil tek underdrain pd saat bw=4,0374 m (cek)

Kehil tek pd perpipaan outlet (filtrasi & bw) dan pipa pencuci

Kehil tek pd perpipaan outlet (filtrasi)

- Panjang pipa = 400 cm
- D pipa = 16 inch (cek)
- Q= 25 l/det
- Kehil tek=7,3.10-4 m= 0,073 cm

Kehil tek mel perlengkapan= 20% 0,073 cm= 0,014 cm

Kehil tek pd pipa pencuci

- Panjang pipa pencuci terjauh = 16 m
- D pipa pencuci = 16 inch
- Debit pencucian= 0,125 m3/dt
- Kehil tek= …..m
- Kehil tek mel perlengkapan= ….= …. m

Kehil tek pd pipa pencuci

- Panjang pipa pencuci terjauh = 16 m
- D pipa pencuci = 16 inch
- Debit pencucian= 0,125 m3/dt
- Kehil tek= 0,06 m
- Kehil tek mel perlengkapan= 20% 0,06= 0,012 m

- Kehil tek total saat filtrasi= 25,66+4,72+0,181+18,7(cek man&lat)+0,073+0,014

  =49,34 cm

- Kehil tek total saat bw= .....m

  =....

  cm

- Kehil tek total saat filtrasi= 25,66+4,72+0,181+18,7(cek man&lat)+0,073+0,014
  =49,34 cm

- Kehil tek total saat bw= 60,59+11,94+0,917+4,0374 m (cek)+ 0,06 m+0,012 m
  =77,56 cm

Saluran pencuci

Gutter (washthrough)

- Rencana: 2 gutter pd tiap filter dg panjang (l)= 4,5 m
- Bentuk gutter segi 4, dg dsr datar, lebar (b)=40 cm
- Q pencucian = 0,125 m3/dt
- Q/gutter= m3/dt
- Air bekas pencucian melimpah sempurna ke gutter, kemudian ke gullet

Saluran pencuci

Gutter

- Rencana: 2 gutter pd tiap filter dg panjang (l)= 4,5 m
- Bentuk gutter segi 4, dg dsr datar, lebar (b)=40 cm
- Q pencucian = 0,125 m3/dt
- Q/gutter= 0,0625 m3/dt
- Air bekas pencucian melimpah sempurna ke gutter, kemudian ke gullet

Tinggi air di gutter

- $Ho=(Qg/(13,64.\ b))^{2/3}$=.... cm

Tinggi air pd bibir pelimpah gutter=

- $Hg= (Qg/(18,24.\ l))^{2/3}$= .... cm
- Buat sketsanya
- Dasar gutter diletakkan 30 cm di atas antrasit, kedalaman gutter dibuat 30 cm

Tinggi air di gutter

- Ho=(Qg/(13,64. b))2/3=23,59 cm

Tinggi air pd bibir pelimpah gutter=

- Hg= (Qg/(18,24. l))2/3= 3,87 cm
- Buat sketsanya
- Dasar gutter diletakkan 30 cm di atas antrasit, kedalaman gutter dibuat 30 cm

- Le antrasit= 51 cm, l ant= 30 cm
- Le pasir=61 cm, l psr= 40 cm
- Jd tinggi bibir pelimpah gutter= 57,17+40+30+30+30=187,17
  =190cm dari dasar bak filter
- Atau 200cm dari muka tanah asli

Gullet

- Gullet direncanakan berada di bawah saluran inlet dg lebar (B)0,75 m
- dg dasar yg rata
- Muka air: Q/VxB, V = kec.aliran= 1,5 m/dt, Q= debit pencucian
  = 0,11m
- Sal gullet dilanjutkan dg saluran penguras.

Sistem inlet, outlet, alat ukur (PR)

Sistem pencucian

- Oleh menara air, td= 5mnt, Vbw=0,694 m/dt, Qbw=0,125 m3/dt
- Kebutuhan air pencucian= 37,5m3 kapasitas menara air
- Cari dimensi bak air: panjang=
- Lebar=
- Tinggi air=2,5 m

Menara Air

- Kehilangan tek slm pencucian= .... m
- Faktor keamanan =1,25 x ..... m= .... m
- Tinggi ini harus dikoreksi dg beda tinggi antara bibir pelimpah gutter dg muka tanah asli= ......m+....m=.... m□tinggi menara total
- Cari dimensi bak air

Menara Air

- Kehilangan tek slm pencucian= 4, 84 m
- Faktor keamanan =1,25 x 4,84 m= 6,025 m
- Tinggi ini harus dikoreksi dg beda tinggi antara bibir pelimpah gutter dg
- Muka tanah asli= 6,025 m+200cm=8,025 m□tinggi menara total
- Cari dimensi bak air

Pompa utk mengisi bak air

- Kapasitas pompa mis 20 l/dt, d pipa=6 inch, l pipa=15 m
- Tek pompa=tinggi menara + tinggi air maks dalam bak + headloss major-minor
  ....+...+....+.....= ..... m-□13m (faktor keamanan 20%)

- daya pompa=.... HP
- Digunakan 2 pompa yg bekerja bergantian

Pompa utk mengisi bak air

- Kapasitas pompa mis 20 l/dt, d pipa=6 inch, l pipa=15 m
- Tek pompa=tinggi menara + tinggi air maks dalam bak + headloss major-minor

  =8,025+2,5+0,215+0,043= 10,78 m-□13m (faktor
- Keamanan 20%)

- daya pompa=45,34 HP
- Digunakan 2 pompa yg bekerja bergantian

SISTEM OPERASIONAL FILTER

- (lihat pustaka apapun ttg water treatment)
- Katup2
- Inlet
- Outlet
- Pencuci
- gutter
- Penguras
- Sistem Kontrol

TO SUM UP

- Perhitungan dimensi bak filter
- Perencanaan media penyaring
- Checking pencampuran
- Perencanaan media penahan/pendukung
- Perencanaan sistem underdrain
- Perhitungan kehilangan tekanan air selama operasi & backwash
- Perencanaan saluran pencuci (gutter, gullet) dan penguras
- Sistem inlet, outlet, alat ukur
- Sistem pencucian (kebutuhan air pencuci, tinggi menara air)
- Sistem pengoperasian filter
- Gambar sketsa, denah, potongan

TLB 314 PDIPAM

Week 12

Genap 2025/2026

Dosen: Rachmawati S. Dj.

Sub CP MK *Week 12-13*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
12-13	6.4	Mahasiswa mampu menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi secara tepat	Ketapatan dalam menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi	Tugas, UAS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 2*50 menit/minggu ▪ *Secondary treatment,* koagulasi, flokulasi dan desinfeksi: 2*3*50 menit	6%

Flocculation (Fair, et al, 1968)
1. Objectives

- Flocculation:
  - Flocculent or flocculated particles conjoin while the suspended fluid is strirred.
- To reduce the load on:
  - the suspending or carrying fluid
  - On subsequent treatment operations

2. Flocculation

- The stirring or agitation of water or ww containing flocs.
- Chemical flocculation:
  - Stirring or agitation soon after the coagulating chemicals has been added mixing
- Mixing quick response
- Stirring/agitation protacted actions to form the conjunction of suspended particles or flocs

3. Mixing & stirring devices

- Sources of power:
  1. Gravitational
  2. Pneumatic
  3. Mechanical
- Pneumatic & mechanical flexible
- Gravitational inflexible seldom used in large plants

4. Gravitational mixing & stirring
a. Baffled channel

- Differs from:
  - an unobstructed open channel
  - A pipeline
- Shear gradients or turbulence are not merely functions of frictional resistance to flow.
- Velocity gradients are purposely intensified by enforced changes in the direction of flow.

- For baffled channels:
  - Of capacity C
  - In which a loss of head h is incurred when the rate of flow is Q
- The useful power input $P = Q\rho gh$
  - Where ρg = the weight density of water

- The power dissipation function (Eq 1):

$$\frac{P}{C} = \mu G^2$$

- Important concept in WTP & WWTP
- Where:
  - P = power input
  - C = relative capacity
  - μ = Viscosity
  - G = the mean temporal shear or velocity gradient (sec^{-1})

- If G = the mean temporal shear or velocity gradient, is combined with
- The mean or displacement time, $t_d = C/Q$
  - Where Q = the rate of flow
- Then (Eq 2):

$$Gt_d = \left(\frac{C}{Q}\right)\sqrt{\frac{P}{\mu C}} = \frac{\sqrt{PC/\mu}}{Q}$$

- For a given value of G t_d, the loading of flocculation units (Eq 3):

$$\frac{Q}{C} = \frac{1}{t_d} = \frac{\sqrt{P/\mu C}}{G t_d}$$

- The hydraulic loading of flocculation units, Q/C, is a function of:
  - Detention time, t_d
  - Power input, P manageable variable in treatment operations
  - Viscosity, μ

- Thus the permissible channel loading at a given value of Gt_d (Eq 4):

$$\frac{Q}{C} = \frac{\sqrt{Q\rho gh / \mu C}}{Gt_d} = \frac{\sqrt{Qgh / \upsilon C}}{Gt_d}$$

- g = gravity constant
- υ = kinematic viscosity of the fluid

Unit conversion

- 1 cuft of water = 62.43 lb = 7, 481 gall
- 1 mgd = 1.547 cuft/sec
- 1 HP = 550 ft lb/sec
- 1 KW = 737.6 ft lb/sec
- Each foot of lost head = 62.43 x 1.547/550 = 0.175 HP/mgd
- Or 62.43 x 1.547/737.6 = 0.131 KW/mgd

- In practice:
- $h = 0.5 - 2$ ft
- $V = 0.5 - 1.5$ fps
- $t_d = 10 - 60$ min

- For (n-1) equally spaced over & under or around-the end-baffles, and
- For velocities v_1 in the channels and v_2 in the baffle slots,
- The loss of head approaches:

$n\ v_1^2/2g + (n-1)\ v_2^2/2g$ + normal channel friction

- Assumption: necessary velocities must be redeveloped at each change in direction of flow
- Substitutional estimate: normal channel friction increased by a reduction of the Chezy or Hazen & Williams coefficient of discharge to 20 and 50

- Normal channel friction:
- $h = (n^2 L v^2)/R^{4/3}$
- Where:
- n = Manning coeff = 0.015
- L = channel length per unit
- v = straight channel velocity
- R = hydraulic radius = A/P
- A = wet area
- P = wet perimeter

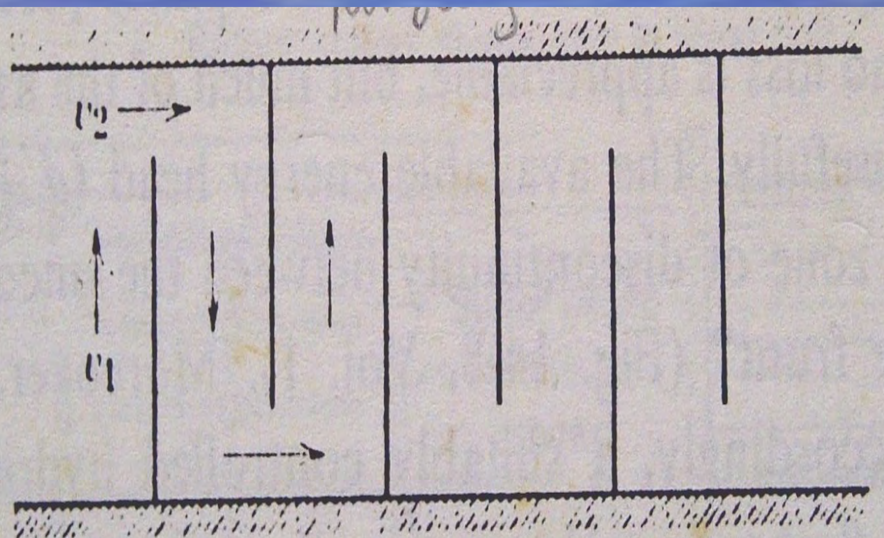


Fig. 26-1. Baffled channel (schematic diagram). Plan of round-the-end baffles, or vertical section of over-and-under baffles.

Example:

Water zigzags through a baffled channel at a velocity of 0.5 fps and speeds up to 1.5 fps in the slots. There are 19 around-the end-baffles. The tank consists of 20 channels each 2.5 ft wide, 8 ft deep on average and 45 ft long. Estimate:

1. The loss of head, neglecting normal channel friction
2. The power dissipated
3. The G and Gt_d values for a flow of 6.46 mgd (10 cfs), with a displacement time of 30 min. Assume a water temperature of 50^0F, i.e., $\mu = 2.7 \times 10^{-5}$ (lb force) (sec)/(sq ft)
4. Calculate the channel loading

1. $h = n\, v_1^2/2g + (n-1)\, v_2^2/2g$

   $h = 20 \times (0.5)^2/2g + 19 \times (0.5 + 1.5)^2/2g$

   $= 1.26$ ft

2. $P = Q\rho gh$

   $P = 10 \times 62.4 \times 1.26 = 790$ ft-lb/sec

3. $$\frac{P}{C} = \mu G^2$$

$G^2 = P/\mu C$ --> $$G = \sqrt{P/\mu C}$$

C = 10 x 30 x 60 = 18000 cu ft $G = \sqrt{P/\mu C}$

G = $(790/2.7 \times 10^{-5} \times 18000)^{1/2}$ = 40 sec^{-1}

G t_d = 40 x 1800 = 7.2 x 10^4

4. Q/C = 6.46 x 10^6 /(1.8 x 10^4) = 360 gpd/cu ft

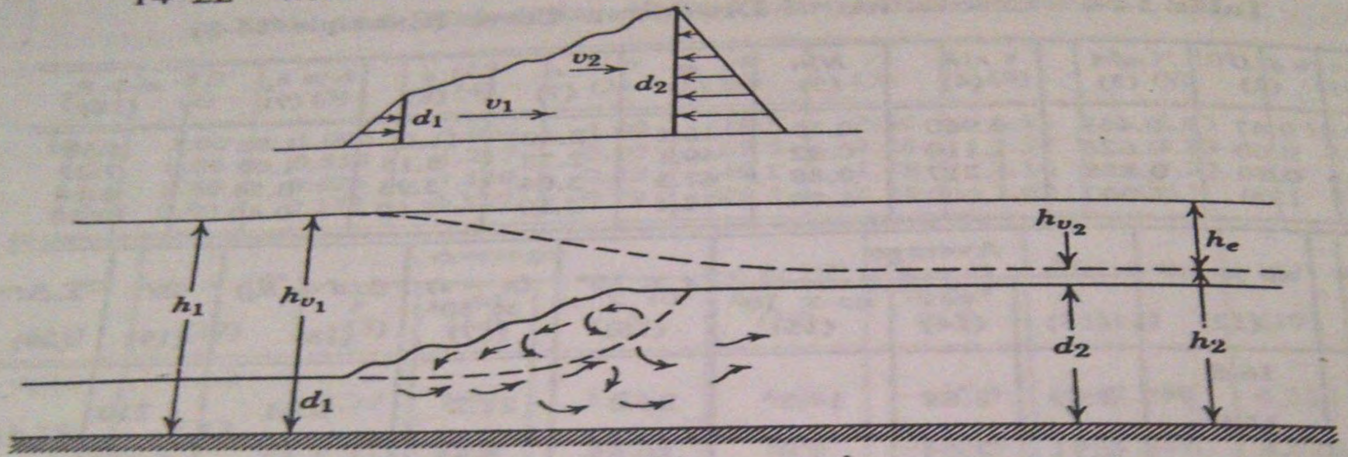
Hydraulic jump mixer

- Includes:
  - A chute
  - Followed by a channel
  - With or without a sill
- The chute □ super critical flow
- The gently sloping channel □ the jump
- The sill □ the location of the jump

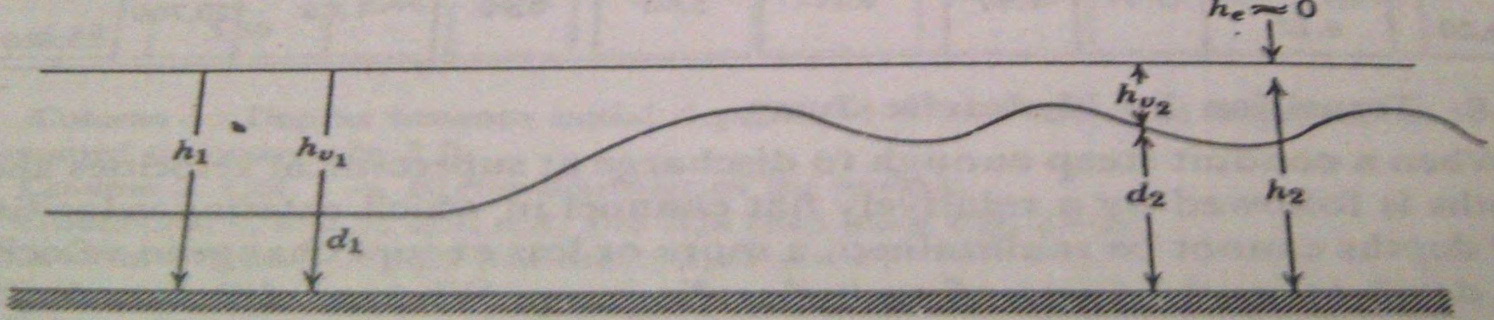
- Hounter Rouse:
- The hydraulic jump □ a breaking wave or turbulent surface roller when:
  - The depth ratio, $d_2/d_1 > 2.375$
  - The Froude number, $F > 2$
- (Eq 5)

$$\frac{d_2}{d_1} = \left[\left(\frac{1}{2}\sqrt{1+8F_r^{\,2}}\right)-1\right] > 2.375$$

- Below the breaking wave, the oncoming flow expands
- Head loss is appreciable
- But much of the associated power is not dissipated fully
- The available energy head $(d + V^2/2g)$ is used up largely at the zone of discontinuity between the oncoming flow and the breaking wave front



(a) F > 2. Breaking-wave jump



(b) 2 > F > 1. Undulating jump

Fig. 14-8. Profiles of hydraulic jumps.

- A controlled hydraulic jump □flash mixer
- The jump occurs in a series of undulations with substantially no loss of head and no power of dissipation of any kind when $1<F<2$

5. Pneumatic mixing & stirring

- When air is injected or diffused into water after suitable compression □ expands isothermally
- Thus the work done by the air= $\int P \, \partial V$
- Where:
- P = the absolute pressure intensity
- V = the volume of air

- Because PV = constant (ex. $P_a V_a$)
- (Eq 6)

$$V_a \int_{V_c}^{V_a} \partial V / V = P_a V_a \ln\left(V_a / V_c \right) = P_a V_a \ln\left(P_c / P_a \right)$$

- a =free or atmospheric condition
- c = compressed condition

- If Q_a cu ft per min of free air are injected into water from a diffuser situated h ft below the water surface, the power dissipated usefully by the rising air bubbles is essentially
- $P = (14.7 \times 144 \times 2.303/60)\ Q_a \log[(h + 34)/34]$ ft-lb per sec (Eq 7), or
- $P = 81.5\ Q_a \log[(h + 34)/34]$ (Eq 8)

- Area: 1 sq ft = 144 sq inch
- Velocity: 1 miles per hour = 1.467 ft per sec
- Pressure: 1 lb per square inch = 2.307 feet of water

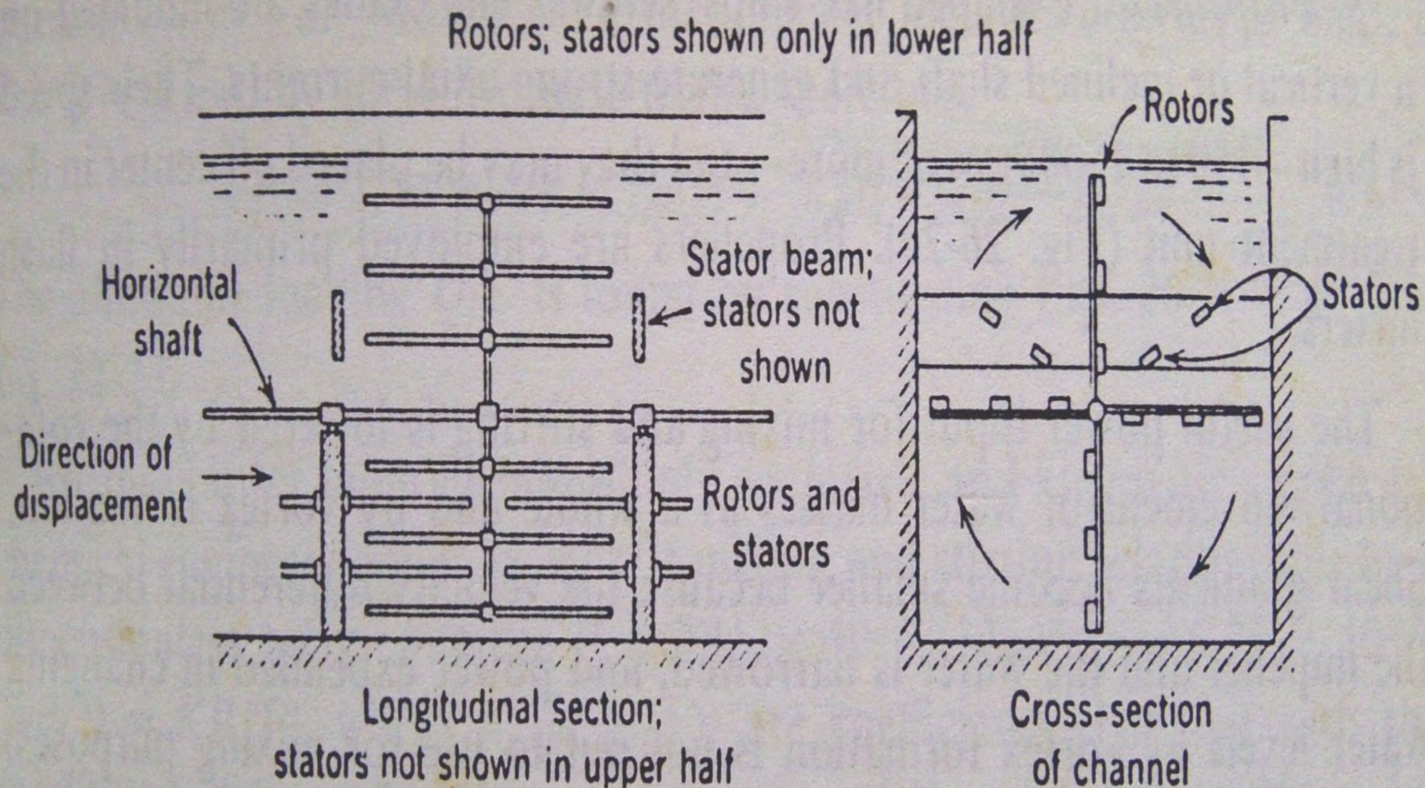
- The allowable loading Q/C of an aerated flocculating tank or channel is found by substituting Eq 3 in Eq 4.

- Compressed air is diffused into treatment units also in:
  - Aeration for gas exchange
  - Cleaning granular filters by air scour
  - Aerating & stirring activated sludge unit

6. Mechanical mixing & stirring

- The impellers employed in mechanical mixing & stirring generate:
  - Mass flow
  - Turbulence
- 3 types of impellers that are commonly used:

1. Paddles
2. Turbines
3. Propellers


Rotors; stators shown only in lower half
Horizontal shaft
Stator beam; stators not shown
Direction of displacement
Rotors and stators
Rotors
Stators
Longitudinal section; stators not shown in upper half
Cross-section of channel
(a)

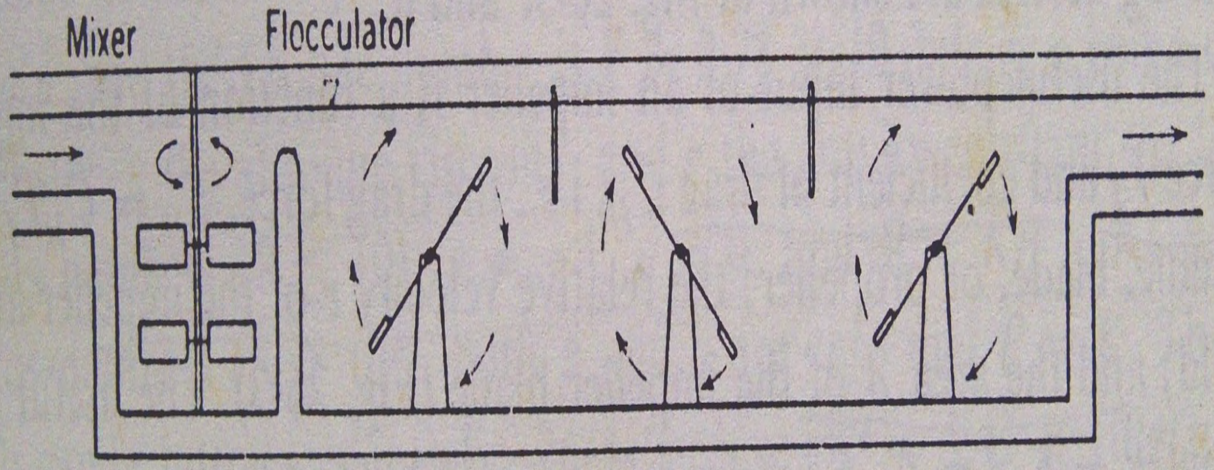
1. Paddles

- Consist of blades attached directly to vertical or horizontal shafts.
- The moving blades (rotors) may be complemented by stationary blades (stators):
  - □ oppose rotational movement of the entire mass of water within the treatment unit
  - □ help to suppress vortex formation

- Paddles are rotated at slow to moderate speeds of 2 – 15 rpm
- The currents generated by them are both radial & tangential.

2. Turbines

- Comprise flat or curve blades attached by a connecting radius arm to a vertical or horizontal shaft.
- Operating in the middle range of speeds (10 – 150 rpm)
- Generate much of the same currents as paddles



(b)

3. Propellers

- Shaped like ships’ screws
- The blades are mounted on a vertical or inclined shaft
- □ generate strong axial currents
- High speed 150 – 1500 rpm or more
- Maybe placed off center in the treatment unit
- Employed primarily in flash mixers

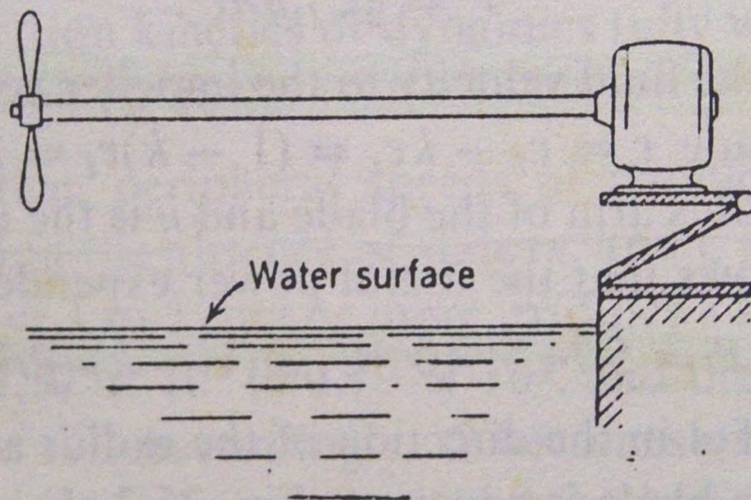
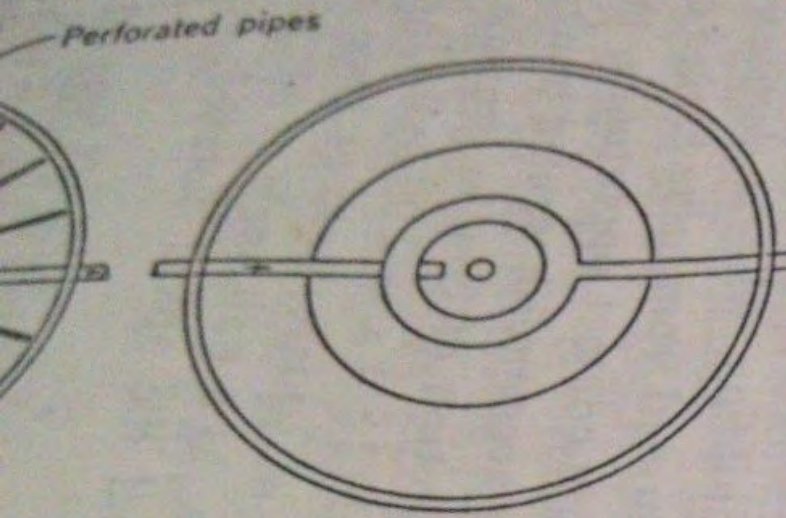
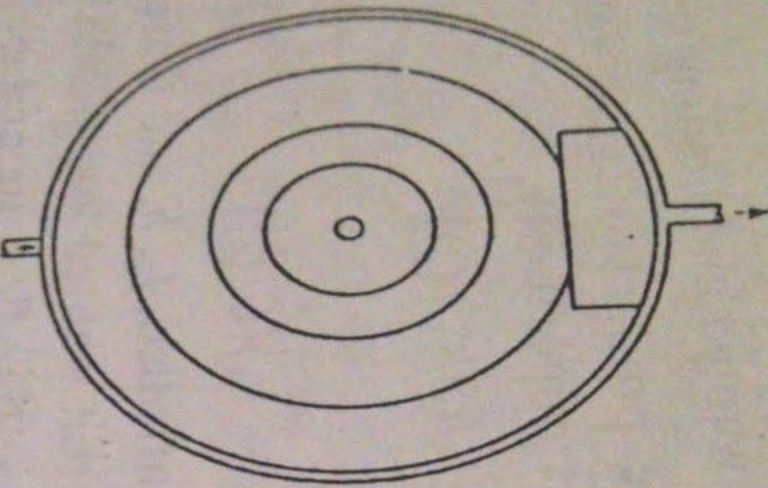


Fig. 26-2. Mixing and stirring impellers. (*a*) Paddle or blade mixer with horizontal, longitudinal shaft, and rotor and stator blades. (*b*) Turbine mixer with vertical shaft followed by cross-channel, horizontal-shaft stirring and resuspension of settling floc in countercurrent fashion. (*c*) Mixing propeller tilted into horizontal position.

- The useful power input for mixing & stirring is lowered by the rotational movement of water masses as a whole and by vortex formation.
- Shear gradients become smaller because:
  - The velocity differential between the impeller and the water is narrowed
  - Power expended in changing water levels by vortex formation is not put to use for mixing purposes.

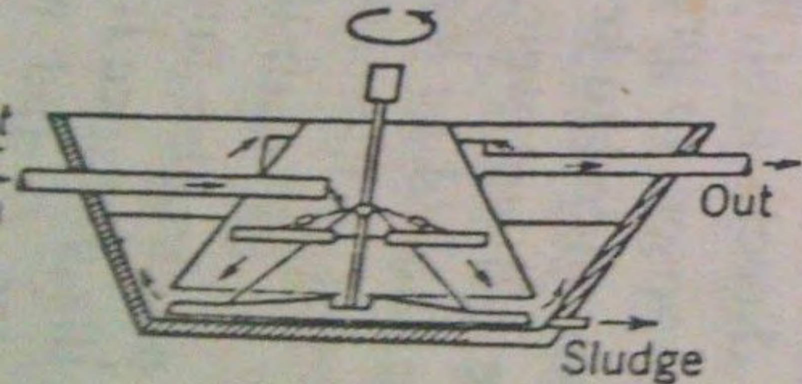
- Stators are useful adjuncts to all types of impellers.
- Combines mixing & settling devices: Fig 26-5c & d

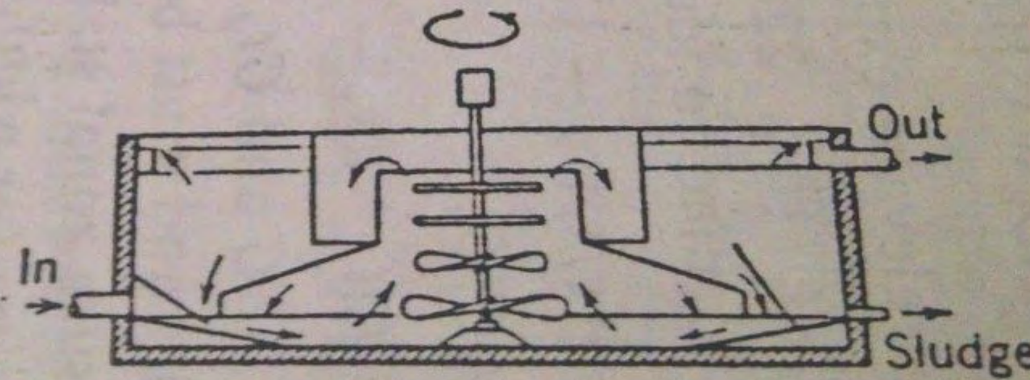




Plan

Plan





Elevation

(c)

Elevation

(d)

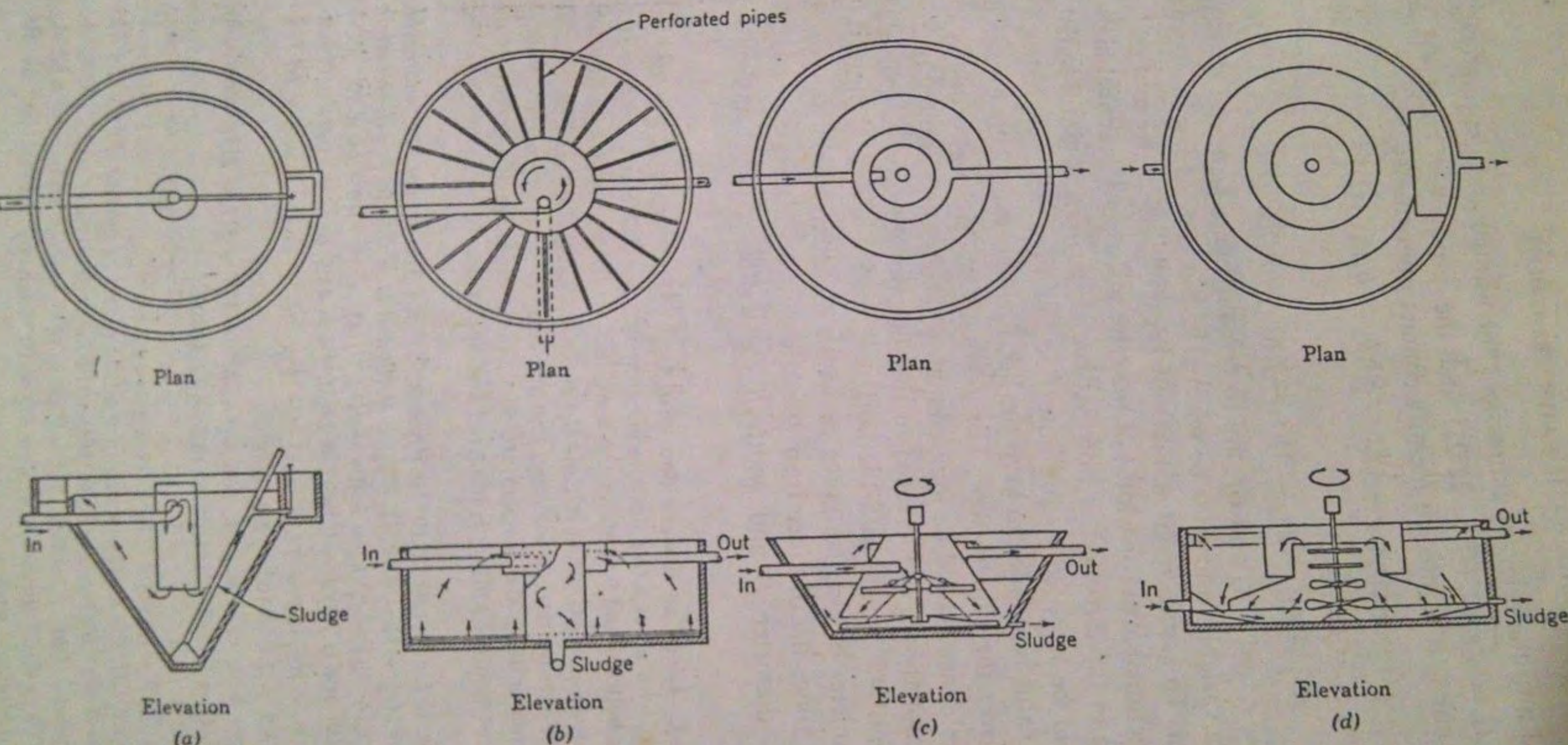


Fig. 26-5. Representative designs of upflow settling tanks. (*a*) Flaring circular or square tank. Sludge is removed during operation; in this case hydrostatically. (*b*) Circular tank with central mixing and flocculating chamber. Pipe grid distributes flow and intermittently collects sludge. (*c*) Circular, flaring tank with central mixing and flocculating chamber. *Spaulding Precipitator.* (*d*) Circular tank with central mixing and flocculating chamber and built-in sludge recirculation. *Accelator.*

- The useful power input of an impeller is a function of:
- The impelling force, F_I
- Coefficient drag, C_D
  - i.e. the drag force, $F_D = C_D F_I$
  - of the paddle, blade or propeller
- The relative velocity, v of the impeller & the fluid
- The area A of the impeller blade

- The useful power input:
- $P = F_D v = C_D F_I v$ (Eq 9)
- Where $F_I = \rho A v^2/2$ (Eq 10)
- Thus: $P = ½ C_D \rho A v^3$ (Eq 11)

- If k is the ratio of the fluid velocity to the impeller velocity (v_i),
- The relative velocity of the blade (Eq 12):
- $v = v_i - k\,v_i = (1 - k)\,v_i = 2\pi\,(1 - k)\,r\,n/60$
- Where:
- r = the effective radius arm of the blade
- n = the number of revolutions per minute

- The useful power expended by a single blade:
- $P = 5.74 \times 10^{-4} C_D \rho [(1 - k) n]^3 r^3 A$ (Eq 13)
- If the dimension of A in the direction of the radius arm is substantial, but the width b is constant

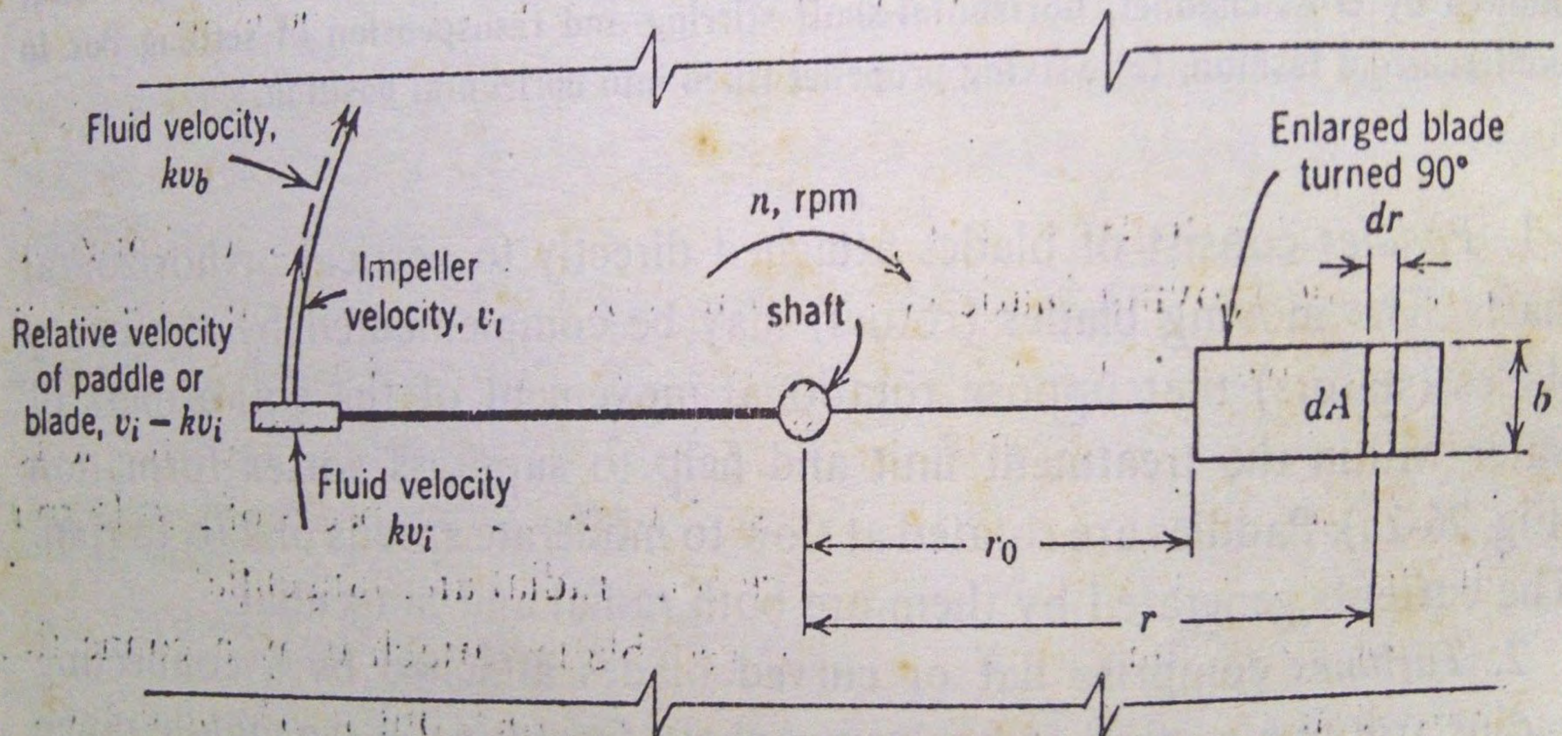


Fig. 26-3. Velocity and power relationships of mechanical mixers or stirrers (schematic diagram).

- Fig 26-3 shows that (Eq 14):

$$r^3 A = \int_{r_o}^{r} r^3 \partial A = b \int_{r_o}^{r} \partial r = \frac{1}{4} b\left(r^4 - r_o^4\right)$$

Because ∂A = b∂r

If the impeller includes a series of blades, r^3A is replaced by $\sum r^3A$. Thus (Eq 15):

$$P = 1.44 \times 10^{-4} C_D \rho [(1-k)n]^3 b \sum\left(r^4 - r_o^4\right)$$

The allowable loading Q/C is found by substituting Eq (15), (13) or (Eq 11) in Eq (3)

- Because power input identifies only geometric & kinematic similarity, chemical engineers prefer to express mixing & stirring relationships by a dimensionless power number (Eq 16):
- $P = 2.16 \times 10^5\ P/(32\rho n^3 r^5) = 6.75 \times 10^3 P/ /(\rho n^3 r^5) = KR^p F^q$
- Where:
- K, p and q are coefficients changing with the conditions of flow
- P = power input
- R = Reynolds number
- F = Froude number

- $R = 6.67 \times 10^{-2} nr^2 \rho/\mu$
- $F = 2.78 \times 10^{-3} nr^2/g$
- Where:
- ρ = mass density
- μ = absolute viscosity
- g = gravity constant

- At low R number, $R \leq 10$, $p = -1$, $q = 0$ and $R = KP^{-1}$
- At high R number, $R \geq 10^5$, $p = 0$, $q = 0$ and $P = K$
- Can be put it into Eq 13 because
- $n^3r^3 = 5.41 \times 10^3 (\mu/\rho)$ RF or
- $P = 1.25\ CG^2/(\rho g r^2 RF)$
- □ G and Gt_d identify conjunction kinetics or dynamics fully when R is high ($R \geq 10^5$)
-

In flocculation practice:

- Peripheral speeds of paddles range from 0.3 to 3 fps
- $k = 0.25$ in the absence of stators
- $C_D = 1.8$ for flat plates

At $n = 1$ to 5 rpm or more, paddles 8 ft in diameter have $R = 7.57 \times 10^4$ to 3.79×10^5 and $P \approx G^2$

Example

A flocculator designed to treat 20 mgd is 100 ft long, 40 ft wide and 15 ft deep. It is equipped with 12-in paddles supported parallel to and moved by four horizontal shafts which rotate at a speed of 2.5 rpm. The center line of the paddles is 6 ft from the shaft, which is at mid-depth of the tank. Two paddles are mounted on each shaft, one opposite the other. If the mean velocity of the water is approximately one-fourth the velocity of the paddles and their drag coefficient is 1.8, find:

1. The velocity differential between the paddles and the water
2. The useful power input and the energy consumption
3. The detention time
4. The value of G and the product G t_d
5. The flocculator loading

Assume a water temperature of 50^0F, μ =

answers

1. $v_i = 2\pi rn = 2\pi \times 6 \times 2.5/60 = 1.57$ fps

$v = (1 - k)\, v_i = (1 - 0.25)\, 1.57 = 1.18$ fps

2. $A = 40 \times 2 \times 4 \times 1 = 320$ sq ft

$P = ½\, C_D\, \rho\, A\, v^3 = ½ \times 1.8 \times (62.4/32.2) \times 320 \times (1.18)^3 = 918$ ft-lb/sec

And 918/550 = 1.67 HP or 1.67 x 0.7457 = 1.24 KW

- The energy consumption per million gallon = 1.67 x 24/20 = 2 HP-hr/mg or 2 /1.341 =1.5 KW-hr/mg treated. For electrical drive, there must be added the energy required to overcome mechanical friction and to provide for electrical losses in the lines and motor (in practice, flocculators consume 2 to 6 kwhr/mg treated).

3. $V = 40 \times 100 \times 15 = 6 \times 10^4$ cu ft

$t_d = 6 \times 10^4$ cuft x 7.48 gall/cuft x 24 hr/d x 60 min/hr /(20×10^6) mgd= 32.5 min

4. $G = (P/\mu C)^{1/2} = [918/(2.74 \times 10^{-5} \times 100 \times 40 \times 15)]^{1/2}$ = 23.7 fps/ft = 23.7/sec

$G\, t_d$ = 23.7/sec x 32.5 min x 60 sec/min= 4.64×10^4

5. $Q/C = 20 \times 10^6 / 6 \times 10^4$ = 333 gpd/cu ft

SOAL

- Diketahui suatu BPAM dengan Qav = 300 l/det. Fm = 1,4. Hasil uji jar test:
- Koagulasi: G = 300/det, td = 90 det
- Flokulasi : G = 90/det, 50/det, 20/det, td utk 3 bak = 10 mnt
- Koagulasi: hydraulic jump, 1 bak
- Flokulasi: baffled channel, 2 bak paralel
- Koagulasi & flokulasi merupakan satu

- Dit:

1. Dimensi bak
2. Tek/energi yang diperlukan
3. Gambar 3D, denah
4. 1 potongan memanjang
5. 1 potongan melintang

- $\mu = 0.273 \times 10^{-5}$ lb sec/ft^2
- Pg = 62.4 lb sec/cu ft
- Q total yang diolah=
- + air yang akan hilang selama proses pengolahan (7.5 – 15)% □ ambil: 10 %
- Free board: (10-20)% x kedalaman air □ ambil 15%

TLB 314 PDIPAM

Week 13

Genap 2025/2026

Dosen: Rachmawati S. Dj.

Sub CP MK *Week 12-13*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7]; Metode Pembelajaran[8]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5]	Teknik[6]	Luring	
1	2	3	4	5	6	9
12-13	6.4	Mahasiswa mampu menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi secara tepat	Ketapatan dalam menjelaskan *secondary treatment*; menganalisis dan merancang koagulasi, flokulasi dan desinfeksi	Tugas, UAS	Tatap Muka, Asistensi, Diskusi Tugas: 2*50 menit/minggu *Secondary treatment,* koagulasi, flokulasi dan desinfeksi: 2*3*50 menit	6%

Principles and Practices of Drinking-water Chlorination

A guide to strengthening chlorination practices in small- to medium-sized water supplies

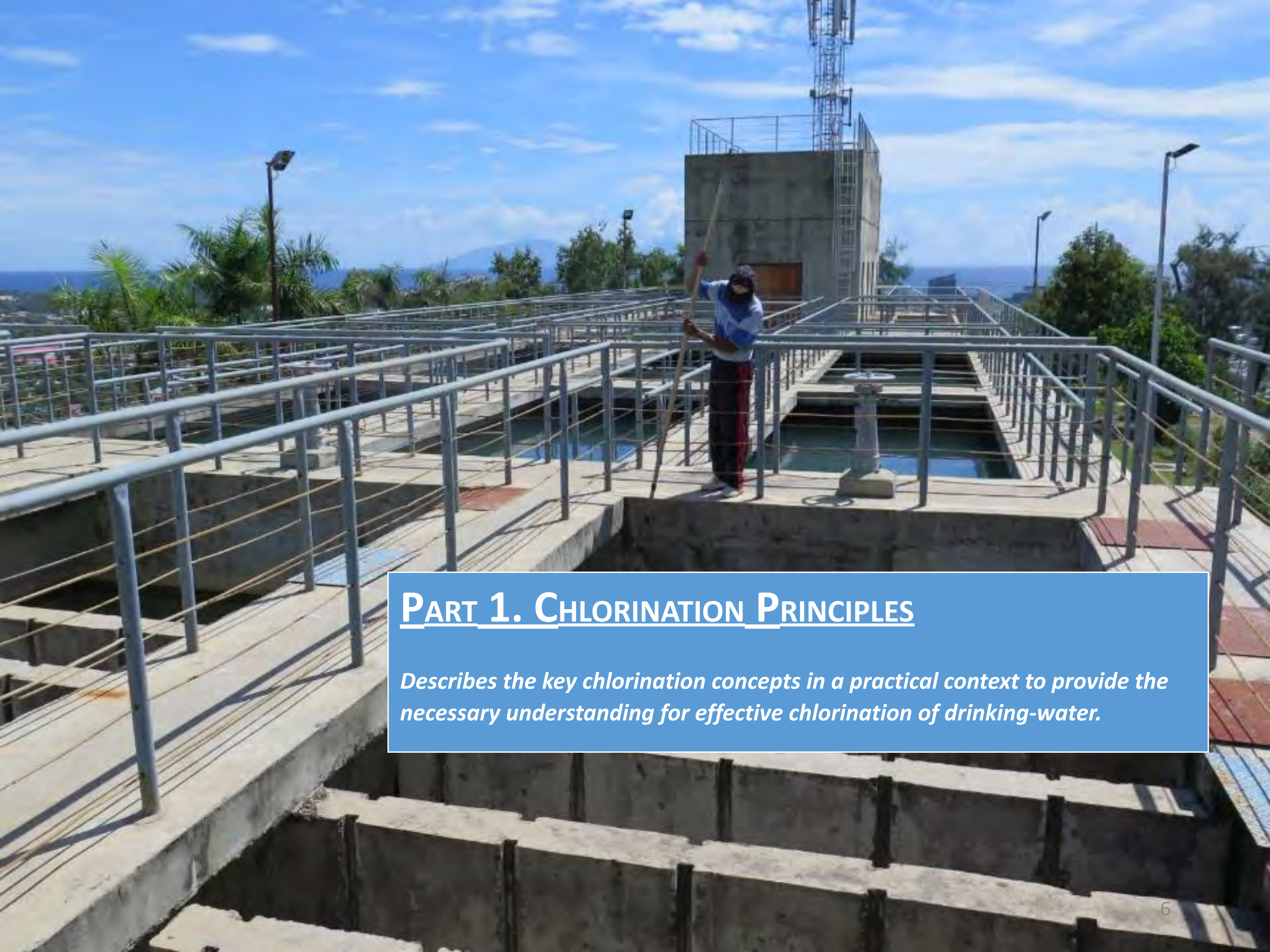
World Health Organization
Regional Office for South-East Asia

Contents

Aim of this training programme

Upon completion of this training course, you will be able to:

- **understand the key principles of drinking-water chlorination**
- **apply these principles practically in the field**
- **perform the basic calculations required to support effective drinking-water chlorination**
- **develop standard procedures to correctly and consistently chlorinate drinking-water**
- **store and handle chlorine safely**



PART 1. CHLORINATION PRINCIPLES

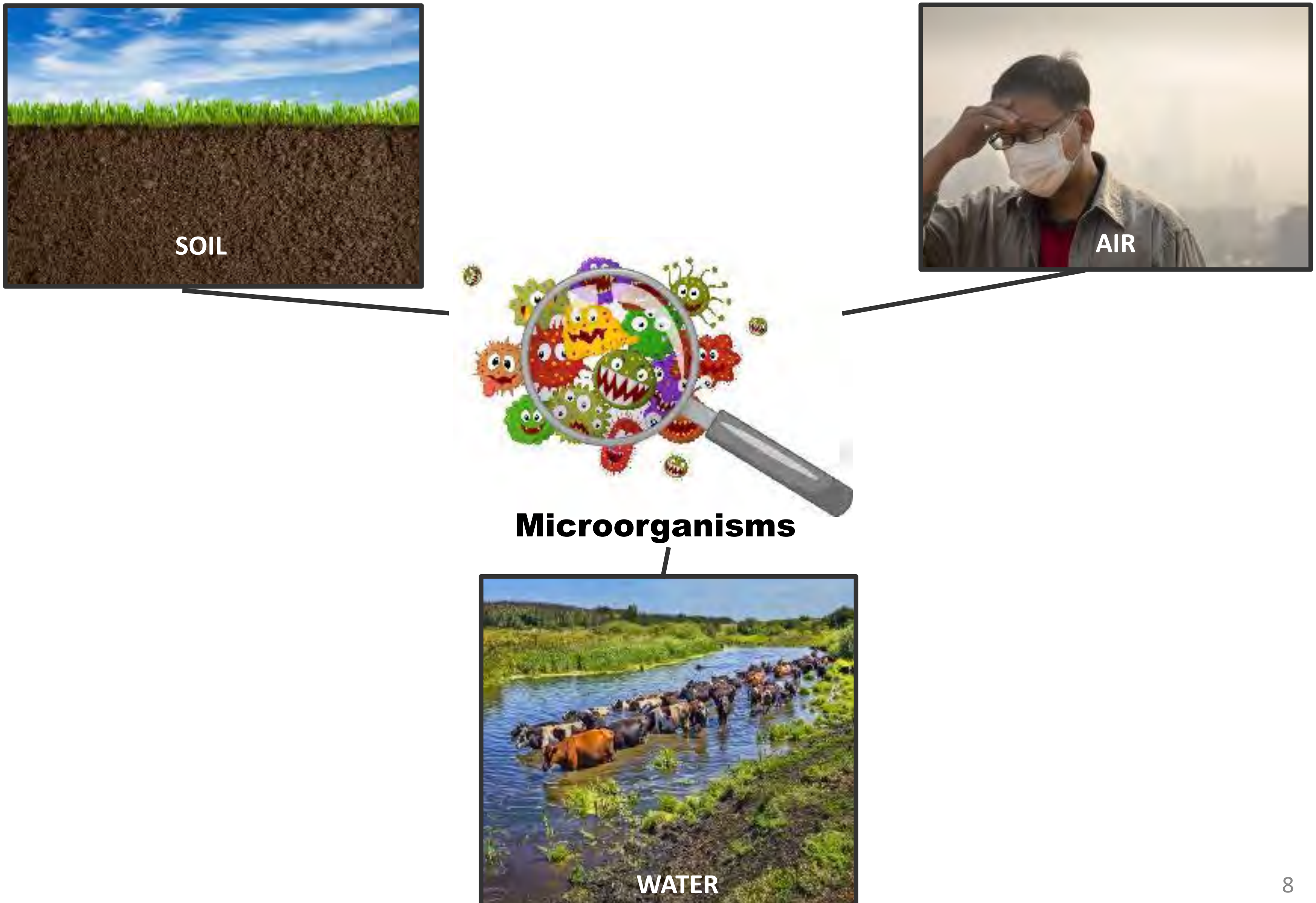
Describes the key chlorination concepts in a practical context to provide the necessary understanding for effective chlorination of drinking-water.

Contents

Part 1. Chlorination Principles

- **What is chlorination?**

Microorganisms – Found in almost all environments



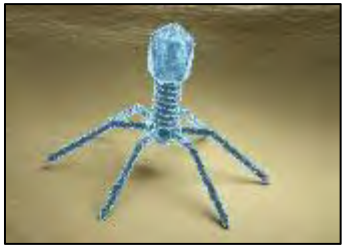
Microorganisms in drinking-water may cause illness

Microorganisms commonly associated with waterborne disease include:

- **bacteria (e.g., *Escherichia coli*, *Vibrio cholerae*)**

BACTERIA

- **viruses (e.g., Hepatitis A, poliovirus A)**



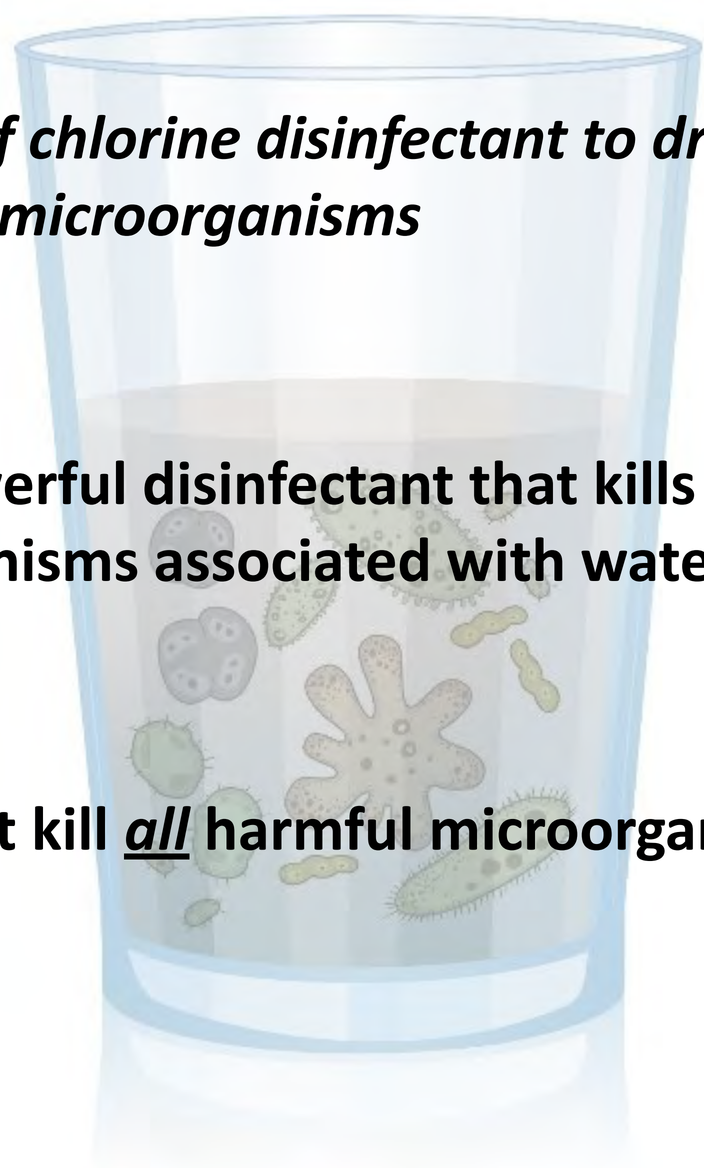
VIRUSES

- **protozoa (e.g., *Cryptosporidium*, *Giardia*).**

PROTOZOA

Chlorination

⇒ ***Addition of chlorine disinfectant to drinking-water to kill or inactivate microorganisms***



Chlorine is a powerful disinfectant that kills *__most__* harmful microorganisms associated with waterborne disease

Chlorine does not kill *__all__* harmful microorganisms

Photo credit: Shutterstock.com

Relative effectiveness of chlorine

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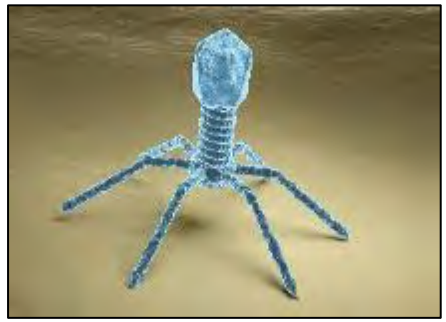


VIRUSES

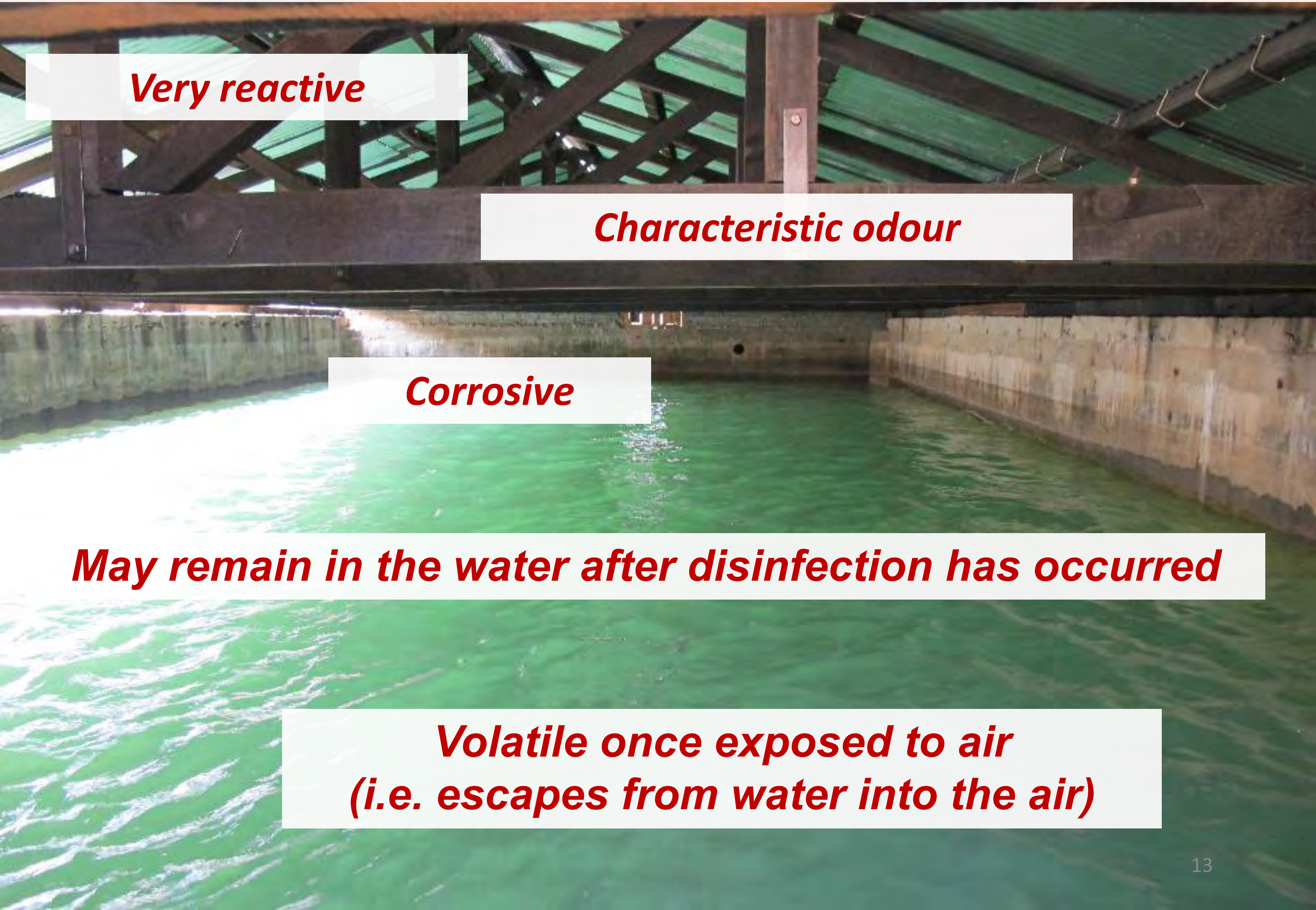
PROTOZOA

MOST EFFECTIVE **EFFECTIVENESS OF CHLORINE** **LEAST EFFECTIVE**

Photo credit: Shutterstock.com

Contents

Properties of chlorine



Very reactive

Characteristic odour

Corrosive

May remain in the water after disinfection has occurred

Volatile once exposed to air
(i.e. escapes from water into the air)

Properties of chlorine

Chlorine may be found in three forms

Powder ***Liquid*** ***Gas***

Photo credit: Shutterstock.com

How to express the strength of chlorine

Chlorine gas typically contains pure chlorine

Chlorine powder and liquid do not contain pure chlorine

- ⇒ **are mixed with other substances (e.g., calcium, sodium or water)**

The strength of chlorine in chlorine powder or chlorine liquid is referred to as the '*concentration*' of chlorine in that substance

Typically, this is expressed as the percentage (%) of active chlorine present

Properties of chlorine: Powder

Appearance: White powder, granules or tablet

Strength: Typically 30 to 70 % active chlorine
Requires mixing with water to make a liquid solution before use (see '*Chlorine liquid*' below)

Stability: May lose strength over time; more stable than chlorine liquid

Application: Typically used for small-sized water treatment plants (< 5 000 cubic meters per day)

Powder

Examples: => Bleaching powder (approx. 35 % active chlorine)

=> High test hypochlorite (approx. 70 % active chlorine)

Properties of chlorine: Liquid

Appearance: Pale yellow to clear liquid

Strength: Typically 1 to 15 % active chlorine

Stability: May lose strength over time; less stable than chlorine powder

Application: Typically used for small- to medium-sized water treatment plants (i.e., <10 000 cubic meters per day)

Liquid

Examples: => Sodium hypochlorite (10 to 15 % active chlorine)
=> Domestic bleach (5 to 10 % active chlorine)
=> Chlorine liquid solution prepared from chlorine powder (typically 1 to 5 % active chlorine)

Photo credit: Shutterstock.com

Properties of chlorine: Gas

Appearance: Green-yellow gas

Strength: Approx. 100 % active chlorine

Stability: Most stable

Application: Typically used for medium- to large-sized water treatment plants (i.e., >10, 000 cubic meters per day)

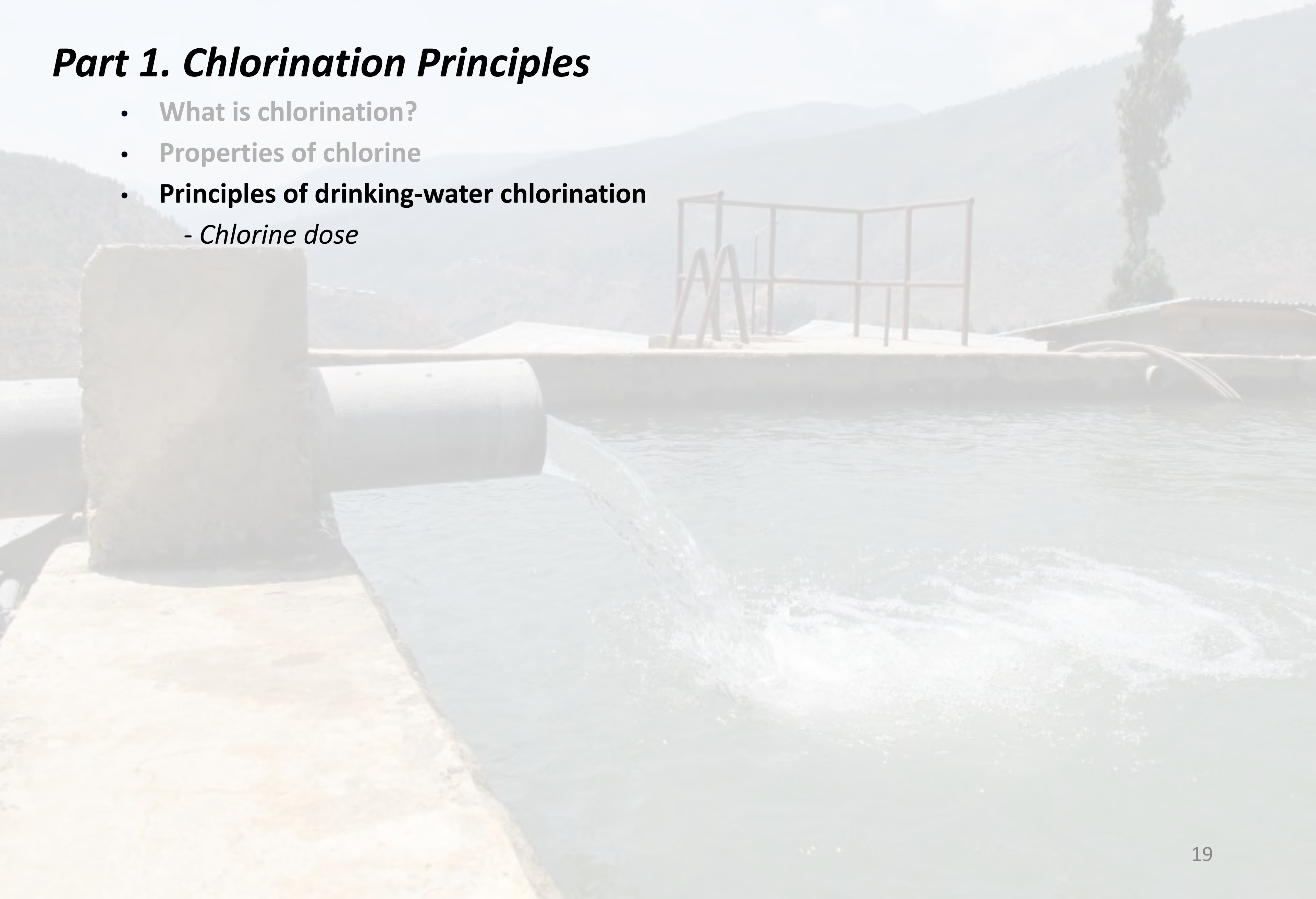
Gas

Example: Chlorine gas (liquefied)

Contents

Part 1. Chlorination Principles

- What is chlorination?
- Properties of chlorine
- **Principles of drinking-water chlorination**
  - *Chlorine dose*



Chlorine dose

How much chlorine is added to the drinking-water (or, the concentration of chlorine in the drinking-water)

Usually expressed as *<u>milligrams per litre</u>* (mg/L).

⇒ ***for example, if drinking-water has a chlorine concentration of 1 mg/L, this means that there is 1 milligram of chlorine present in 1 litre of water***

Contents

Part 1. Chlorination Principles

- What is chlorination?
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  - *- Chlorine dose*
  - *- Types of chlorine present in drinking-water*

Chlorine reactions in drinking-water

Chlorine Dose
Amount of chlorine added to the water

↓

Chlorine Demand
Chlorine consumed during reaction with organic and inorganic material present

↓

Total Chlorine
Chlorine remaining after chlorine demand has been satisfied and disinfection has occurred

↓

Residual Chlorine
Free chlorine available for disinfection (may prevent recontamination of water)

Combined chlorine
Chlorine bound to organic and nitrogen compounds (weak disinfection capacity)

Residual chlorine (or free chlorine, or free available chlorine)

⇒ **Chlorine remaining after disinfection has taken place**

⇒ **An effective disinfectant**

⇒ **Presence of residual chlorine indicates that:**

1. **disinfection has occurred**
2. **the disinfected water has a degree of residual protection from microbial recontamination (e.g., during storage and distribution)**

WHO recommends that a minimum residual chlorine concentration of <u>0.2 mg/L</u> is maintained to the point of delivery to the consumer[1].

[1] World Health Organization (2011). Guidelines for Drinking-water Quality. 4^{th} Edn. Geneva, Switzerland.

Chlorine demand

When chlorine is added to water, it reacts with any organic and inorganic material (*chlorine reactive substances*)

⇒ **during these reactions, chlorine is consumed**

referred to as the 'chlorine demand'

⇒ **as chorine is consumed during these reactions, the concentration of chlorine decreases**

Chlorine demand

It is important to understand how much chlorine will be consumed during the disinfection process:

- ⇒ **This allows you to estimate how much chlorine you need to add to the drinking-water at the water treatment plant to ensure there will be sufficient residual chlorine present in the water to protect the water during storage and distribution**

Chlorine demand

Understanding the chlorine demand of the raw water is important for effective disinfection

- ⇒ **if the water has a *<u>higher concentration</u>* of chlorine reactive substances, the chlorine demand will be *<u>higher</u>***

- ⇒ **if the water has a *<u>lower concertation</u>* of chlorine reactive substances, the chlorine demand will be *<u>lower</u>***

Relationship between chlorine demand & chlorine dose

DIRTY WATER | **CLEAN WATER**

***High* concentration of organic & inorganic material**

***High* chlorine demand (i.e. high chlorine consumption)**

***Low* concentration of organic & inorganic material**

***Low* chlorine demand (i.e. low chlorine consumption)**

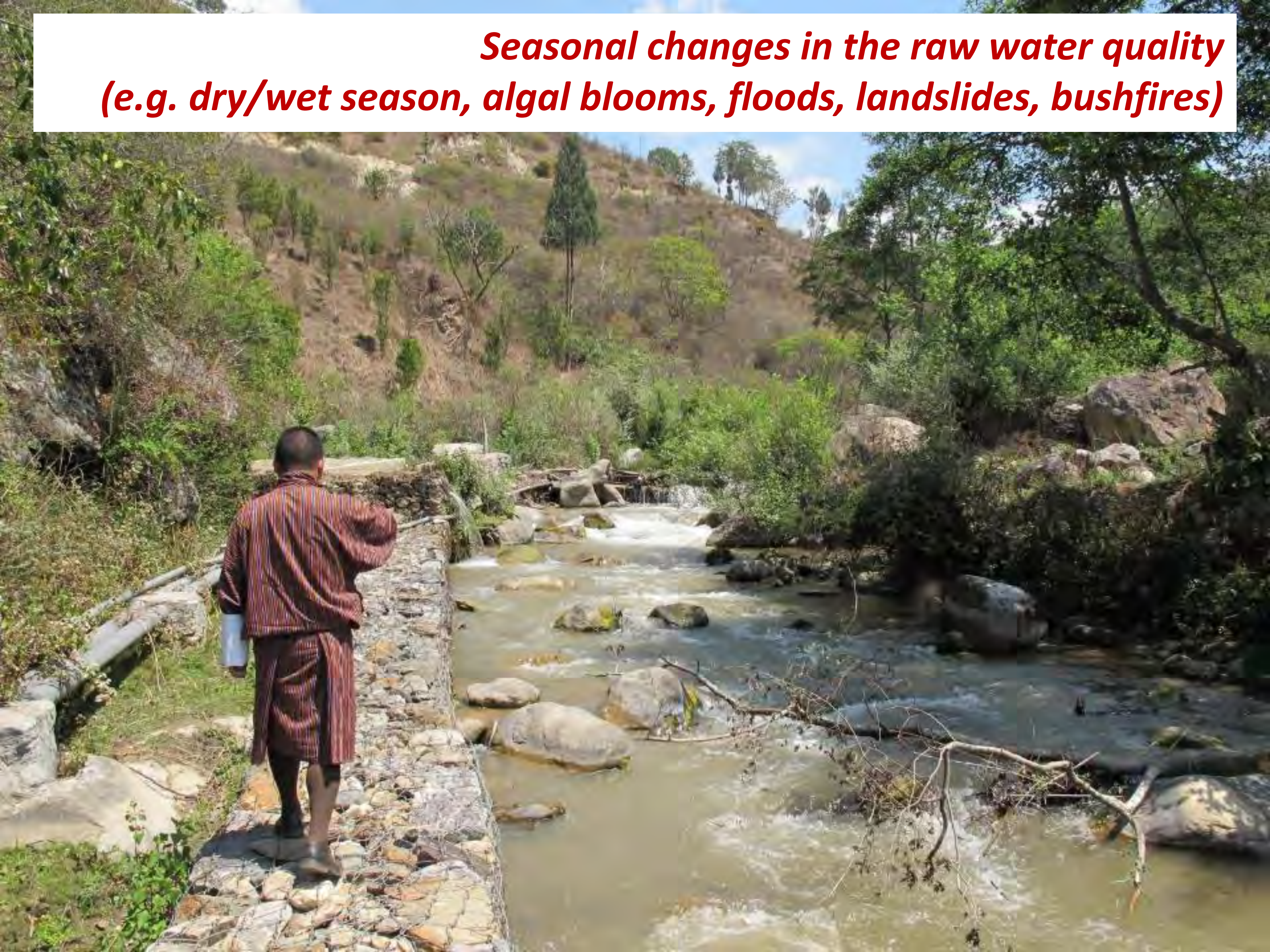
Chlorine demand

Chlorine demand of water is constantly changing

⇛ **Changes as water quality changes**

Examples of events that influence the chlorine demand include….

Seasonal changes in the raw water quality
(e.g. dry/wet season, algal blooms, floods, landslides, bushfires)



Failure of a water treatment process (e.g. sedimentation, filtration)

Introduction of contamination post treatment (e.g. leaking/bust water main, accumulation of sediment or microbial biofilm within water mains)

Chlorine demand

Consideration of the chlorine demand is most important at the water treatment plant, immediately *prior* to the addition of chlorine

Where practical, chlorine demand is a useful parameter to monitor

- ⇒ **Where routine monitoring is not practical, you should be aware of the impact of changing raw water quality (i.e. changing chlorine demand) on the required chlorine dose**
- ⇒ **E.g. poorer water quality => higher chlorine demand => higher chlorine dose required**

Contents

Part 1. Chlorination Principles

Chlorine decay

=> The decrease (or reduction) in the concentration of chlorine in drinking-water as it passes from the water treatment plant, through the distribution system, to the point of consumer delivery

Due to chlorine decay, the concentration of chlorine at the end of the distribution system will usually be less then the concentration at the water treatment plant

Chlorine decay

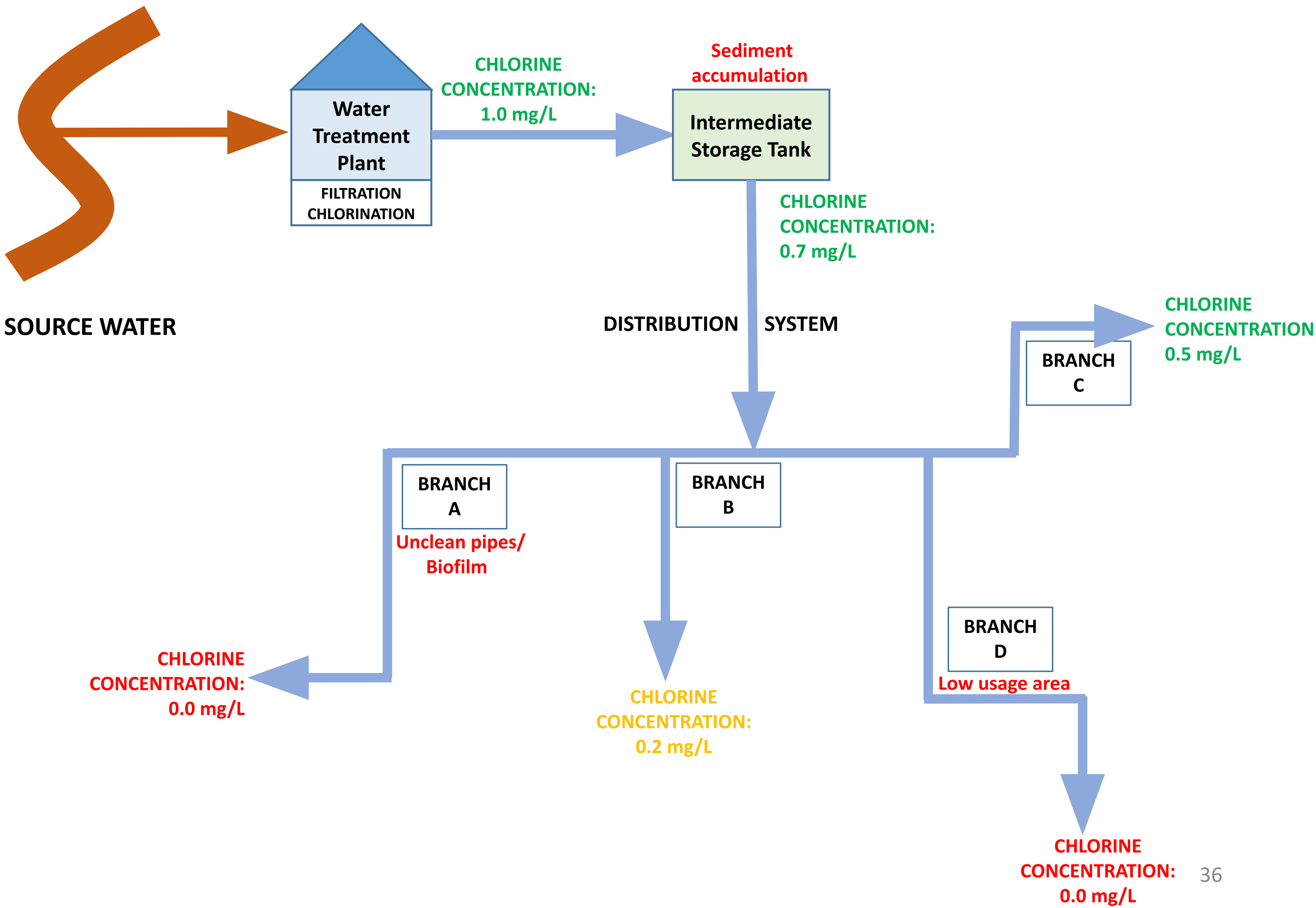
The rate and extent of chlorine decay may be influenced by:

- ⇒ **the level of chlorine reactive substances that are present in the treated water as well as the distribution tanks and pipes (i.e., organic and inorganic material)**

- ⇒ **the type of material used in the distribution network tanks, pipes and fittings**

- ⇒ **how long the water remains in the distribution system (or the 'water age')**

Chlorine decay



Understanding the *chlorine demand* and *chlorine decay* of your water supply system is important:

⇒ **helps you to determine the correct chlorine dose at the water treatment plant**

Remember, must dose enough chlorine at the water treatment plant to ensure you have ≥ 0.2 mg/L at the point of consumer delivery.

Strategies to minimize chlorine decay in a water supply system

- **Optimize water treatment process to ensure high quality treated water (i.e., water entering the distribution system has a low chlorine demand)**
- **Maintain intermediate storages and distribution pipes (e.g., for removal of accumulated sediment and microbial biofilms)**
- **Optimize the hydraulic regime during distribution (i.e., minimise water age and low-flow/stagnant areas)**
- **Minimize unaccounted water (i.e., leaks, illegal connections) which may be vulnerable points for entry of contamination**
- **Aim for 24 hours supply (where feasible) to maintain positive pressure in the system to minimize risks of contamination entry**

Contents

Ct concept for disinfection

Chlorine requires time to kill or inactive microorganisms during disinfection

⇒ **this is referred to as '*contact time*'**

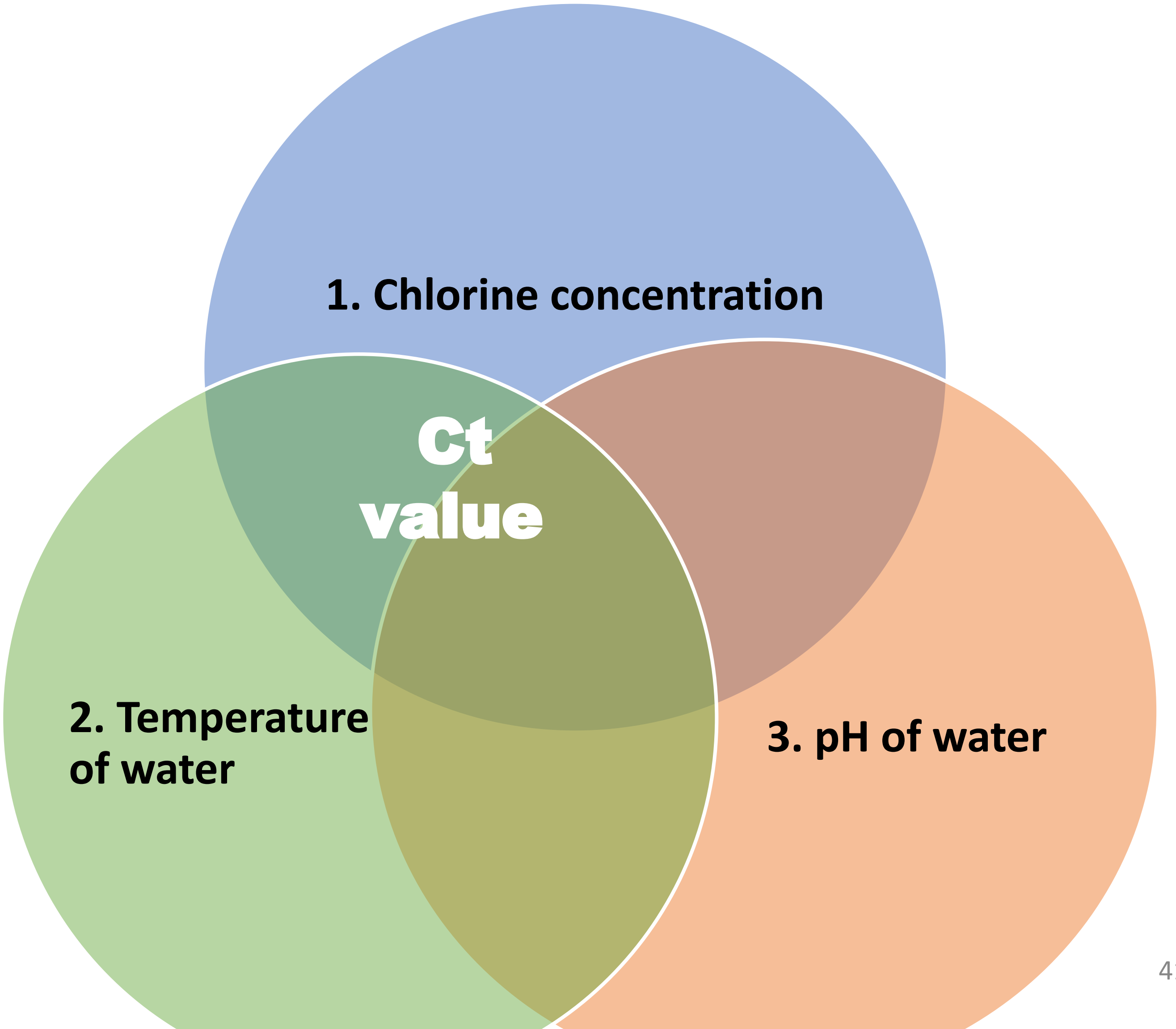
The contact time must be considered in conjunction with the chlorine concentration and other factors, to ensure that effective disinfection of drinking-water occurs

⇒ **this is referred to as the '*Ct*' concept for disinfection**

The Ct value is the product of disinfectant concentration and contact time with the drinking-water

Ct = Residual Chlorine Concentration (mg/L) x Time of Contact (min)

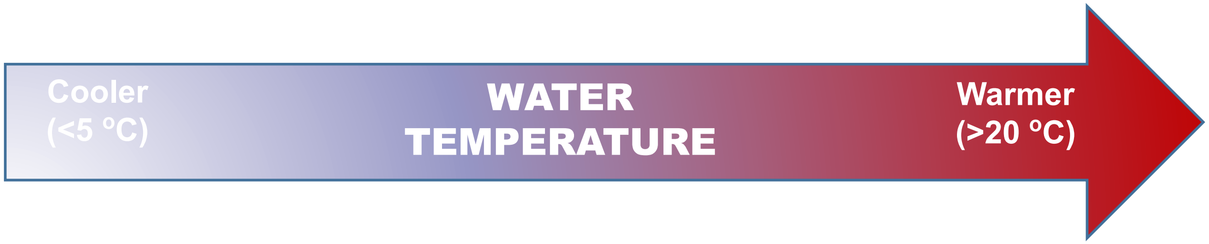
Factors influencing the Ct value



Influence of chlorine concentration on disinfection

Influence of water temperature on disinfection

MORE contact time or ***higher*** chlorine concentration needed



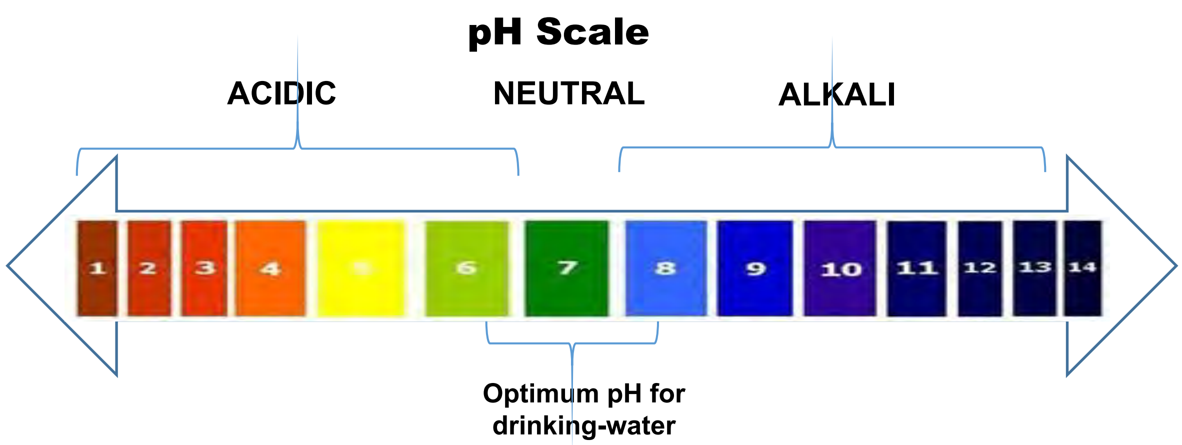
LESS contact time or ***lower*** chlorine concentration needed

Influence of pH on disinfection

pH measures if the water is acid or alkaline (or basic)

- ⇒ **measured on a scale of pH 0 to pH 14**
- ⇒ **pH 7 considered neutral, pH <7 considered acidic and pH >7 considered alkali**

LESS contact time or ***lower*** chlorine concentration needed



MORE contact time or ***higher*** chlorine concentration needed

Influence of pH on disinfection

For effective chlorination, the pH of the water should be < pH 8.0

However

To balance water quality considerations, including chlorination, the optimum pH of drinking-water is generally between pH 6.5 and pH 8.5

⇒ **Where water is >pH 8.0, higher chlorine concentrations or more contact time will be required!**

Turbidity may also indirectly impact contact time

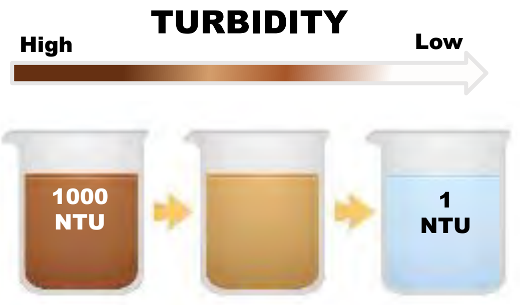
Suspended organic/inorganic particles in water

- ⇒ gives water an opaque (or cloudy) appearance

Turbidity may influence the effectiveness of chlorine disinfection

- ⇒ indicates the presence of chlorine reactive substances, which may react with and consume chlorine, thereby increasing the chorine demand
- ⇒ May also 'shields' microorganisms from the lethal/inactivating effects of chlorine

MORE contact time or ***higher*** chlorine concentration needed



LESS contact time or ***lower*** chlorine concentration needed

Photo credit: Shutterstock.com

Type of microorganism and chlorine disinfection

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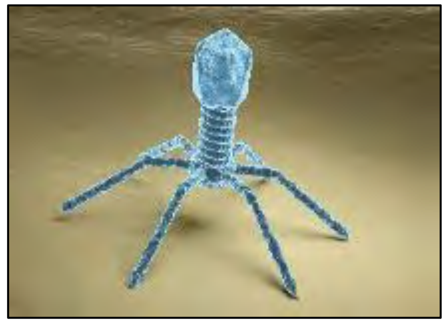


VIRUSES

PROTOZOA

LESS contact time or ***lower*** chlorine concentration needed

MOST EFFECTIVE → **LEAST EFFECTIVE**

MORE contact time or ***higher*** chlorine concentration needed

Photo credit: Shutterstock.com

Minimum required contact time for effective disinfection

How much contact time is needed for effective disinfection?

For effective disinfection, the WHO[1] recommends
at least 30 minutes contact time,
where the residual chlorine concentration is ≥0.5 mg/L
and the pH of the water is <pH 8.

⇒ ***Minimum recommendation only – should determined on a site-specific basis (more to follow on this in Part 2…)***

[1] World Health Organization (2011). Guidelines for Drinking-water Quality. 4th Edn. Geneva, Switzerland.

Contents

Aesthetic considerations (i.e. relating to taste or odour)

Chlorine may result in a distinctive taste & odour in drinking-water

- ⇒ different individuals vary in their ability to detect chlorine taste/odour
- ⇒ in general, chlorine has a taste/odour threshold >0.3 mg/L

If chlorine is present in drinking-water at concentrations that are unacceptable to consumers:

- ⇒ may result in an individual using alternative, less safe, water sources

Photo credit: Shutterstock.com

Aesthetic considerations (i.e. relating to taste, odour, appearance)

For this reason the aesthetic impact of chlorine on drinking-water should be considered when optimizing the chlorine dose

HOWEVER…

⇒ ***Disinfection should always be prioritized over aesthetic considerations!!!***

Aesthetic considerations

To balance effective disinfection against aesthetic considerations:

- ⇒ **a *<u>residual chlorine concentration of between 0.2 to 0.5 mg/L</u>* should be targeted at all points in the distribution network**

However, this may need to be higher in certain circumstances, to ensure a minimum residual chlorine concentration of <u>0.2 mg/L</u> is maintained to the point of consumer delivery

- ⇒ **discussed further in next section…**

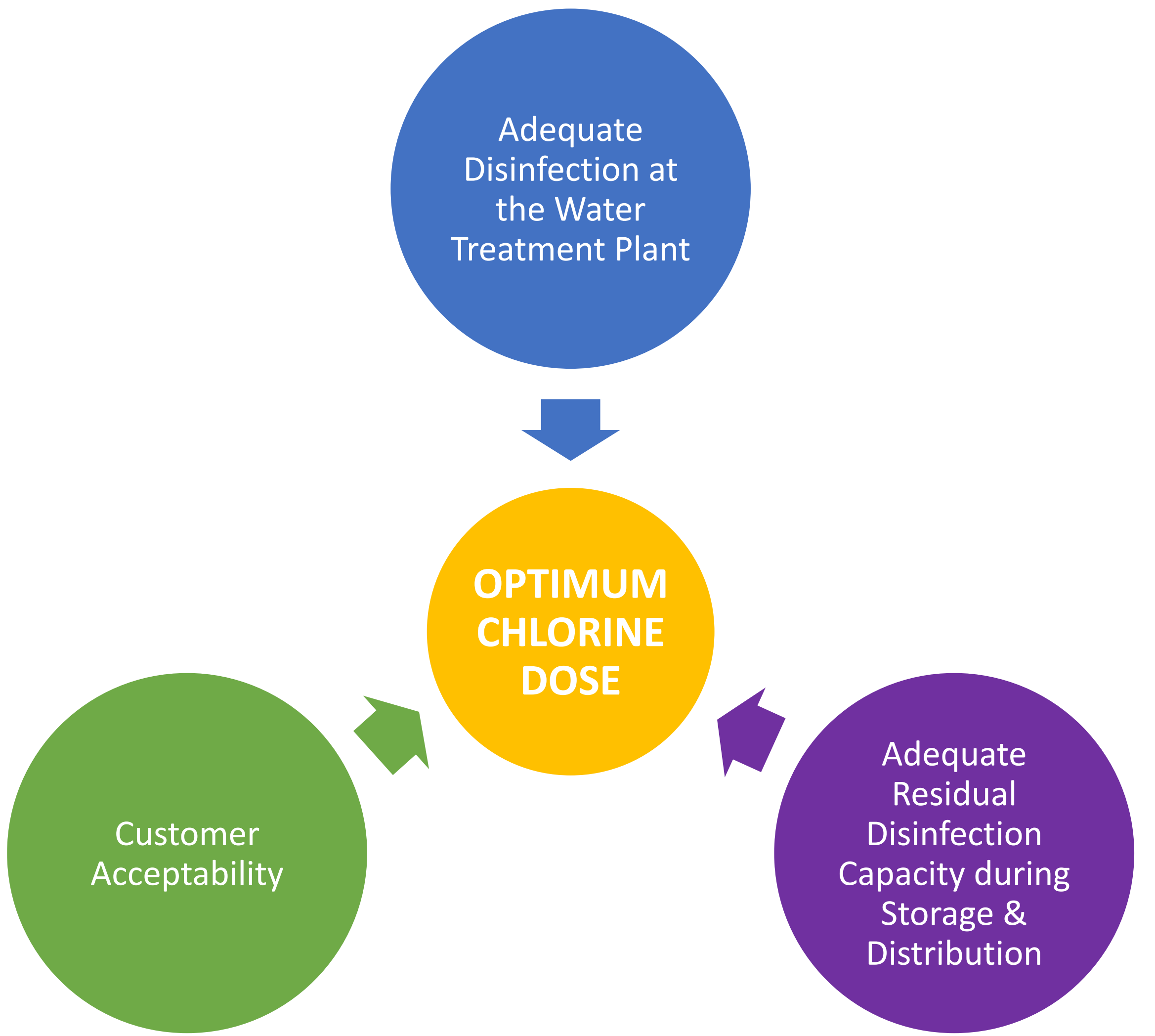
Contents

Part 1. Chlorination Principles

- What is chlorination?
- Properties of chlorine
- **Principles of drinking-water chlorination**
  - *- Chlorine dose*
  - *- Types of chlorine present in drinking-water*
  - *- Chlorine demand*
  - *- Chlorine decay*
  - *- Ct concept for disinfection*
  - *- Aesthetic considerations for chlorination*
  - *- Optimizing the chlorine concentration in a water supply system*

Optimizing the chlorine dose

Requires balancing the following key considerations…



Optimizing the chlorine dose

Risk of microbial contamination

Aesthetically unacceptable

Optimizing the chlorine dose

Priority **must always be to add sufficient chlorine such that:**

⇒ **The *minimum required contact time* for effective disinfection *is achieved***

⇒ **The *residual chlorine concentration* at all points in distribution system is *≥0.2 mg/L***

To balance effective disinfection against consumer acceptability considerations:

⇒ **a *residual chlorine concentration of between 0.2 to 0.5 mg/L* in the distribution network should be targeted**

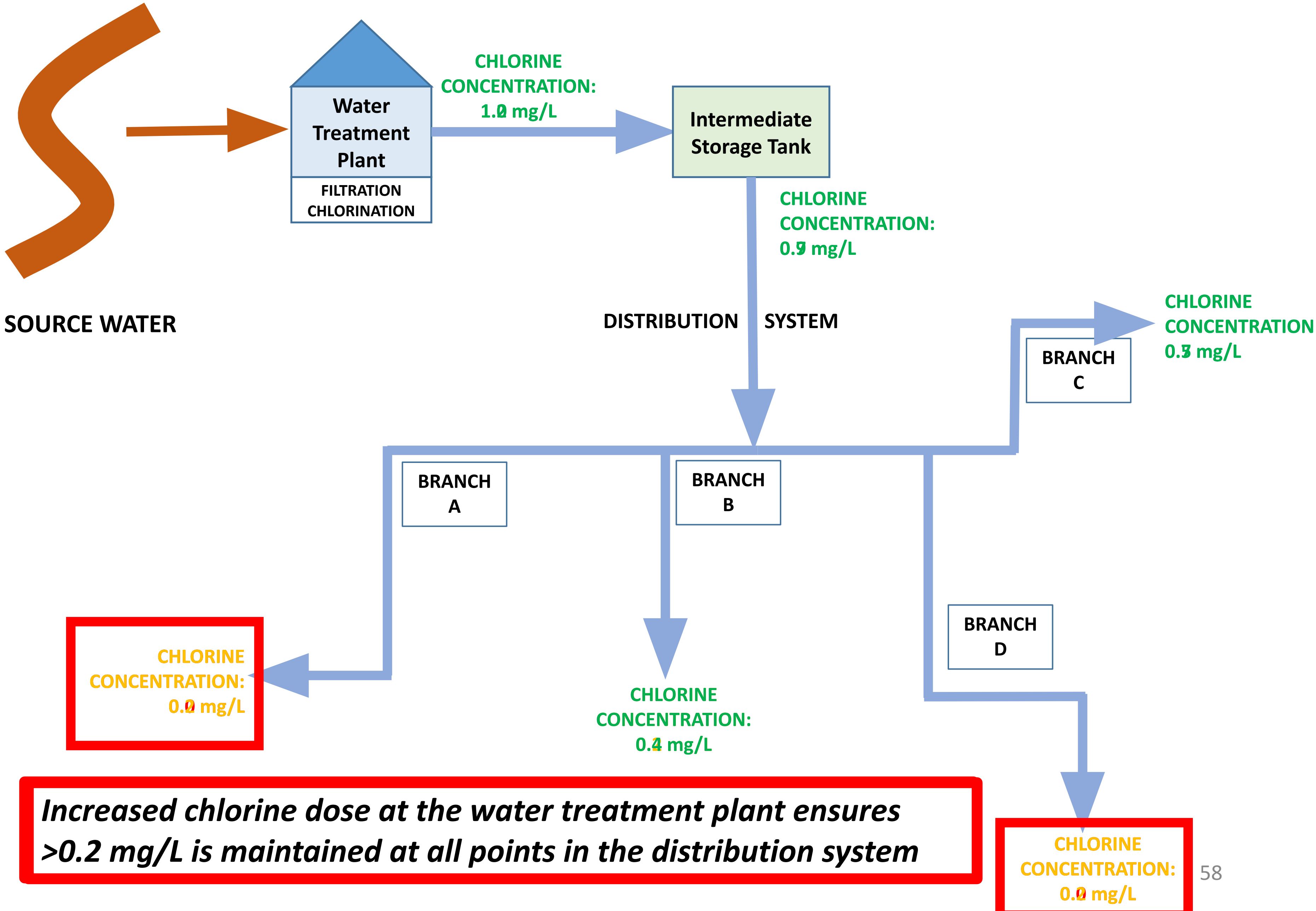
⇒ ***Effective disinfection and residual protection should always be prioritized over aesthetic considerations***

Optimizing the chlorine dose

May need to maintain a higher residual chlorine concentration in some parts of the distribution system to ensure *__a minimum residual chlorine concentration of 0.2 mg/L__* is achieved throughout the entire system

- ⇒ **for example, having a higher residual chlorine earlier in the system**
- ⇒ **this may be needed to maintain an adequate residual chlorine concentration at the very end of the distribution system**

Optimizing the chlorine dose



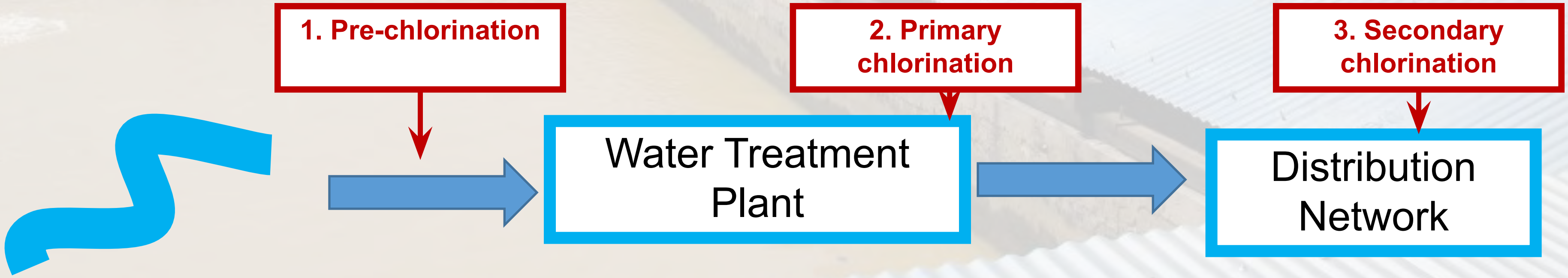
Increased chlorine dose at the water treatment plant ensures >0.2 mg/L is maintained at all points in the distribution system

Contents

Points of chlorine dosing

Chlorine may be added:

1. **Pre-chlorination (before water treatment plant)**
2. **Primary chlorination (after water treatment process)**
3. **Secondary chlorination (during distribution)**



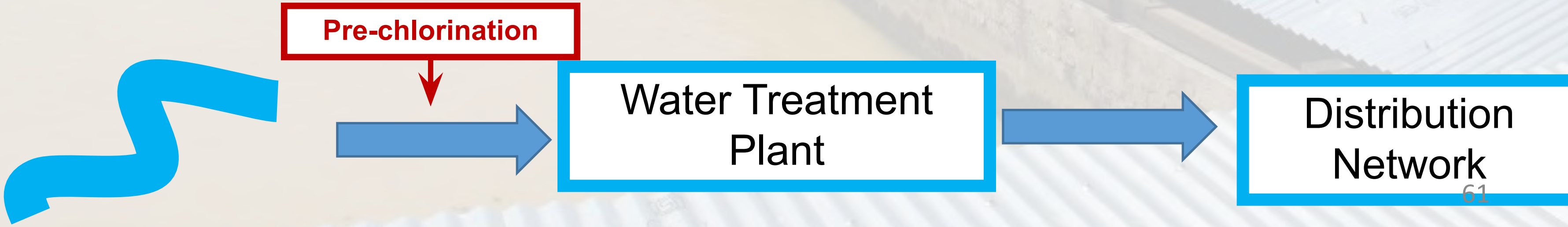
Points of chlorine dosing

1. Pre-chlorination (before water treatment plant)

- ⇒ used to remove minerals (e.g. Iron, manganese)
- ⇒ chlorine makes them insoluble (particulate)
- ⇒ can be removed during water treatment (filtration)
- ⇒ can also remove taste/odour

Potential issues:

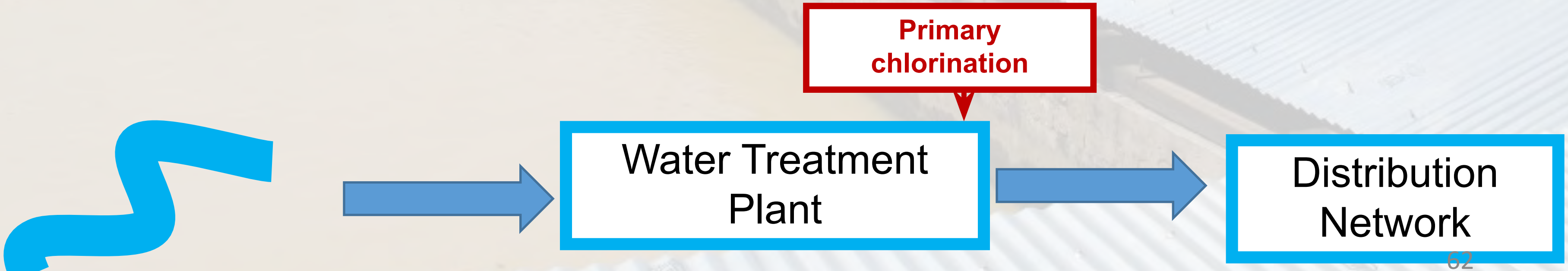
- ⇒ raw water may have a high chlorine demand which requires high chlorine dose (high operational cost)
- ⇒ formation of disinfection by-products in high organic waters



Points of chlorine dosing

2. Primary chlorination (after water treatment)

- ⇒ used for disinfection; most common & effective point of application
- ⇒ most effective to add chlorine when turbidity is as low as possible – ideally <1 NTU (i.e., after clarification, filtration)
- ⇒ clean, filtered water so lower chlorine demand
  - ⇒ use less chlorine
  - ⇒ less risk of disinfection by-product formation
    - ⇒ ***Disinfection should not be compromised in attempting to control disinfection by-products***



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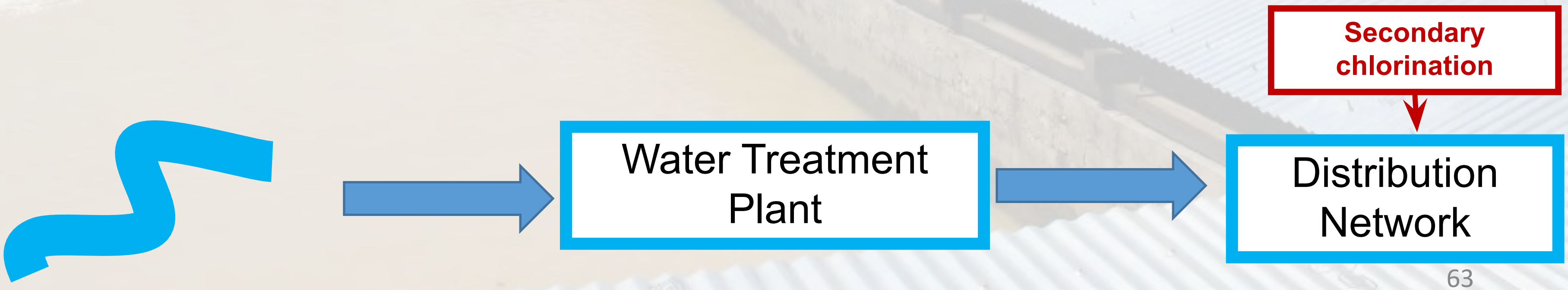
Points of chlorine dosing

3. Secondary ('booster') chlorination

- ⇒ used to maintain sufficient chlorine concentration during distribution to protect the water from recontamination i.e. ≥0.2 mg/L
- ⇒ 'booster station' adds more chlorine to the water at strategic points during distribution when the chlorine concentration is too low i.e. <0.2 mg/L
- ⇒ helps keep the water safe to the very end of the distribution system
- ⇒ common in large distribution networks



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Part 1. Chlorination Principles

- What is chlorination?
- Properties of chlorine
- Principles of drinking-water chlorination
  - *- Chlorine dose*
  - *- Types of chlorine present in drinking-water*
  - *- Chlorine demand*
  - *- Chlorine decay*
  - *- Ct concept for disinfection*
  - *- Aesthetic considerations for chlorination*
  - *- Optimizing the chlorine concentration in a water supply system*
  - *- Points of chlorine application*
- **Summary**

Summary of the optimal conditions required for effective chlorination

Turbidity: **<1 NTU (lower where possible)**

(where < 1 NTU is not possible, <5 NTU should be the aim; above 5 NTU, disinfection should still be practised, but higher chlorine doses or contact times will be required to inactivate harmful microorganisms)

pH: **<pH 8.0**

(Above pH 8.0, chlorination should still be practised but higher chlorine doses or contact times will be required to inactivate harmful microorganisms)

Minimum contact time: **30 minutes contact time with a minimum residual chlorine concentration of 0.5 mg/L, where the pH of the water is <pH 8.**

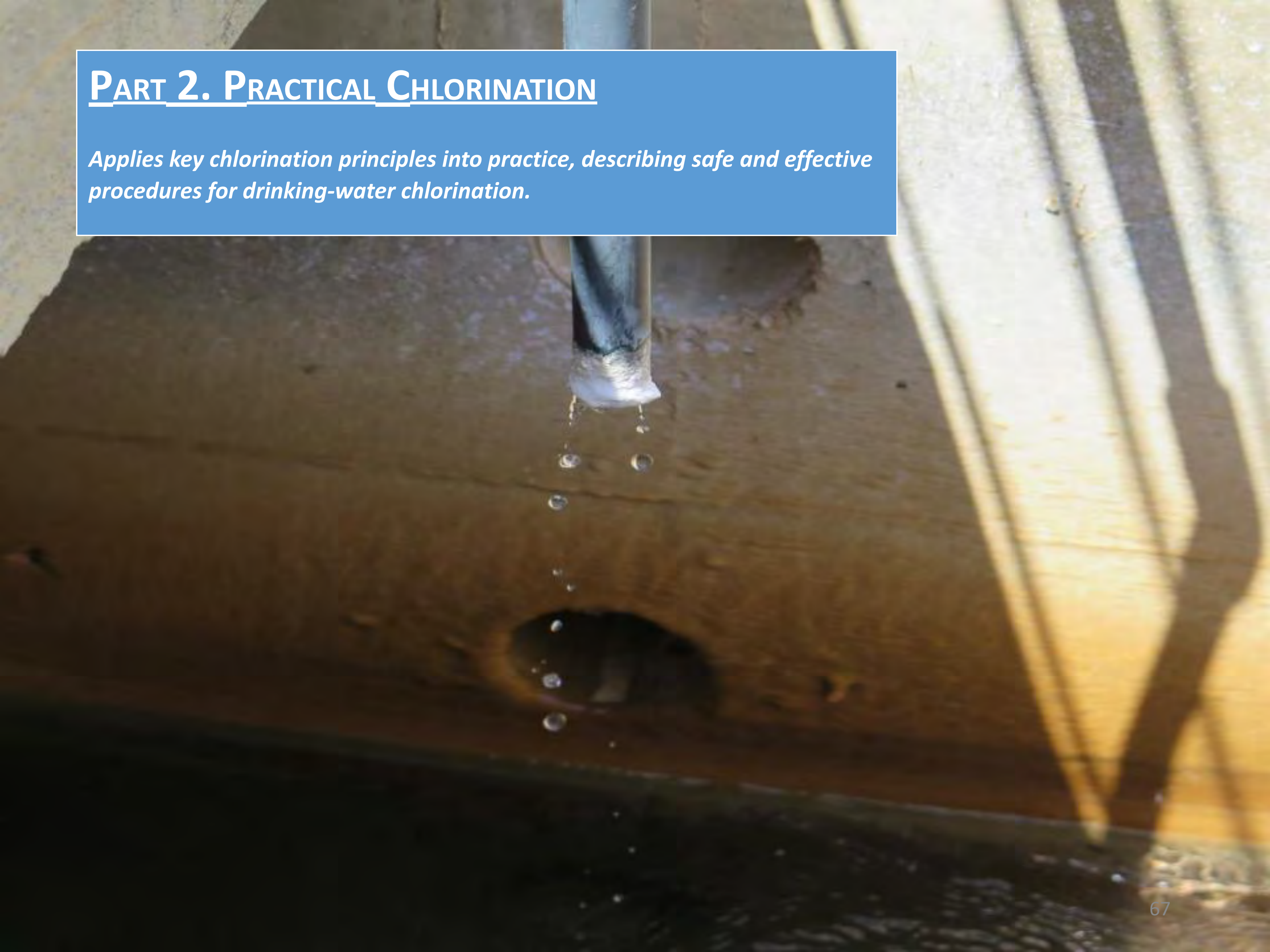
Summary of the optimal conditions required for effective chlorination

A minimum residual chlorine concentration of 0.2 mg/L must always be maintained to the point of consumer delivery

The residual chlorine concentration during distribution to the point of delivery should aim to be between <u>0.2 to 0.5 mg/L</u>

- ⇒ **may need to be higher than 0.5 mg/L in particular circumstances to ensure that a minimum residual chlorine concentration of 0.2 mg/L is always maintained**

The concentration of chlorine in water supplied to consumers should always be <u><5 mg/L</u>



Part 2. Practical Chlorination

Applies key chlorination principles into practice, describing safe and effective procedures for drinking-water chlorination.

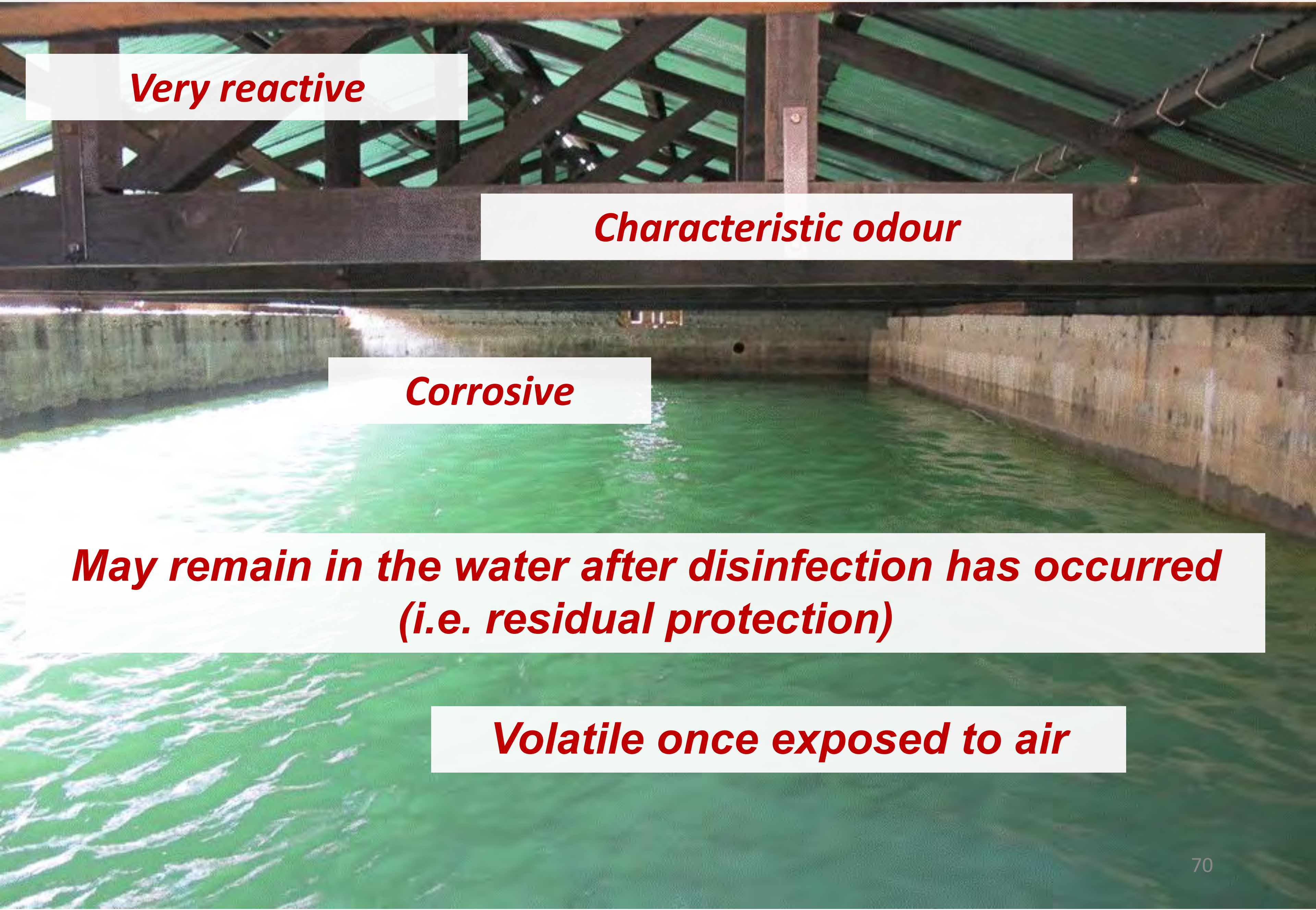
Contents

Contents

Part 2. Practical Chlorination

- **Safe handling and storage of chlorine**

*Remember…*Properties of chlorine



Very reactive

Characteristic odour

Corrosive

May remain in the water after disinfection has occurred (i.e. residual protection)

Volatile once exposed to air

Safe handling and storage of chlorine powder & liquid

Contact with concentrated forms of chlorine may result in irritation, chemical burns and even death

=> contact includes clothes, skin, eyes, mouth and inhalation into the lungs

=> Protecting the health and safety of staff is critical

All staff in contact with chlorine must receive basic training in:

1. **the required personal protective equipment (PPE)**
2. **precautions to be exercised when handling and storing different forms of chlorine, alongside**
3. **basic first-aid measures in the event of accidental contact**

Chlorine powder: Protective personal equipment required for handling

- **Wear gloves**


GLOVES

- **Wear overalls**


OVERALLS

- **Wear a dust mask**


DUST MASK

- **Wear safety glasses**


SAFETY GLASSES

Photo credit: Shutterstock.com

Chlorine liquid: Protective personal equipment required for handling

- Wear gloves

- Wear overalls

- Wear a face shield

Any enclosed building used for storage or preparation of chlorine should always be well ventilated.

If chlorine aerosols, mists, vapours or dust are not adequately controlled by ventilation, appropriate respiratory protection should be considered.

Powder & liquid chlorine may lose strength over time

For example…

New bag
35 % chlorine

0 months → 12 months

Old bag
e.g. 30 % chlorine

Powder & liquid chlorine may lose strength over time

Chlorine liquid solutions are generally less stable than chlorine powder (i.e., lose strength more quickly)

Type of chlorine (approx. % active chlorine concentration)		**Loss of initial active chlorine concentration (%)[1, 2, 3]**
Chlorine powder	Bleaching powder (35 %)	5 to 18 % after 40 days
	High test hypochlorite (70 %)	
Chlorine liquid	Sodium hypochlorite (15 %)	50 % after 100 days
	Sodium hypochlorite (10 %)	50 % after 220 days
	Sodium hypochlorite (5 %)	50 % after 790 days

Source:

[1]World Health Organisation. Calcium hypochlorite. Fact Sheet 2.19. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_19.pdf?ua=1 visited on 13 July, 2015.

[2]World Health Organisation. Sodium hypochlorite. Fact Sheet 2.20. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_20.pdf?ua=1 visited on 13 July, 2015.

[3]American Water Works Association (2006). Chlorination/chloramination practices and principles. AWWA Manual M20. 2nd Edn. Colorado, United States of America.

Powder & liquid chlorine may lose strength over time

May have important implications for water quality:

- ⇒ **if the chlorine powder or liquid is less concentrated, the risk of chlorine under-dosing may exist (i.e., not adding enough chlorine for effective disinfection)**
  - ⇒ **may present a microbiological water quality risk**

Appropriate chlorine storage practices must be in place to:

1. ***minimize the rate and extent of chorine degradation during storage, and***
2. ***protect staff safety***

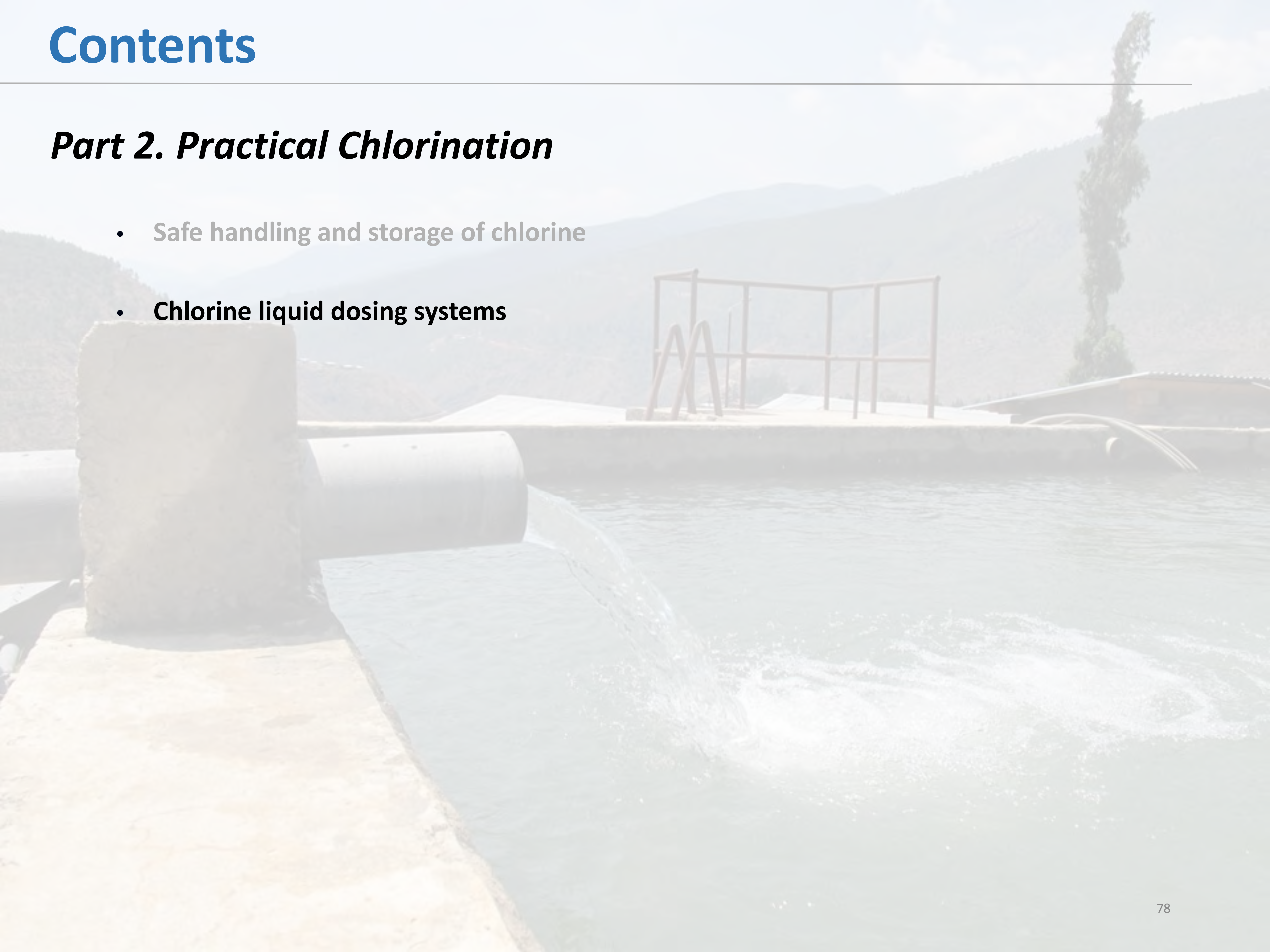
Chlorine powder and liquid: Appropriate storage practices

- **Store in a cool, dry, well ventilated place in air-tight containers**
- **Store away from sunlight**
- **Do not store for excessive periods of time (i.e., many months, years)**
- **Store in chlorine resistant containers**
- **Keep containers closed/sealed when not in use**
- **Check for container leaks/spills regularly**
- **Avoid contact and breathing in chlorine powder dust or chlorine liquid splashes/mists/aerosols**
- **Always mark and date new chlorine stock individually**
- **Use ‘*First In First Out’* stock management principles**

Contents

Part 2. Practical Chlorination

- Safe handling and storage of chlorine
- **Chlorine liquid dosing systems**



Chlorine liquid dosing systems

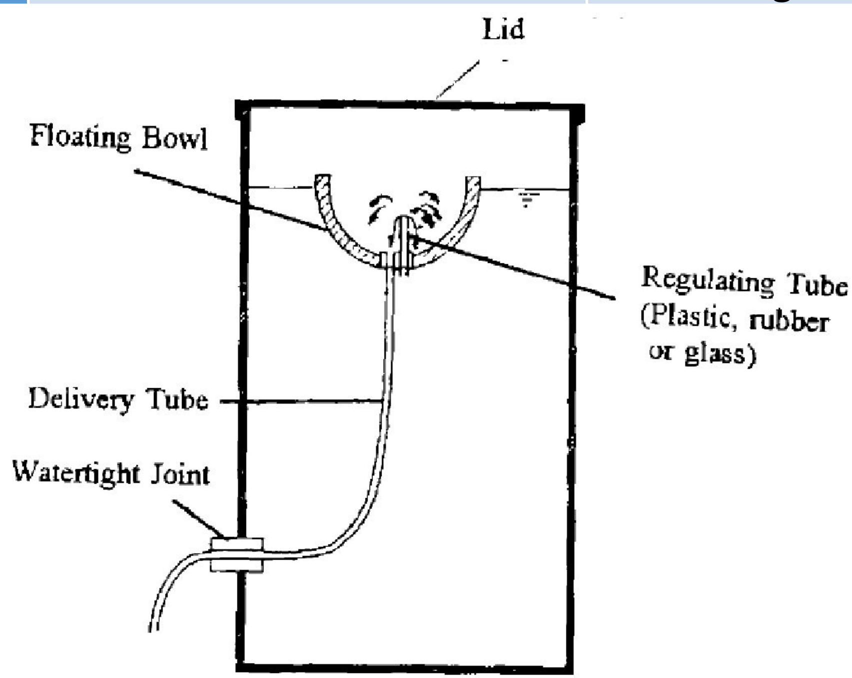
Used to dose chlorine liquid into the drinking-water

<u>Two options:</u>

1. **Non-pump-based systems (e.g., gravity)**
2. **Pump-based systems**

1. Non-pump based dosing systems

System[1]	Basis	Comments
Drip-feed chlorinators	**Feeds a constant rate of drops of chlorine liquid solution using a constant head device to maintain the drip feed**	**- Assume constant water flow rate (inaccurate dosing if flow rate changes)** **- Suitable for small supplies** **- Risk of siphoning must be managed**

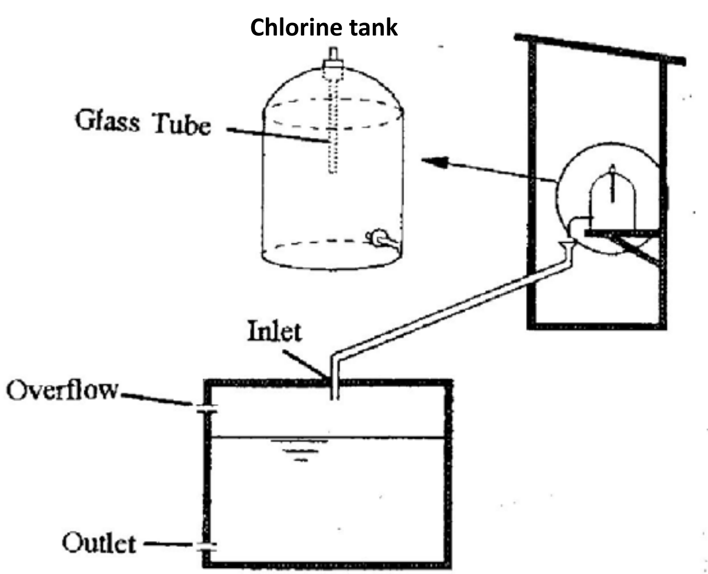


[1]World Health Organisation. Dosing hypochlorite solutions. Fact Sheet 2.22. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_22.pdf?ua=1 visited on 12 August, 2015.

Credit: World Health Organization

1. Non-pump based dosing systems

System[1]	Basis	Comments
Constant head aspirator	**Drips a constant rate of chlorine liquid solution using an aspirator and glass tube**	- **Simple, robust device** - **Durable if given appropriate basic maintenance** - **Easy installation** - **Coarse and fine drip-rate control possible** - **Assume constant water flow rate (inaccurate dosing if flow rate changes)**

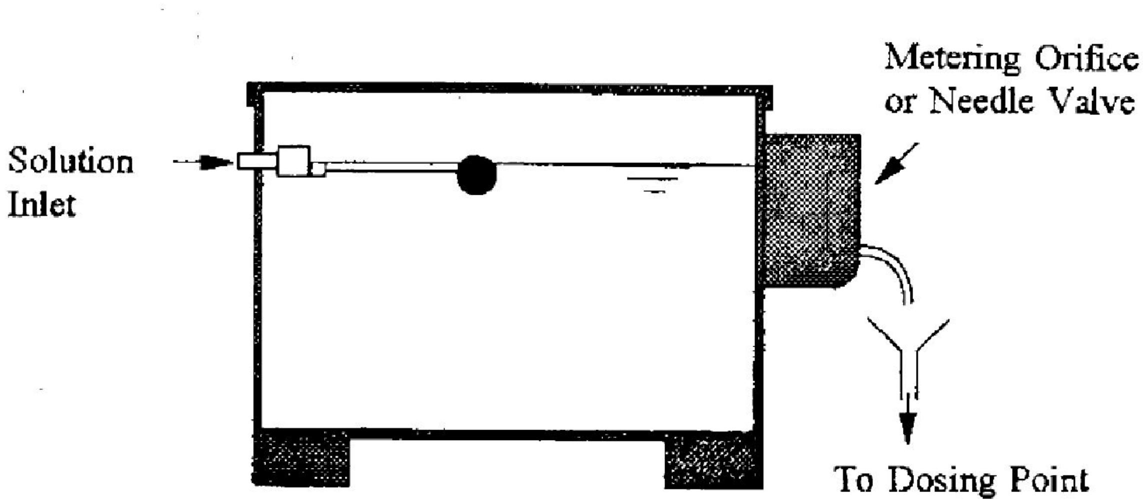


[1]World Health Organisation. Dosing hypochlorite solutions. Fact Sheet 2.22. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_22.pdf?ua=1 visited on 12 August, 2015.

Credit: World Health Organization

1. Non-pump based dosing systems

System[1]	Basis	Comments
Gravity feeder	**Relies on gravity and a metering orifice/valve to control the flow of chlorine liquid solution**	**- Requires a second tank and ball valve to maintain constant head pressure**



[1]World Health Organisation. Dosing hypochlorite solutions. Fact Sheet 2.22. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_22.pdf?ua=1 visited on 12 August, 2015.

Credit: World Health Organization

1. Non-pump based dosing systems

Lower cost

Simple to operate and maintain (no mechanical parts, servicing)

Not suitable for larger capacity water supply systems

Less accurate and less operational control

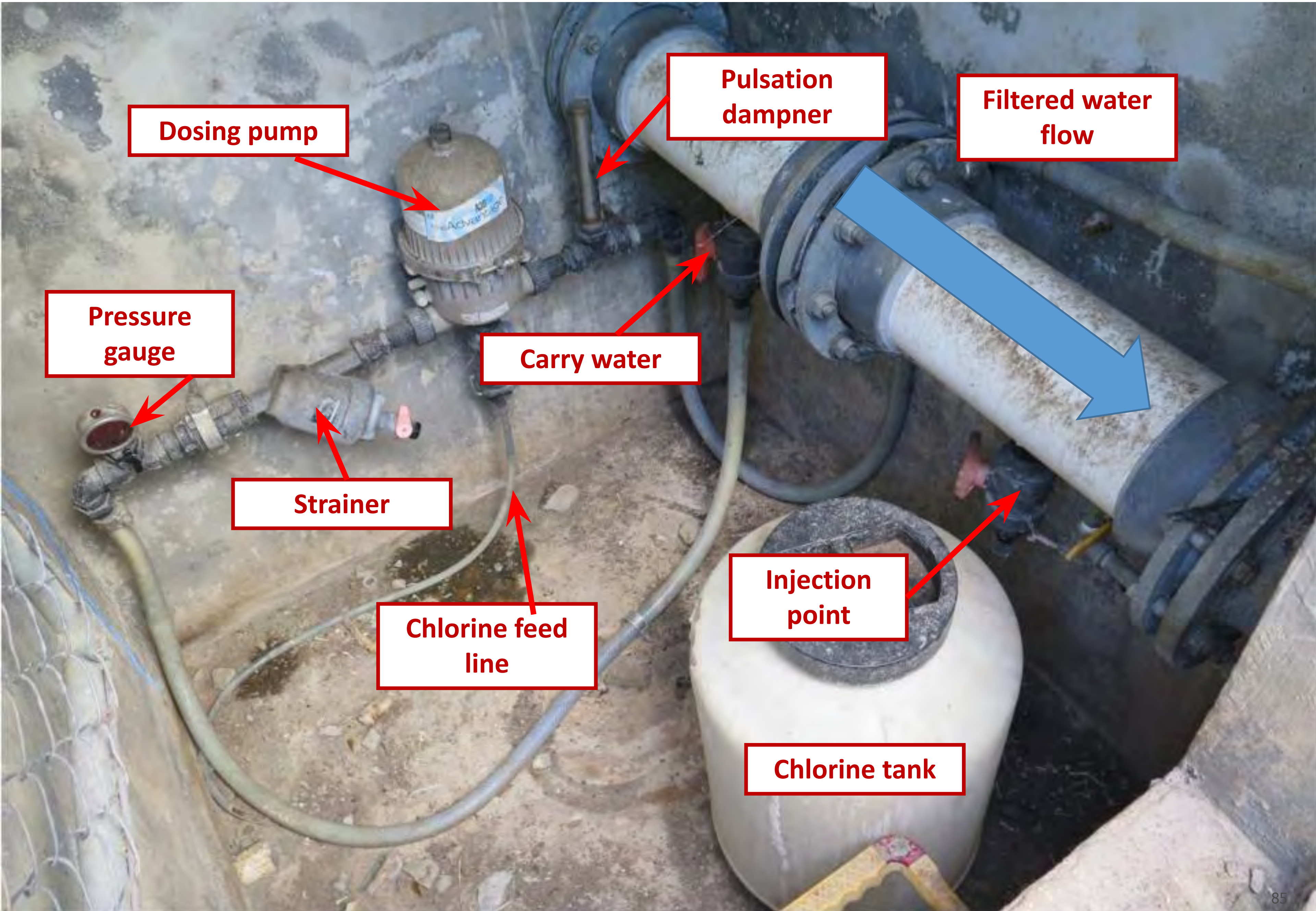
=> greater risk of chlorine under-/over-dosing

Suitable for small supplies, limited resource settings

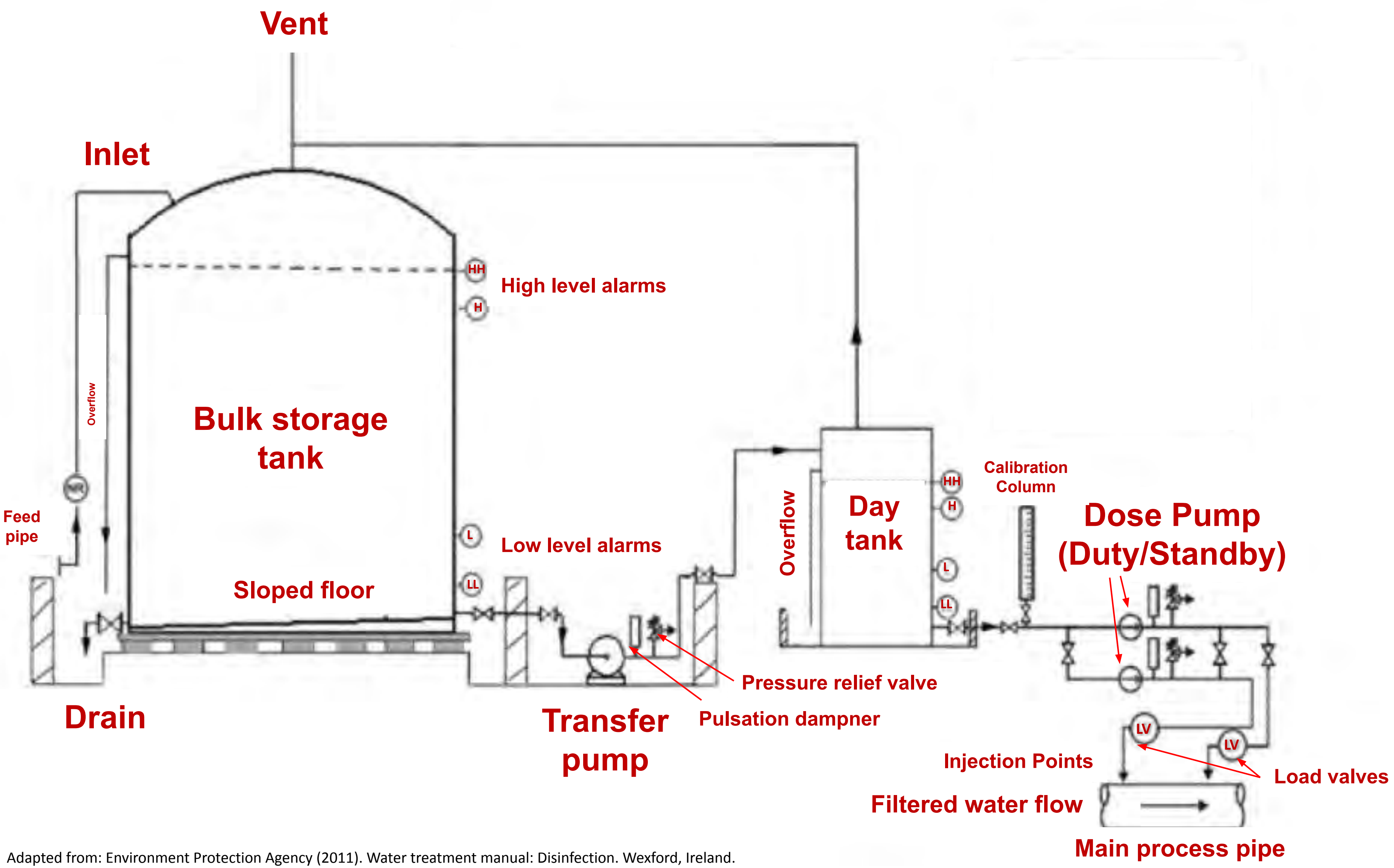
2. Pump-based dosing systems

Vary in their complexity and design….

2. Pump-based dosing systems: More basic



2. Pump-based dosing systems: More advanced



Adapted from: Environment Protection Agency (2011). Water treatment manual: Disinfection. Wexford, Ireland.

Credit: Environment Protection Agency, Ireland

2. Pump-based dosing systems

Allow much greater accuracy and operational control

- ⇒ may be linked to control signals (e.g. flow-paced, residual trim and associated alarming)
- ⇒ less risk of chlorine under-/over-dosing

More costly

Require maintenance, servicing and parts

- ⇒ may require specialised technician and supply chain for parts

Recommended where resources permit

Contents

Part 2. Practical Chlorination

- Safe handling and storage of chlorine
- Chlorine liquid dosing systems
- **Chlorine dosing calculations**
    - *How to calculate the chlorine demand*

Remember….Chlorine demand

Reaction between chlorine and any organic and inorganic material (*chlorine reactive substances*) present in the water

⇒ **During these reactions, chlorine is consumed**

⇒ **Residual chlorine in the water decreases**

Important to understand the chlorine demand of the raw (untreated) water to optimise the chlorine dose

How to calculate the chlorine demand (Eq. 1)

Chlorine Demand (mg/L) = Actual Chlorine Dose (mg/L) - Total Residual Chlorine (mg/L)

Example:

⇒ **If the actual chlorine dose is 3 mg/L**

⇒ **The total residual chlorine is 1 mg/L (after 30 minutes contact time), then using Eq. 1:**

Chlorine Demand (mg/L) = 3 mg/L - 1 mg/L

= 2 mg/L

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Part 2. Practical Chlorination

- Safe handling and storage of chlorine
- Chlorine liquid dosing systems
- **Chlorine dosing calculations**
  - *How to calculate the chlorine demand*
  - *How to calculate the Ct value*

Remember…. Ct value

Ct is calculated as follows:

Residual chlorine concentration (C) x Contact time (t)

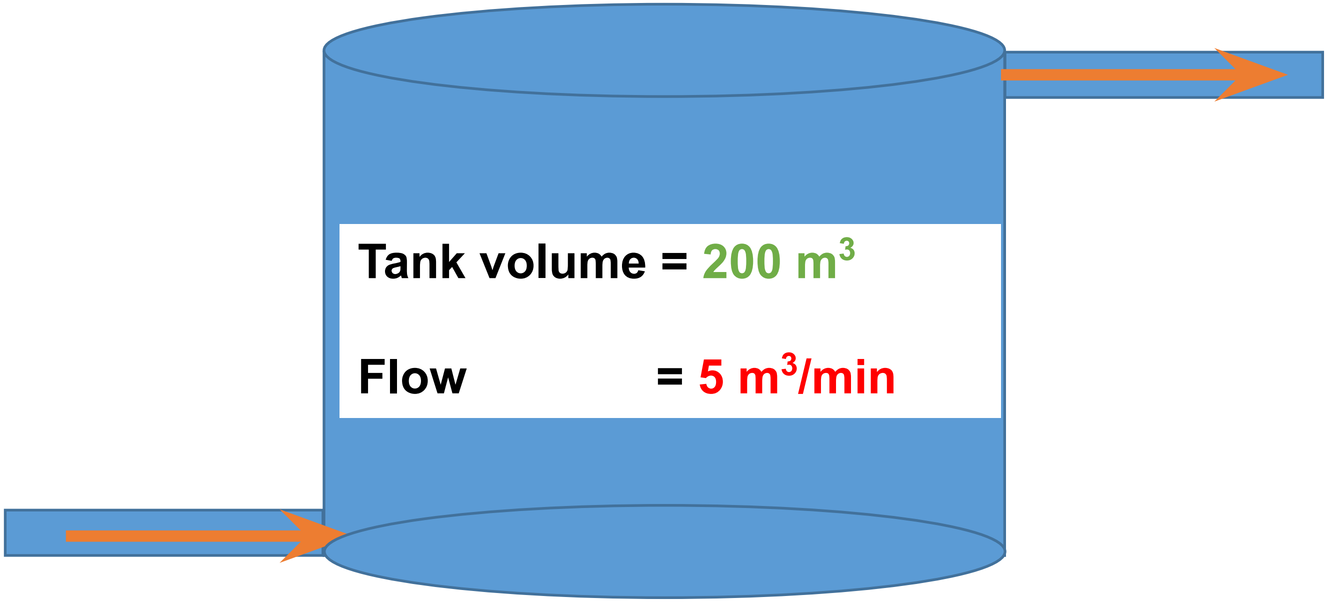
<u>Where:</u>

Residual chlorine: **Concentration of residual chlorine (in mg/L)**

Contact time: ***Amount of time (in minutes) there is contact between the chlorine and the water (e.g. detention time in a storage tank, reservoir, or pipe)***

How to calculate the detention time for a storage

Detention time (min) = Storage volume (m^3) ÷ Flow (m^3/min)



Detention time = 200 m^3 ÷ 5 m^3/min

= 40 min

How to calculate the Ct value (Eq. 2)

Ct (min.mg/L) = Residual chlorine concentration (mg/L) x Contact time (min)

Example:

⇒ **Residual chlorine concentration is 0.5 mg/L**

⇒ **Tank has a detention time of 40 minutes, then using Eq. 2:**

Ct (min.mg/L) = 0.5 mg/L x 40 min

= 20 min.mg/L

Minimum recommended Ct value

WHO[1] recommends a minimum contact time of 30 minutes where the residual chlorine is 0.5 mg/L and the pH is <8

(i.e., 15 min.mg/L)

However, Ct values should be determined on a site specific basis, considering:

- **the temperature of the water**
- **the pH of the water**
- **turbidity of the water**
- **‘short-circuiting’ within the storage (that is, the potential for preferential flow and reduced mixing/detention time)**

A more detailed example for accurately determining the minimum required Ct value using Ct tables is presented in Toolbox C of the accompanying guide

[1] World Health Organization (2011). Guidelines for Drinking-water Quality. 4th Edn. Geneva, Switzerland.

Contents

Part 2. Practical Chlorination

- Safe handling and storage of chlorine
- Chlorine liquid dosing systems
- **Chlorine dosing calculations**
  - *How to calculate the chlorine demand*
  - *How to calculate the Ct value*
  - *How to calculate the required chlorine dose*

How to calculate the required chlorine dose (Eq. 3)

Required Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Desired Residual Chlorine (mg/L)

<u>Example:</u>

- ⇒ **The chlorine demand is known to be 2 mg/L**
- ⇒ **The desired residual chlorine is 1 mg/L, then using Eq. 3:**

Required chlorine dose (mg/L) = 2 mg/L + 1 mg/L

= 3 mg/L

Contents

Part 2. Practical Chlorination

- **Safe handling and storage of chlorine**
- **Chlorine liquid dosing systems**
- **Chlorine dosing calculations**
  - *How to calculate the chlorine demand*
  - *How to calculate the required chlorine dose*
  - *How to calculate the amount of chlorine powder required to make a chlorine liquid solution*

Preparing chlorine liquid from chlorine powder

Establish which type of chlorine powder is in use:

1. bleaching powder – typically 35 % active chlorine, or
2. high test hypochlorite typically 70 % active chlorine

=> if unsure, contact supplier or manufacturer

Consider the age and storage conditions of the chlorine powder

⇒ concentration of active chlorine in the chlorine powder may be less than expected if old stock is in use and/or stock has been stored inappropriately

Preparing chlorine liquid from chlorine powder

Determine what concentration you wish to prepare the chlorine liquid solution:

- ⇒ **typically chlorine liquid solutions are made between 1 and 5 % active chlorine**

- ⇒ **higher concentrations of liquid solutions may be prepared in certain circumstances (e.g., pump or bulk storage capacity limitations)**
  - **may result in accumulation of undissolved sediment (or ‘sludge’) from inert material present in the powder (risk of blockages)**
  - **requires appropriate settling time for undissolved sediment and decanting**

⇒ **Appropriate <u>concentration</u> and <u>volume</u> of chlorine liquid solution to be prepared must be determined on a specific basis**

How to calculate the required amount of chlorine powder (Eq. 4)

Weight of chlorine powder (mg/L) =

$$\frac{1\,000 \times \text{Volume of chlorine liquid required (L)} \times \text{Desired chlorine liquid concentration (\%)}}{\text{Active chlorine concentration in the chlorine powder (\%)}}$$

Example:

⇒ Require 500 L of chlorine liquid solution

⇒ Require chlorine liquid concentration to be 2 % active chlorine

⇒ Using bleaching powder (35 % active chlorine), then using Eq. 4:

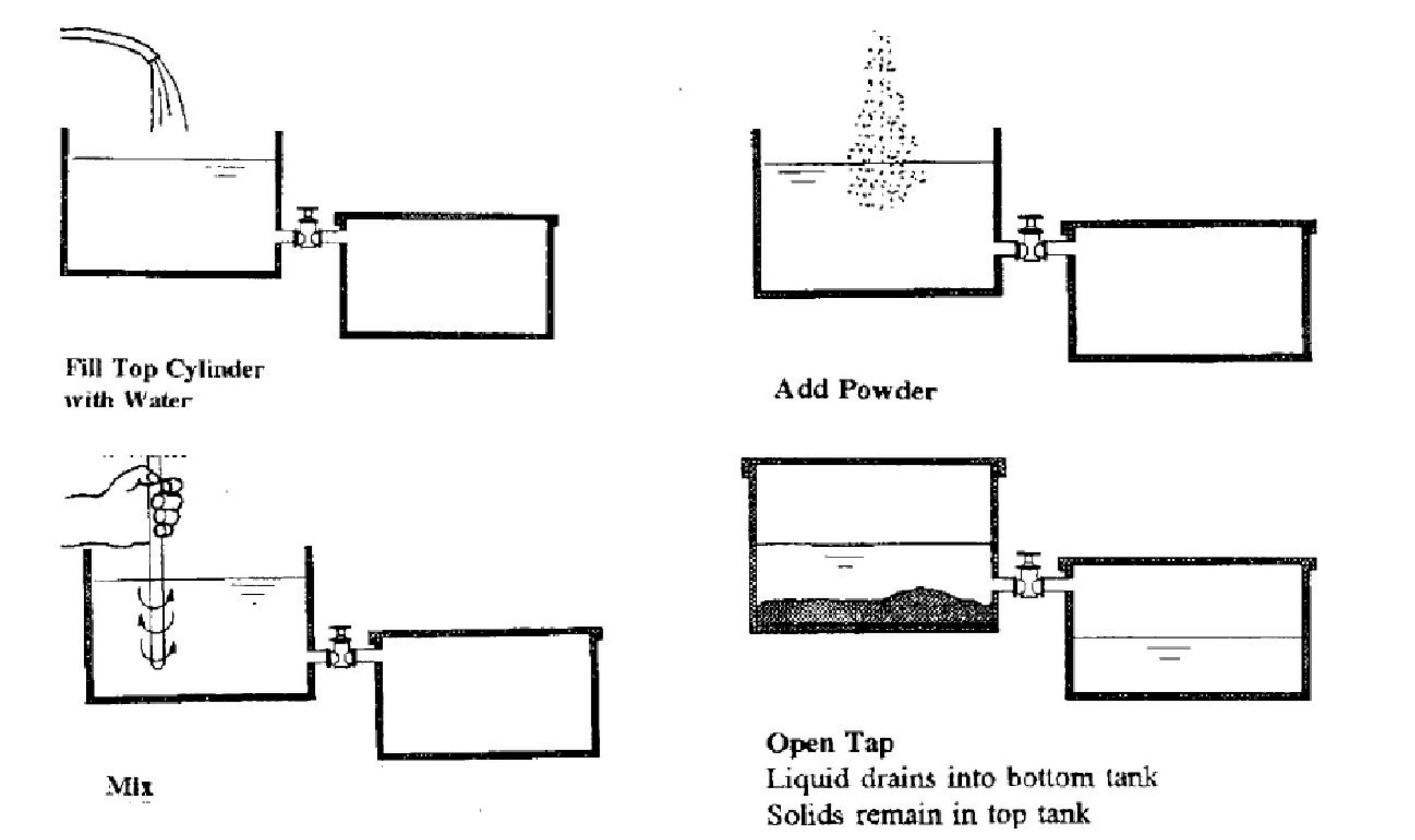
$$\text{Weight of chlorine powder (mg/L)} = \frac{1\,000 \times 500\text{ L} \times 2\,\%}{35\%}$$

= 28 571 g (or 28.6 kg) per 500 L of water

Preparing chlorine liquid from chlorine powder

Generally require two containers:

1. **One for mixing and settling of undissolved sediment (e.g., up to 24 hours settling time)**
2. **One for decanting settled solution into for storage and dosing**



World Health Organisation. Calcium hypochlorite. Fact Sheet 2.19. http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_19.pdf?ua=1 visited on 13 July, 2015.

Summary of Steps for Preparing Chlorine Liquid from Chlorine Powder

1. Determine what strength chlorine powder you are using	• Bleaching powder ~35 % active chlorine, or • High test hypochlorite ~ 70 % active chlorine
2. Determine the concentration you want the chlorine liquid solution to be	• Typically liquid chlorine solutions between 1 to 5 % active chlorine is used • May be higher in certain situations
3. Determine how much chlorine powder must be added to prepare the desired chlorine solution	• Determine the total volume of liquid chlorine solution required • Calculate amount of chlorine powder required for this volume using Equation 4
4. Mix chlorine powder in the desired volume of water in an appropriate container	• Allow sufficient time for the undissolved powder to settle • Pour off (decant) the liquid chlorine solution • Ready to use ☺

Contents

Part 2. Practical Chlorination

- **Safe handling and storage of chlorine**
- **Chlorine liquid dosing systems**
- **Chlorine dosing calculations**
  - *How to calculate the chlorine demand*
  - *How to calculate the Ct value*
  - *How to calculate the required chlorine dose*
  - *How to calculate the amount of chlorine powder required to make a chlorine liquid solution*
  - *How to calculate the chlorine dose rate*

Chlorine dose rate

'*Chlorine dose rate*' means how much chlorine liquid solution you are adding to the water over time

May be measured in various ways

- ⇒ mL per second
- ⇒ mL per minute
- ⇒ L per hour

How to calculate the chlorine dose rate (Eq. 5)

$$\text{Chlorine Dose Rate (mL/h)} = \frac{\text{Required chlorine dose (mg/L)} \times \text{Treated water flow rate } (m^3/h)}{\text{Chlorine liquid concentration (\%)} \div 100}$$

Example:

⇒ Require 3 mg/L chlorine dose (see Eq. 3)

⇒ Flow rate at the water treatment plant is 100 cubic meters per hour (100 m^3/h)

⇒ Chlorine liquid concentration is 2 % (see Eq. 4), then using Eq. 5:

$$\text{Chlorine Dose Rate (mL/h)} = \frac{3 \text{ mg/L} \times 100 \text{ } m^3/h}{2 \% \div 100}$$

$$= 15\,000 \text{ mL/h (or 250 mL/min)}$$

How to calculate the actual chlorine dose (Eq. 6)

May rearrange Eq. 5 to determine actual chlorine dose; useful for determining chlorine demand (Eq. 1)

Actual Chlorine Dose (mg/L) =

$$\frac{[\text{Chlorine dose rate (mL/h)} \times \text{Chlorine liquid concentration (\%)}] \div 100}{\text{Flow rate } (m^3/h)}$$

Example:

⇒ **Chlorine dose rate is 6 000 mL/h**

⇒ **Chlorine liquid concentration is 2 % (see Eq. 4)**

⇒ **Flow rate at the water treatment plant is 100 cubic meters per hour (100 m^3/h) then using Eq. 6:**

$$\text{Actual Chlorine Dose (mg/L)} = \frac{(6\,000 \text{ mL/h} \times 2\ \%) \div 100}{100\ m^3/h}$$

$$= 1.2 \text{ mg/L}$$

Adjusting the chlorine dose

1) **Always adjust stepwise (i.e., in small increments)**

⇒ **do not make large adjustments all at once or you risk over-/under-dosing**

2) **Always consider time taken for water to turn-over in the tank or pipe before additional adjustments are made**

⇒ **e.g. may take 2 days for higher chlorinated water to reach a particular monitoring point in the distribution system**

⇒ **make sure the tank/pipe/section of network is completely replenished with 'new' water with the adjusted chlorine dose**

3) **Increase the frequency of chlorine monitoring following:**

⇒ **changes in the chlorine dose**

⇒ **preparation/delivery of a new batch of chlorine liquid**

Chlorine Dosing Cheat Sheet

For a quick and easy way to perform chlorine dosing calculations, see the '*Chlorine Dosing Cheat Sheet*' described in Toolbox B

- ⇒ **prompts you to input the required information**
- ⇒ **automatically performs the calculation**

Example:

How to determine the weight of chlorine powder required to prepare a chlorine liquid solution

1. Input the volume of liquid chlorine solution required in litres (L)
2. Input the desired active chlorine concentration in the final liquid chlorine solution in percentage (%)
3. Input the concentration of active chlorine in the chlorine powder in percentage (%)

Where possible, test the strength of the chlorine powder before use; if not possible to do this, check the estimated concentration with the manufacturer/supplier

In general, if using bleaching powder - use 35 %; if using high test hypochlorite - use 70 %

Total volume of liquid chlorine solution required	1	L
Desired concentration of final chlorine liquid solution	1	%
Active chlorine concentration in the chlorine powder	35	%
Weight of chlorine powder required	29	g
	or	
	0.029	kg

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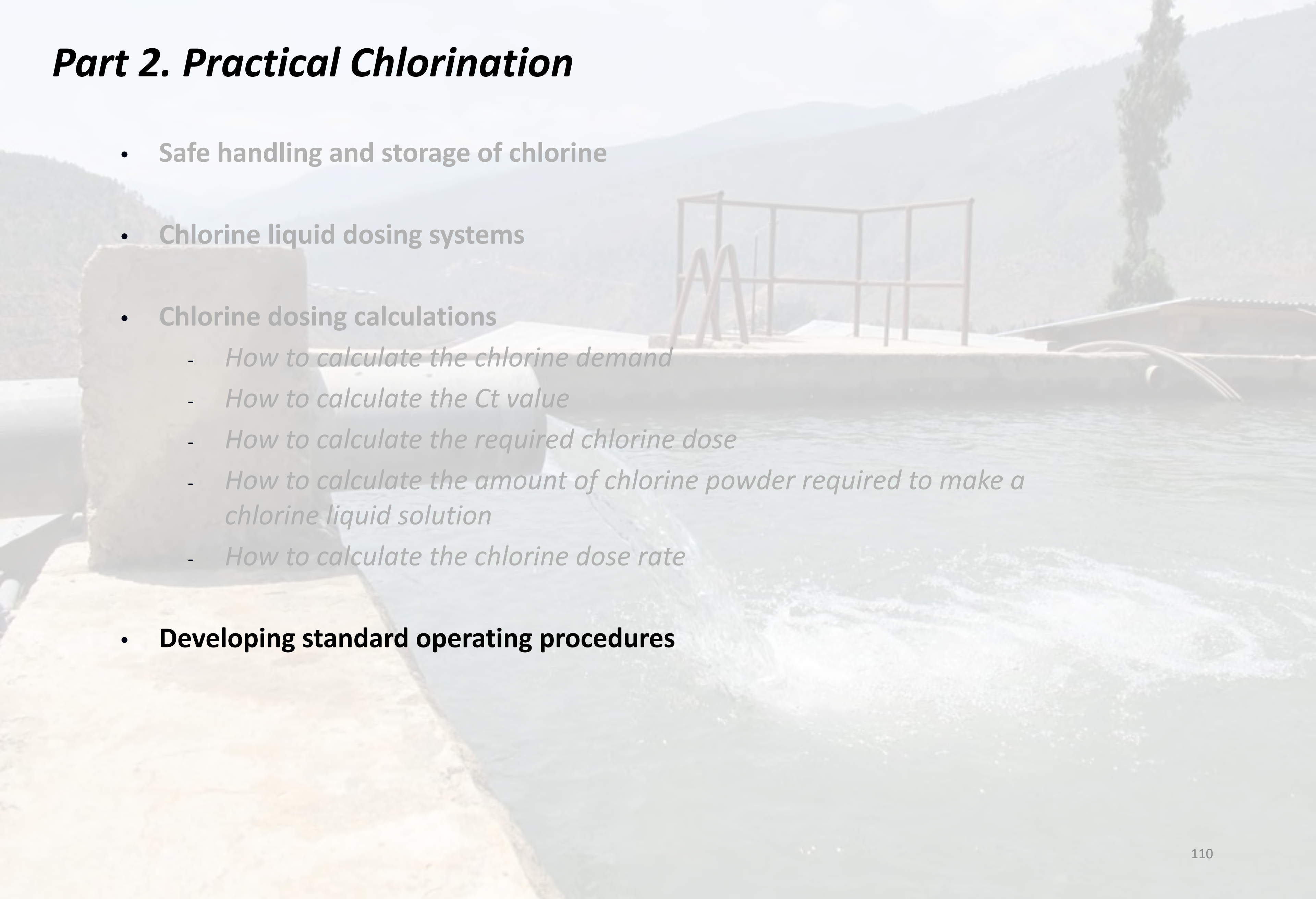


Part 2. Practical Chlorination

Standard operating procedures (SOPs)

To be developed for any operational tasks that are performed routinely, including chlorination

Help operational staff perform duties safely, correctly and with consistency

Include important safety information

Examples of information that should be included within SOPs for chlorination….

Suggested SOPs for chlorination

1. **Calculating the weight of chlorine powder required to make a chlorine liquid batch**

2. **Preparing a batch of chlorine liquid from chlorine powder**

3. **Calculating the chlorine dose**

=> suggested content for each of this is presented on the following slides…

SOP: Calculating the weight of chlorine powder required to make a chlorine liquid batch

- **PPE required for safe completion of the task**
- **The type of chlorine powder to be used (e.g., bleaching powder or high test hypochlorite)**
- **The desired solution strength of the chlorine liquid being prepared (e.g., 1 % chlorine liquid solution)**
- **The volume of chlorine liquid solution to be prepared**
- **The calculation used to determine the weight of chlorine powder required**

=> For an example see Generic SOP 1 and 2 (Toolbox A)

SOP: Preparing a batch of chlorine liquid from chlorine powder

- PPE required for safe completion of the task
- The unit weight of chlorine powder required to prepare a batch of liquid chlorine (e.g., 35 g of bleaching powder per litre of water)
- The receptacle that the solution will be mixed in (e.g., dedicated concrete tank or a plastic container)
- The means by which the powder will be mixed with the water (e.g., a dedicated mixing device)
- The amount of settling time required following mixing and before use
- The appropriate chlorine storage conditions

=> For an example see Generic SOP 3 (Toolbox A)

SOP: Calculating the chlorine dose

- **PPE required for safe completion of the task**
- **The calculation used to determine the chlorine dose rate based on the strength of the chlorine liquid solution and the water treatment plant flow rate**
- **Precautions to be taken when adjusting the dose rate (including increased monitoring of the chlorine concentration in the drinking-water following adjustment)**

=> For an example see Generic SOP 4 (Toolbox A)

Other chlorination SOPs may include…

- **Chlorine stock management**
- **Operation and maintenance of chlorine dose pumps**
- **Emergency response procedure in the event of accidental human contact or release to the environment**
- **Emergency response procedure in the event of accidental human contact or release to the environment**

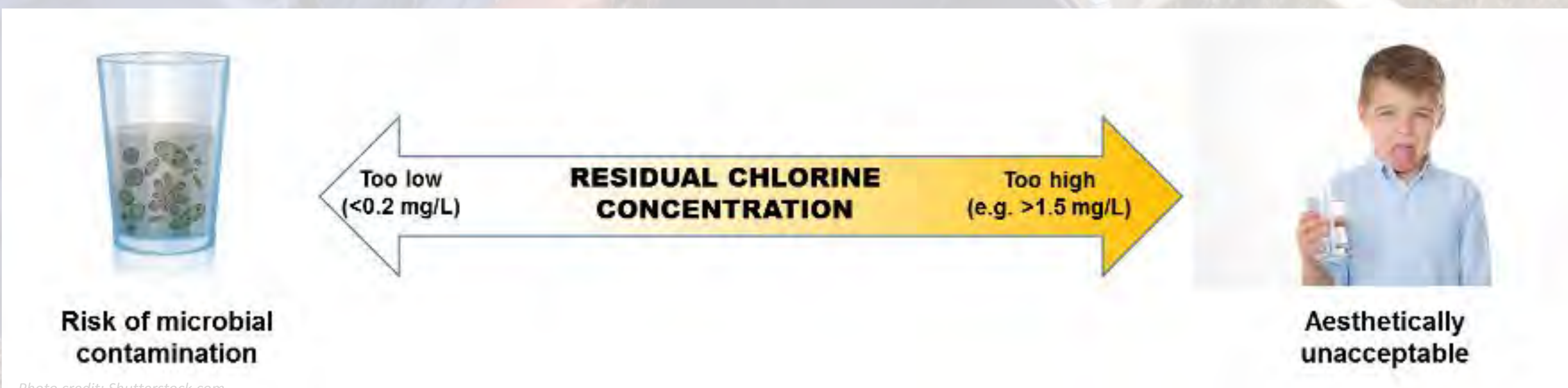
Contents

Part 2. Practical Chlorination

Chorine monitoring (operational monitoring)

Careful monitoring and optimization of the chlorine concentration through the water supply system is critical:

- ⇒ **ensures that sufficient chlorine is added to the water for adequate disinfection and residual protection from recontamination**
- ⇒ **minimizing risks of consumer acceptability issues (i.e., taste, odour)**

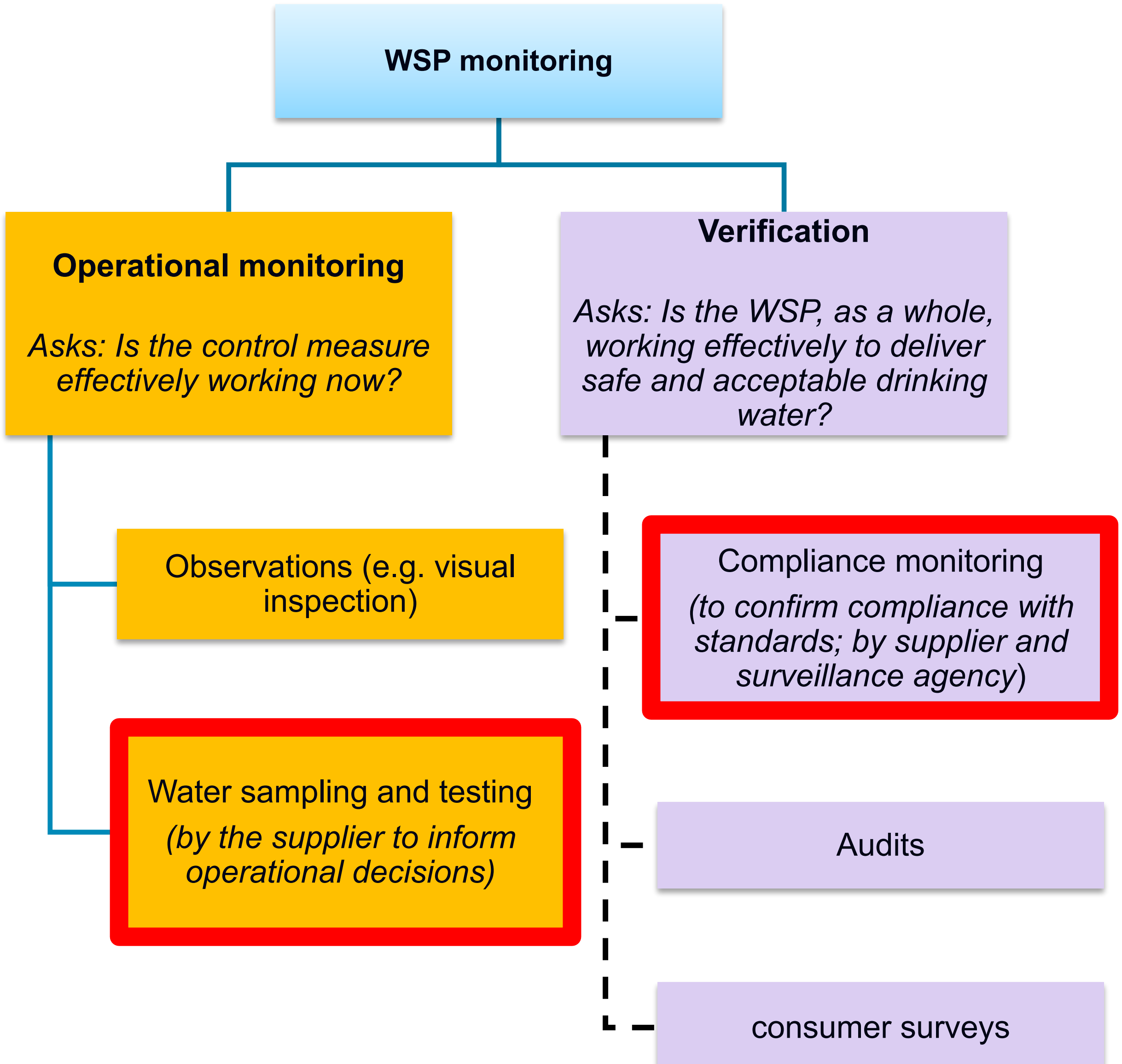


Chorine monitoring

Should be performed as part of ***Operational Monitoring***

- ⇒ simple, routine checks to confirm that the measures in place to manage water quality risk are operating effectively (i.e., ***control measures***)
- ⇒ ***critical limits*** determine the point at which the control measures is no longer working within an acceptable range
- ⇒ ***corrective actions*** are then required to restore correction functioning of the control measure and minimise the risk of unsafe water supply

Operational monitoring is different to verification monitoring



Acknowledgement: Darryl Jackson; Angella Rinehold

Examples of equipment for chorine monitoring

Chlorine test strips

Chlorine comparator

Chlorine meter

ACCURACY/RESOLUTION

$$$$$$$$$$$$

Photo credit: Shutterstock.com

Chorine testing equipment

Test Equipment	Cost	Accuracy/ Resolution	Advantages	Disadvantages
Chlorine test strips	M	L	- Easy to use, disposable - No calibration/servicing required	- Poor degree of resolution (e.g., may only measure in 0.5 mg/L increments) - Visual measurement (colour change); open to user interpretation - Requires supply chain for replacement strips
Chlorine comparator test kit	M	M	- Easy to use - Durable for field use - No calibration/servicing required	- Visual measurement (colour change); open to user interpretation - Requires reagents (DPD powder), supply chain
Chlorine meter	H	H	- High degree of resolution over a wide range (0.05 to 10 mg/L in 0.01 mg/L increments) - Easy to use	- Less durable for field use - Calibration/servicing required - Requires reagents, replacement parts (bulb), supply chain

L - Low; M - Medium; H - High.

Chorine monitoring

Chlorine monitoring locations in the distribution system should include:

- ⇒ **the start, middle and end of the distribution network**
- ⇒ **known water quality trouble spots (that is, where poor water quality has been historically found, such as the end-points of the network, low-flow areas and dead legs)**

Number of sample points and the frequency of sampling will differ depending on the specific circumstances of the water supply system

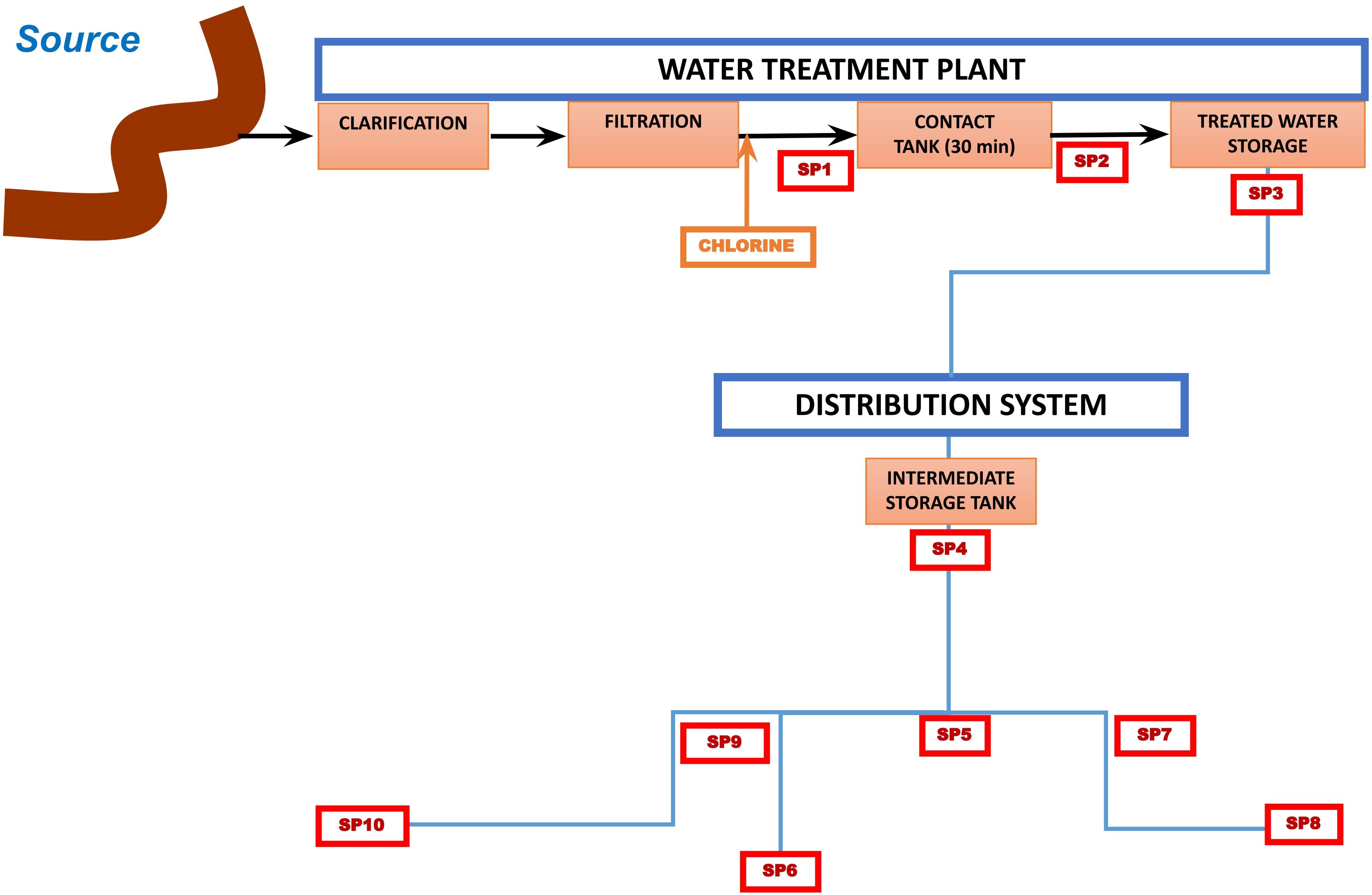
- ⇒ **should be sufficient to manage the risk of sub-optimal chlorination**

Chorine monitoring

Chlorine monitoring should generally occur (for sample point reference, see next slide):

- ⇒ **immediately after chlorine has been added to the water (dosed water; SP1)**
- ⇒ **after contact time has elapsed (SP2)**
- ⇒ **at the point of entry to the distribution system (SP3)**
- ⇒ **throughout the distribution system to the point of consumer delivery (including storage tanks, reservoirs; for example, SP4 to 10; Note - number of sample points will differ depending on the specific circumstances of the water supply system)**
- ⇒ **at a frequency that is appropriate to manage the risk of sub-optimal chlorine concentration in the particular drinking-water supply**

Example chorine monitoring locations in a water supply system



Chorine monitoring

Feedback of data from chlorine operational monitoring is essential to ensure that the chlorine dose is being optimized

Chlorine operational monitoring data will indicate if:

- ⇒ **Chlorine dose at the water treatment plant needs to be optimized**
- ⇒ **Potential changes in raw/treated water quality**
- ⇒ **Potential presence of contamination in storage or distribution**
- ⇒ **Likelihood of recontamination during delivery to consumer**

Contents

Chlorine summary…

Chlorine is added to water to kill microorganisms

=> kills <u>most</u> microorganisms in a short time

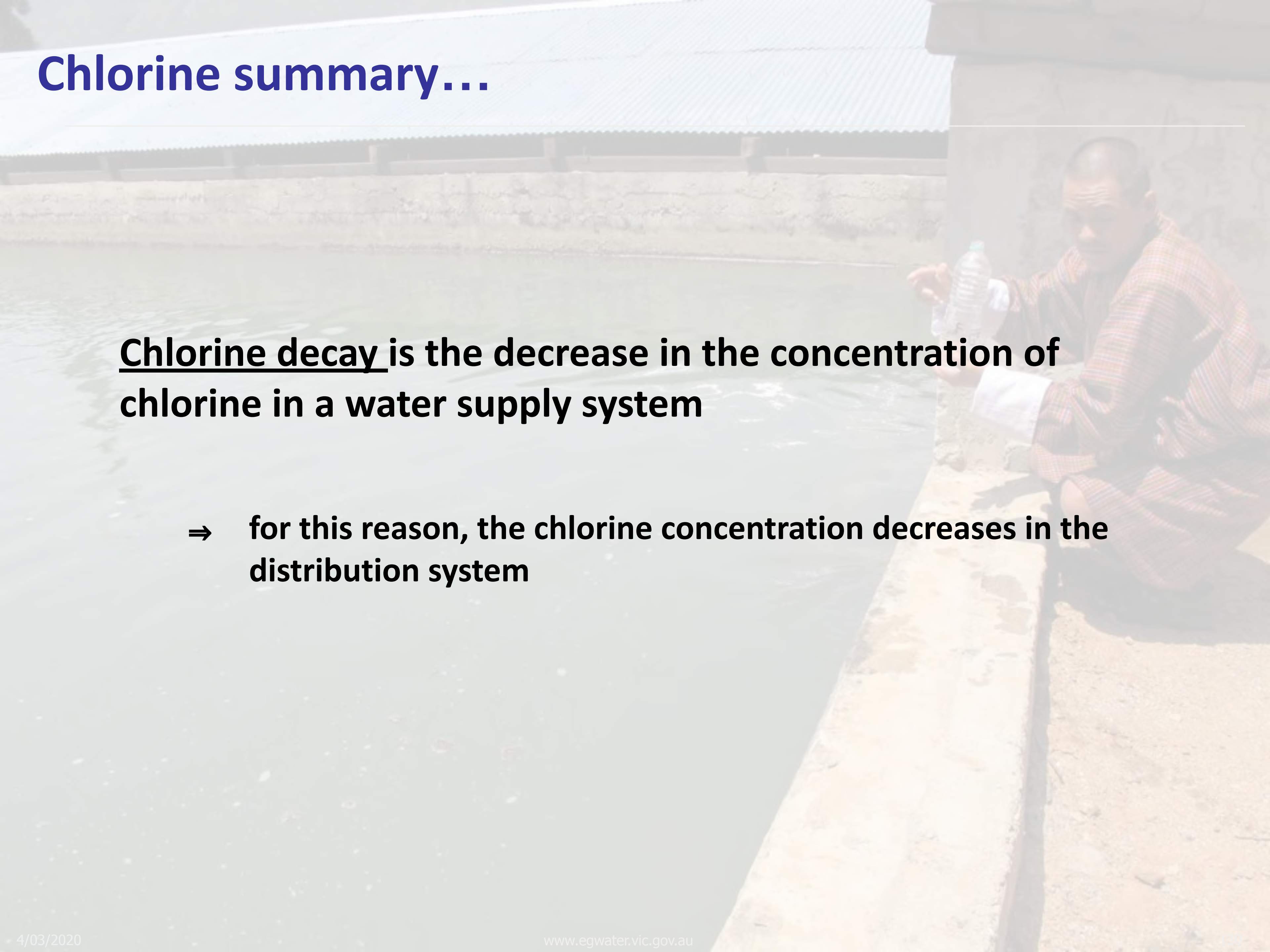
=> not all microorganisms will be killed by chlorine

Chlorine summary…

Chlorine is very reactive

- ⇒ **reacts with microorganisms, organic material, sediment, pipe material**

Chlorine summary…



<u>Chlorine decay</u> is the decrease in the concentration of chlorine in a water supply system

- ⇒ **for this reason, the chlorine concentration decreases in the distribution system**

Chlorine summary…

<u>Chlorine demand</u> indicates how much chlorine will be consumed during chlorine reactions

⇒ **helps inform what chlorine dose is required for effective disinfection**

⇒ **if water has <u>high</u> chlorine demand it <u>consumes</u> more chlorine and needs a <u>high</u> chlorine dose**

⇒ **if water has <u>low</u> chlorine demand it <u>consumes</u> less chlorine and needs a <u>low</u> chlorine dose**

Chlorine summary…

<u>Chlorine residual</u> is the concentration of free chlorine remaining <u>after</u> the chlorine demand has been satisfied and disinfection has taken place

- ⇒ critically important water quality parameter for public health
- ⇒ implies that there is residual protection from recontamination from microorganisms during storage/distribution
- ⇒ residual chlorine concentration should always be ≥0.2 mg/L at the point of delivery to the consumer

Chlorine summary…

<u>Chlorine contact time</u> is the amount of time required for effective disinfection to take place

- ⇒ **a minimum Ct value of 15 min.mg/L (where pH <8.0) is required in all cases**
- ⇒ **this is 30 minutes contact time with a residual chlorine concentration of 0.5 mg/L**
- ⇒ **minimum required Ct value should be determined on a case-by-case basis (see Appendix C of the accompanying manual)**

Chlorine summary…

Ct value is influenced by:

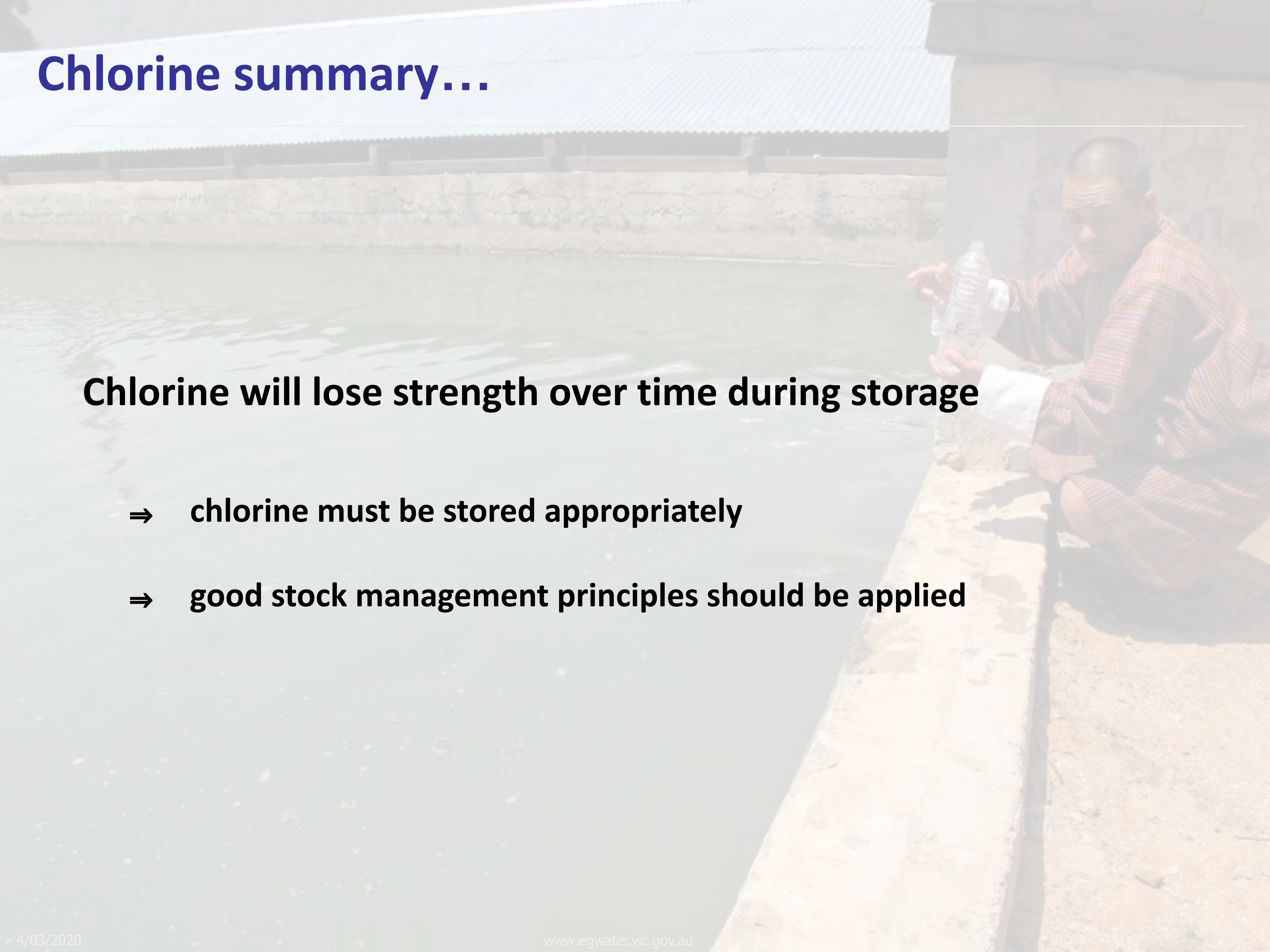
- ⇒ **pH**
- ⇒ **temperature**
- ⇒ **chlorine concentration**
- ⇒ **turbidity**

Chlorine summary…

All forms of chlorine are dangerous to handle

- ⇒ **must be handled safely**
- ⇒ ***<u>Powder</u>*: Overalls, gloves, safety glasses, dust mask**
- ⇒ ***<u>Liquid</u>*: Overalls, gloves and face shield**

Chlorine summary…



Chlorine will lose strength over time during storage

⇒ chlorine must be stored appropriately

⇒ good stock management principles should be applied

Chlorine summary…

Conditions required for effective disinfection

Turbidity: <1 NTU (lower where possible)

(where < 1 NTU is not possible, <5 NTU should be the aim; above 5 NTU, disinfection should still be practised, but higher chlorine doses or contact times will be required to inactivate harmful microorganisms)

pH: <pH 8.0

(Above pH 8.0, chlorination should still be practised but higher chlorine doses or contact times will be required to inactivate harmful microorganisms)

Minimum contact time: 30 minutes contact time with a minimum residual chlorine concentration of 0.5 mg/L, where the pH of the water is <pH 8.

Chlorine summary…

Once chlorination at the water treatment plant is complete, the residual chlorine concentration during distribution to the point of delivery should aim to be between <u>0.2 to 0.5 mg/L</u>.

⇒ **a minimum residual chlorine concentration of 0.2 mg/L must always be maintained at the point of delivery**

The concentration of chlorine in water supplied to consumers should always be <u><5 mg/L</u>

Summary…

For sections references, please refer to the accompanying guide

any
questions...

Photo credit: Shutterstock.com

Quiz

Multiple choice…..

Quiz

Q.1) Chlorine is added to water to:

a) ***Make it taste better***

b) ***Kill/inactivate harmful microorganisms***

c) ***Improve the pH***

d) ***Remove turbidity***

Quiz

Q.1) Chlorine is added to water to:

a) ***Make it taste better***

b) ***Kill/inactivate harmful microorganisms***

c) ***Improve the pH***

d) ***Remove turbidity***

Quiz

Q.2) Microorganisms may be found in:

- ***a) Soil***
- ***b) Water***
- ***c) Sewage***
- ***d) All of the above***

Quiz

Q.2) Microorganisms may be found in:

a) Soil

b) Water

c) Sewage

d) All of the above

Quiz

Q.3) Chlorine will kill/inactivate:

a) All microorganisms

b) Some microorganisms

c) Only bacteria

d) No microorganisms

Q.3) Chlorine will kill/inactivate:

a) ***All microorganisms***

b) ***Some microorganisms***

c) ***Only bacteria***

d) ***No microorganisms***

Quiz

Q.4) Over time, chlorine powder and liquid will:

a) ***Never lose strength***

b) ***lose strength***

c) ***Gain strength***

d) ***Combine to give chlorine gas***

Quiz

Q.4) Over time, chlorine powder and liquid will:

a) ***Never lose strength***

b) ***lose strength***

c) ***Gain strength***

d) ***Combine to give chlorine gas***

Quiz

Q.5) Chlorine will react with:

a) ***Microorganisms***

b) ***Other organic material***

c) ***Inorganic material***

d) ***All of the above***

Quiz

Q.5) Chlorine will react with:

a) Microorganisms

b) Other organic material

c) Inorganic material

d) All of the above

Quiz

Q.6) Due to chlorine decay, the concentration of chlorine during distribution will:

a) ***Increase***

b) ***Decrease***

c) ***Stay the same***

d) ***Fluctuate up and down***

Quiz

Q.6) Due to chlorine decay, the concentration of chlorine during distribution will:

a) ***Increase***

b) ***Decrease***

c) ***Stay the same***

d) ***Fluctuate up and down***

Quiz

Q.7) If water has high chlorine demand, it will:

a) ***Consume more chlorine***

b) ***Consume very little chlorine***

c) ***Consume no chlorine***

d) ***Produce chlorine***

Quiz

Q.7) If water has high chlorine demand, it will:

a) ***Consume more chlorine***

b) ***Consume very little chlorine***

c) ***Consume no chlorine***

d) ***Produce chlorine***

Quiz

Q.8) Chlorine residual is the concentration of chlorine:

a) ***Before chlorine demand has been satisfied***

b) ***After chlorine demand has been satisfied***

c) ***Equal to the total chlorine***

Quiz

Q.8) Chlorine residual is the concentration of chlorine:

a) ***Before chlorine demand has been satisfied***

b) ***After chlorine demand has been satisfied***

c) ***Equal to the total chlorine***

Quiz

Q.9) Chlorine contact time is the amount of time needed for:

a) Effective disinfection to occur

b) For chlorine concentration to decrease to zero

c) For chlorine to burn your skin

d) All of the above

Quiz

Q.9) Chlorine contact time is the amount of time needed for:

a) ***Effective disinfection to occur***
b) ***For chlorine concentration to decrease to zero***
c) ***For chlorine to burn your skin***
d) ***All of the above***

Quiz

Q.10) Chlorine contact time depends on the:

a) ***pH of the water***

b) ***Temperature of the water***

c) ***Chlorine concentration in the water***

d) ***All of the above***

Quiz

Q.10) Chlorine contact time depends on the:

a) pH of the water

b) Temperature of the water

c) Chlorine concentration in the water

d) All of the above

Quiz

Q.11) Chlorine disinfection works best when turbidity is:

- ***a) >1 NTU***
- ***b) <1 NTU***
- ***c) >5 NTU***
- ***d) Turbidity does not impact disinfection***

Quiz

Q.11) Chlorine disinfection works best when turbidity is:

a) ***>1 NTU***

b) ***<1 NTU***

c) ***>5 NTU***

d) ***Turbidity does not impact disinfection***

Quiz

Q.12) The residual chlorine concentration in the distribution network should always be:

a) Undetectable

b) <0.2 mg/L

c) ≥0.2 mg/L

d) >5 mg/L

Quiz

Q.12) The residual chlorine concentration in the distribution network should always be:

a) Undetectable

b) <0.2 mg/L

c) ≥0.2 mg/L

d) >5 mg/L

Quiz

Q.13) If the residual chlorine concentration is <0.2 mg/L in distribution samples, the water is:

a) ***Safe from recontamination by microorganisms***

b) ***At risk from recontamination by microorganisms***

c) ***Unpleasant taste and odor***

d) ***None of the above***

Quiz

Q.13) If the residual chlorine dose is <0.2 mg/L in the distribution network, the water is:

a) ***Safe from recontamination by microorganisms***

b) ***At risk from recontamination by microorganisms***

c) ***Unpleasant taste and odor***

d) ***None of the above***

Quiz

Q.14) The chlorine dose at the water treatment plant should always be:

a) ***1 mg/L***

b) ***<0.2 mg/L***

c) ***5 mg/L***

d) ***Sufficient to ensure effective disinfection and a chlorine concentration ≥0.2 mg/L to the point of consumer delivery***

Quiz

Q.14) The chlorine dose at the water treatment plant should always be:

a) 1 mg/L

b) <0.2 mg/L

c) 5 mg/L

d) Sufficient to ensure effective disinfection and a chlorine concentration ≥0.2 mg/L to the point of consumer delivery

Quiz

Q.15) For effective chlorination, the pH of the water should always be:

a) ***>pH 8.5***

b) ***<pH 8.5***

c) ***pH does not impact chlorination***

Quiz

Q.15) For effective chlorination, the pH of the water should always be:

a) ***>pH 8.5***

b) ***<pH 8.5***

c) ***pH does not impact chlorination***

DISAIN PENGOLAHAN LUMPUR
week 14
Genap 2025/2026

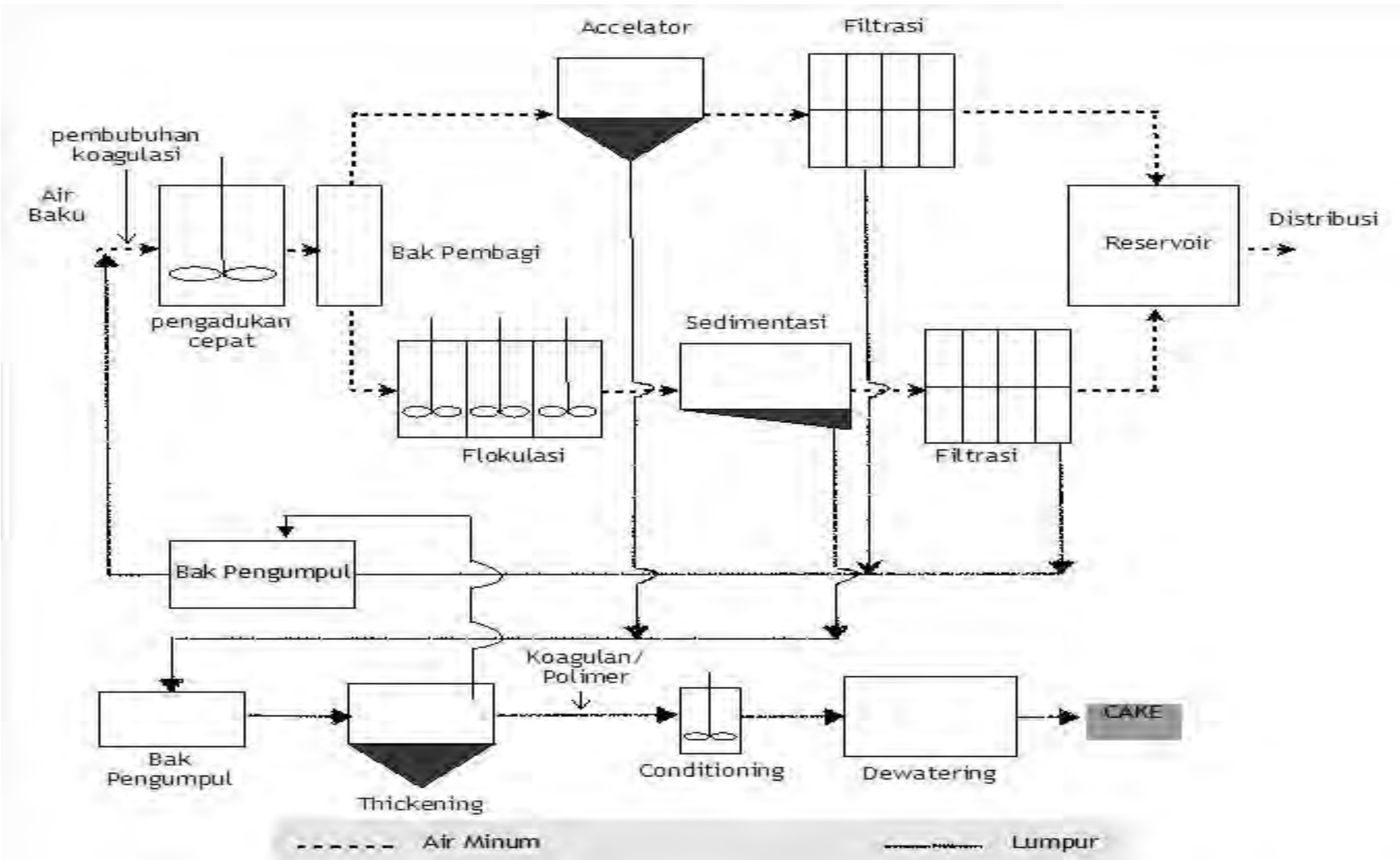
TL 314 PDIPAM

Rachmawati S. Dj

Sub CP MK *Week 14-15*

Mg Ke-	Sub CPMK	Kemampuan Akhir Tiap Tahapan Belajar (SubCPMK)	Penilaian		Bentuk Pembelajaran[7)]; Metode Pembelajaran[8)]; Penugasan Mahasiswa (estimasi waktu)	Bobot Penilaian[10] (%)
			Indikator[5)]	Teknik[6)]	Luring	
1	2	3	4	5	6	9
14-15	6.5	Mahasiswa mampu menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)* secara tepat	Ketepatan dalam menjelaskan *tertiary treatment*; menganalisis dan merancang pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)* secara tepat	Tugas, UAS	▪ Tatap Muka, Asistensi, Diskusi ▪ Tugas: 2*50 menit/minggu ▪ *Tertiary treatment*; pengolahan lumpur (*sludge thickening, conditioning,* dan *dewatering)*: 2*3*50 menit	5%
16	UAS					

Gambar 1. Skema Rencana Pengelolaan Residu Lumpur IPA Badak Singa

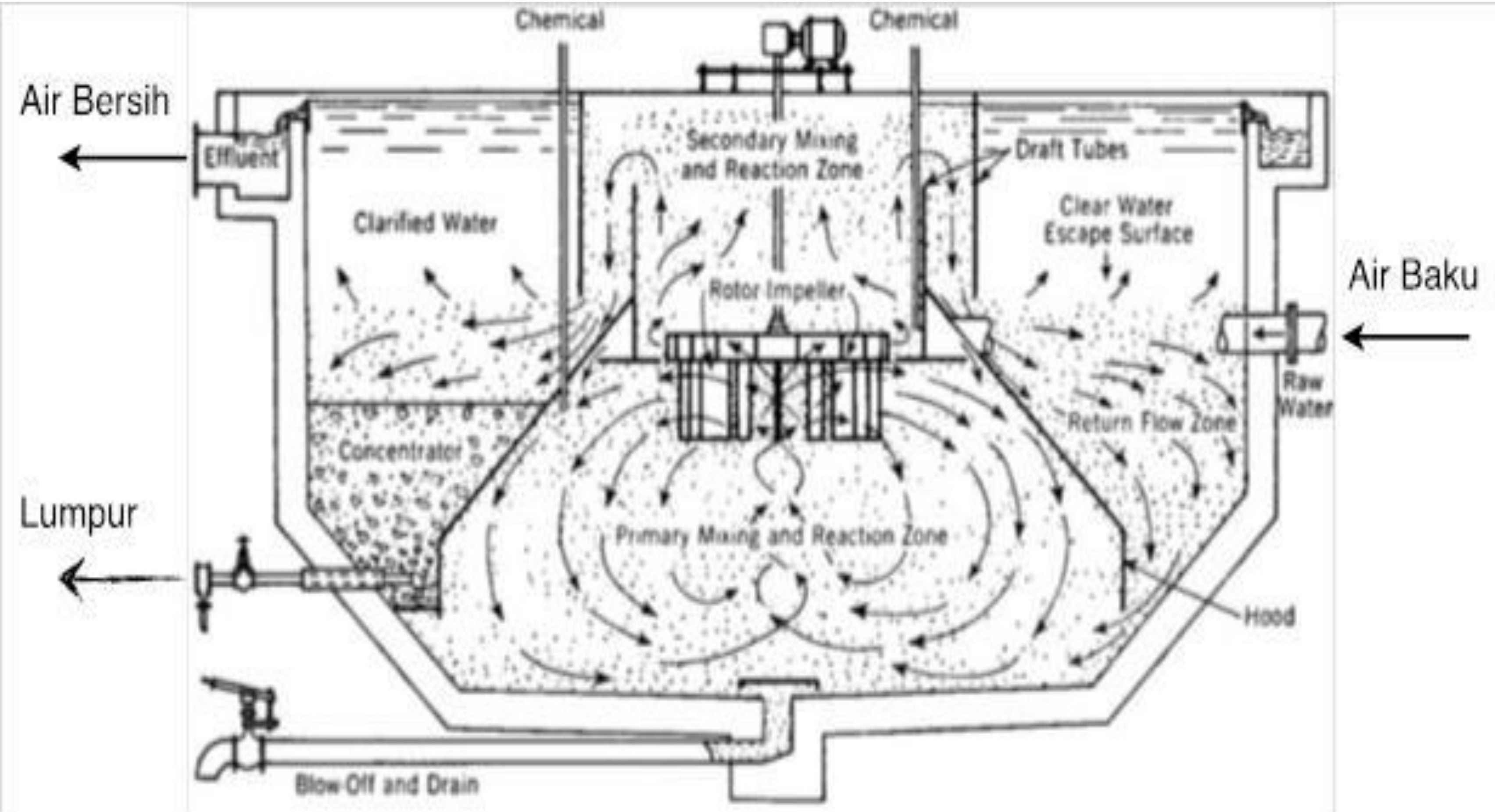


1. UNIT PENGHASIL LUMPUR

1.1. ACCELATOR

- merupakan unit pengolahan air minum yang dioperasikan secara mekanis dengan sistem resirkulasi lumpur (Gambar 2).
- Accelator mengoptimalkan proses flokulasi dan meningkatkan kecepatan pengendapan flok.
- Flok yang terbentuk selanjutnya akan dipisahkan dan diendapkan pada dasar kompartemen di bagian sisi *accelator* (Konsentrator).
- Lumpur tersebut akan dibuang secara otomatis selama ±15 detik, secara berkala setiap 2 jam.
- Dalam kondisi tertentu, pembuangan lumpur dapat dilakukan sesuai kebutuhan.

Gambar 2. accelator



1.2. bak sedimentasi

- Sebagai unit pengendap, lumpur yang dihasilkan pada bak sedimentasi berasal dari debit pengolahan 800 liter/detik, atau 200 liter/detik di setiap bak sedimentasi.
- Aliran air dari bak flokulasi akan mengalir ke bak sedimentasi dari arah bawah dan flok-flok yang telah terbentuk akan mengendap akibat gaya gravitasi pada bidang di sepanjang pelat-pelat baja putih.
- Selanjutnya flok-flok yang menumpuk pada pelat-pelat tersebut akan turun mengalir ke bak lumpur.
- Seperti halnya pada *accelator*, pengurasan bak lumpur dilakukan secara otomatis setiap 2 jam.

1.3. UNIT FILTRASI SISTEM 1

- Residu berasal dari air pencucian 20 bak filtrasi yang dilakukan secara bergantian.
- Air tersebut bercampur dengan flok atau partikel yang sebelumnya terperangkap dan menyumbat media saringan.
- Pencucian atau *backwash* dilakukan menggunakan gelembung udara selama beberapa menit untuk melepaskan flok atau partikel yang terperangkap dalam media filter.
- Setelah dibiarkan selama 2 menit, air akan dialirkan untuk memisahkan partikel dan flok dari bak filtrasi.
- Kecepatan aliran pencucian adalah $35m^3/m^2$/jam selama 3-6 menit.

1.3. UNIT FILTRASI SISTEM 1

- Pada praktiknya jadwal pencucian bervariasi antara 15-30 jam, tergantung pada kemampuan masing-masing bak filter.
- Indikasi bahwa kemampuan filtrasi sudah menurun dan harus mengalami *backwash* adalah saat air permukaan dalam bak meningkat.
- Peningkatan muka air tersebut menunjukkan bahwa media filtrasi telah tersumbat.

1.4. UNIT FILTRASI SISTEM 2

- Seperti halnya pada filtrasi sistem I, residu berasal dari pencucian 8 bak filtrasi.
- Metode pencucian dan jangka waktu pencucian juga serupa.
- Dengan luas permukaan bak diketahui sebesar 36 m^2, maka volume air untuk pencucian dan kemudian bercampur dengan kotoran saringan dapat dihitung.
- Perhitungan menggunakan asumsi bahwa seluruh saringan pasir cepat memiliki kemampuan penyaringan yang relatif merata.

2. KARAKTERISTIK LUMPUR

- Jumlah lumpur yang dihasilkan akan sebanding dengan dosis koagulan pada pengolahan.
- Koagulan yang digunakan pada pengolahan di IPA Badak Singa adalah larutan tawas alumunium dengan konsentrasi 6-7% (terhadap volume air). Kandungan unsur alumunium dalam senyawa alum adalah 9,1%, sehingga dalam proses pembentukan flok akan menghasilkan 0,44 mg/L padatan alumunium untuk setiap penambahan 1 mg/L senyawa alum.
- Selanjutnya nilai 0,44 tersebut menjadi koefisien koagulan dalam perhitungan kuantitas lumpur.

TABEL 1. Kualitas Lumpur IPA Badak Singa

No	PARAMETER	SATUAN	BAKU MUTU	HASIL PENGUJIAN
1.	Arsen	mg/L	5	<0.005
2.	Barium	mg/L	100	0.63
3.	Kadium	mg/L	1	<0.003
4.	Krom Total	mg/L	5	<0.01
5.	Nikel	mg/L	-	<0.005
6.	Raksa	mg/L	0.2	<0.001
7.	Selenium	mg/L	1	<0.01
8.	Seng	mg/L	50	0.53
9.	Tembaga	mg/L	10	0.03
10.	Timbal	mg/L	0.5	<0.1

Sumber:

1. Hasil Analisa Laboratorium Pengendalian Kualitas Lingkungan (LPKL) PDAM Tirtawening Kota Bandung Tahun 2012.
2. Standar Baku Mutu: PPRI Nomor 85 Tahun 1999.

2. KARAKTERISTIK LUMPUR

- Data kualitas lumpur hasil sampingan produksi air minum IPA Badak Singa dapat menjadi dasar dalam pengelolaan lumpur untuk tahap *disposal* (pembuangan) atau untuk pemanfaatan lainnya.
- Hasil pemeriksaan laboratorium pada Tabel 1 menunjukkan bahwa kualitas lumpur IPA Badak Singa telah memenuhi baku mutu Peraturan Pemerintahan Republik Indonesia (PPRI) No. 85 Tahun 1999.

3. KUANTITAS LUMPUR

3.1. MASSA LUMPUR

- Jikakarateristiklumpurberdasarkankoagulantelahdiketahui,makatimbulanlumpurdapatdihitungdenganpersamaanberikut (Cornwell et al, 1987):
- $S = (8{,}34Q)(0{,}44Al + S + A)$
- Nilaipadatantersuspensidapatditentukanberdasarkannilaikekeruhan air bakudenganpersamaanberikut:
- $SS(mg/l) = b.NTU$

3.1. MASSA LUMPUR

- Perhitungan timbulan lumpur juga dapat dihitung menurut Qasim (2000) dengan persamaan berikut:
- $Q_{raw\ solid}\ (\mathrm{kg/hari}) = \mathrm{kekeruhan} \times \mathrm{a} \times 10^{-6}\ \mathrm{kg/mg} \times 10^{3}\ \mathrm{L/m^3} \times \mathrm{Q}$
- Berdasarkan data kekeruhan dan debit, massa lumpur IPA Badak Singa dengan kapasitas pengolahan maksimal 1,8 m3/detik dapat dihitung.

TABEL 2. Timbulan massa lumpur IPA Badak Singa

Kapasitas	Q air baku (m^3/detik)	Dosis kogulan (mg/L)	Turbiditas (NTU)	Massa lumpur (kg/hari)
rata-rata	1,8	20,97	87,9	
maksimum	1,8	30,97	190,58	

Soal menghitung massa lumpur (Q)

Kapasitas IPA rata2	1.88	m3/s	PDAM, 2014
dosis PAC rata-rata	30.56	mg/l	PDAM, 2014
dosis PAC maksimum	76.67	mg/l	PDAM, 2014
Kekeruhan rata-rata	48.00	NTU	PDAM, 2014
Kekeruhan maksimum	435.00	NTU	PDAM, 2014
rasio suspended solid	1.3	mg/l / mg/l	Kawamura, 2000

menghitung massa lumpur (Q)

SS rata-rata		mg/l
SS maksimum		mg/l
Cornwell (rata2)		kg/hari
Cornwell maks		kg/hari
Qasim (rata2)		kg/hari
Qasim maks		kg/hari
Kawamura (rata2)		kg/hari
Kawamura maks		kg/hari
massa lumpur rata-rata		kg/hari
massa lumpur maks		kg/hari

3.2. VOLUME LUMPUR

- Volume lumpurditentukanolehkandunganpadatandalamlumpurdan kandunganairnya.
- Persamaanyang menghubungkan volume lumpurdenganmassanyaialahsebagaiberikut (Metcalf & Eddy, 2004):

$$V = \frac{M_s}{\rho_w S_{sl} p_s}$$

- Denganasumsibahwa solid content lumpurdaribaksedimentasisebesar 2%, beratjenis air 997,5 kg/m3, dan specific gravity lumpuradalah 1,02 (Metcalf & Eddy, 2004), maka volume lumpurdapatdihitung.

TABEL 3. VOLUME LUMPUR

Kapasitas	Massa lumpur (kg/hari)	Volume lumpur (m^3/hari)
Rata-rata		
Maksimum		

4. ALTERNATIF PENGOLAHAN LUMPUR

- Sesuai dengan Gambar 1, lumpur dari seluruh bak sedimentasi dan *accelator* akan diolah hingga membentuk *cake*.
- Pemilihan sistem pengolahan yang efektif dan efisien, dilakukan berdasarkan pemanfaatan lahan, kualitas *cake*, kemudahan operasional, dan investasi yang diperlukan.
- Sebagai bahan pertimbangan dalam pemilihan metode *thickening* yang paling optimal, dapat digunakan Tabel 4.

Soal menghitung volume lumpur

Specific gravity lumpur	1.02	kg/m3	Pengukuran
Solid content lump kimia	0.02		Pengukuran
rho air	997.50	kg/m3	

menghitung volume lumpur

volume rata-rata		m3/hari
volume maksimum		m3/hari

BAK PENGUMPUL-
menghitung volume dikumpulkan

pembuangan lumpur/blowdow	2	jam/hari
banyak blowdown/hari		per hari
durasi blowdown	20	detik
volume lumpur sedimentasi		m3/hari
volume dikumpulkan		m3
Bentuk bak	rectangular	

BAK PENGUMPUL- menghitung dimensi bak: panjang, lebar, vol aktual

Parameter	Besaran	Satuan	Keterangan
kedalaman	3	m	
luas permukaan		m2	
panjang		m	Vol aktual
lebar		m	
Vol Aktual		m3	

POMPA MIXING- menghitung kapasitas & jumlah pompa

1X pengadukan 4 jam

Parameter	Besaran	Satuan	Keterangan
Kapasitas pompa		m3/jam	
		liter/detik	
jumlah pompa	2	unit	

POMPA sludge feed –menghitung kapasitas & jumlah pompa

Parameter	Besaran	Satuan	Keterangan
jumlah pompa	4	unit	2 operasi 2 cadangan
kapasitas pompa		m3/detik	
		liter/detik	

GRAVITY THICKENER

Kriteria desain

Parameter	Besaran	Satuan	Keterangan
Kedalaman	3.0 - 4.0	m	USEPA, 2003
	4.5 - 6.5	m	Qasim, 1985
diameter max	25.000	m	USEPA, 2003
slope	1:6 - 1:3		USEPA, 2003
waktu detensi primary	24 - 48	jam	USEPA, 2003
waktu detensi secondary	18 - 30	jam	USEPA, 2003
solid content efluen	2.0 - 10	%	Qasim, 1985
Hydraulic loading	2.0 - 33	m3/m2.hari	Qasim, 1985
Solid loading	10.0 - 144	kg/m2.hari	Qasim, 1985
SVR	0.5 - 2	hari	Qasim, 1985

GRAVITY THICKENER – Data Perencanaan

Perencanaan *thickener* dilakukan berdasarkan kondisi maksimum IPA sehingga timbulan lumpur berada pada kondisi maksimumnya.

Parameter	Besaran	Satuan	Keterangan
solid loading	120.000	kg/m2/hari	jkt palyja
solid content influen	0.020		
solid content effluen	0.040		
slope	1.0 : 4.0		

Perhitungan Dimensi

Parameter	Besaran	Satuan	Keterangan
jumlah unit	2	unit	
berat lumpur per unit		kg/hari	
volume lumpur per unit		m3/hari	
luas area per unit		m2	
diameter		m	
diameter aktual		m	
cek HLR		m3/m2.hari	
cek SLR		kg/m2.hari	
kebutuhan Kedalaman		m	
freeboard		m	
zona jernih		m	
zona pengendapan		m	
zona thickening		m	
kedalaman tengah		m	
Total kedalaman aktual		m	
solid capture 90%		kg/hari	
Q lumpur		m3/hari	
Keliling thickener		m	

Lumpur dan supernatan

Parameter	Besaran	Satuan	Keterangan
volume lumpur hasil proses		m3/hari	solid capture 90%
cek SVR			
Supernatan		m3/hari	
solid yang terbuang		kg/hari	
Solid dalam supernatan		kg/hari	
konsentrasi solid		mg/l	
Keliling thickener		m	

SOLID VOLUME RATIO

the volume of the sludge blanket held into the thickener divided by the volume of the thickener sludge removed per day

$$SVR = \frac{\left[\frac{\pi}{12}\, xD\ aktual^2\ x\ H_{tengah}\right] + \left[\frac{\pi}{4}\, xD\ aktual^2\ x\ H_{thickening}\right]}{volume\ lumpur\ hasil\ proses/jumlah\ unit}$$

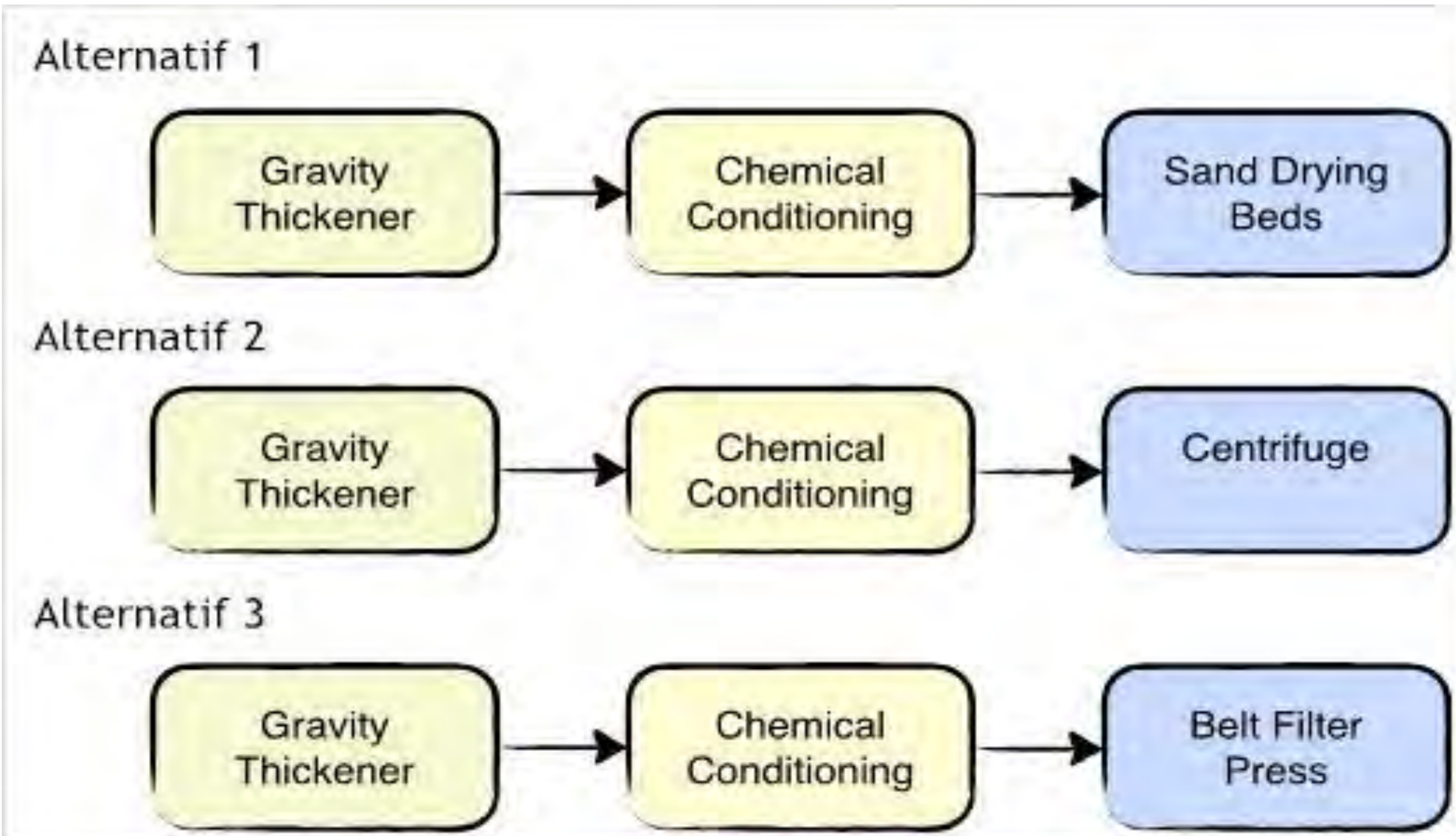
TABEL 4. PERBANDINGAN METODE THICKENING

Metode	Kelebihan	Kekurangan
Gravity	- Pengoperasian sederhana, tidak memerlukan *skill* tinggi - Biaya operasional dan energi yang diperlukan rendah - Tidak memerlukan *conditioning*	- Memerlukan lahan luas - Potensi menimbulkan bau - Konsentrasi solid tidak teratur dan rendah (2-3%) - Menghasilkan padatan melayang
Flotation	- Menghasilkan konsentrasi solid lebih baik (3,5-5%) - Hanya memerlukan lahan kecil - Hanya memerlukan sedikit penambahan bahan kimia - Komponen perlengkapan relatif sederhana	- Biaya operasional dan memerlukan energi lebih tinggi - Memerlukan operator khusus - Kapasitas penyimpanan kecil
Gravity Belt	- Efektif untuk lumpur dengan konsentrasi solid 0,4-6% - Memiliki pengaturan proses - Kebutuhan biaya investasi awal dan konsumsi energi relatif rendah	- Sangat bergantung pada polimer - Memerlukan perawatan khusus - Potensi timbulan bau - Memerlukan bangunan

4. ALTERNATIF PENGOLAHAN LUMPUR

- Berdasarkan Tabel 4, metode *gravity thickening* lebih mudah diterapkan, karena mudah dalam pengoperasiannya dan biaya pemeliharaannya relatif rendah dibandingkan dengan teknologi lainnya.
- Oleh karena itu, untuk pemilihan sistem pengolahan lumpur, disusun tiga alternatif pengolahan lumpur yang menggunakan metoda gravitasi untuk proses pemekatannya (thickening).
- Gambar 3 memperlihatkan ketiga alternatif pengolahan lumpur yang diusulkan.

GAMBAR 3. Skema Alternatif Pengolahan Lumpur



4. ALTERNATIF PENGOLAHAN LUMPUR

- Proses *chemical conditioning* setelah melewati *thickener* dilakukan untuk meningkatkan kemampuan proses *dewatering.*
- Adapun pertimbangan usulan 3 alternatif untuk proses dewatering dapat dilihat pada Tabel 5.

TABEL 5. Perbandingan Metode Dewatering

Metode	Kelebihan	Kekurangan
Drying beds dan *Drying Lagoon*	- Biaya investasi rendah bila telah tersedia lahan yang memadai - Konsumsi energi dan bahan kimia rendah hingga nol - Tidak memerlukan skil khusus untuk operator	- Memerlukan lahan yang sangat luas - Memerlukan proses stabilisasi lumpur - Desain harus mempertimbangkan pengaruh cuaca - Pembuangan *cake* secara rutin memerlukan penanganan khusus - Potensi berbau
Centrifuge	- Relatif hanya memerlukan lahan kecil - Tidak memerlukan penanganan operator secara berkesinambungan - Lingkungan pengolahan bersih dan relatif tidak menimbulkan bau	- Biaya investasi awal tinggi - Memerlukan energi tinggi setiap kali beroperasi - Memerlukan *grit removal* sebelum lumpur diproses - Memerlukan perbaikan secara periodik yang menyebabkan pengolahan lumpur terhenti - Memerlukan personel dengan skil khusus
Vacuum Filtration	- Produk *cake* dapat dibuang langsung	- Tidak dapat menyaring lumpur encer
Belt Filter Press	- Biaya investasi awal, operasional, dan energi relatif rendah - Mudah untuk mematikan sistem - Perawatan mudah	- Sangat sensistif terhadap karakter lumpur - Sensitif terhadap jenis dan dosis polimer
Filter/Plate Press	- Konsentrasi menghasilkan konsentrasi solid tinggi (??) - Solid tersuspensi dalam *filtrate* rendah - Cocok untuk proses *dewatering* jenis lumpur yang sulit ditangani - Pelat dapat ditambahkan sesuai kebutuhan penambahan kapasitas tanpa penambahan ruang yang signifikan	- Pengoperasian bersifat *batch* - Biaya investasi dan tenaga kerja tinggi - Memerlukan keahlian dalam perawatan - Seringkali memerlukan bahan kimia anorganik yang menghasilkan solid tambahan

4. ALTERNATIF PENGOLAHAN LUMPUR

- Alternatif metode *dewatering* lainnya tidak diperhitungkan , karena pertimbangan investasi awal yang tinggi, biaya operasional besar, dan pemeliharaan, serta pengoperasiannya memerlukan keahlian khusus.

BAK PENAMPUNG LUMPUR CONDITIONING

- Lumpur dari *gravity thickener* dikumpulkan pada bak penampung sebelum dialirkan ke unit *dewatering*.Pada unit ini juga dilakukan *conditioning* dengan pembubuhan bahan kimia.

Volume **BAK PENAMPUNG LUMPUR CONDITIONING**

- Waktu detensi direncanakan 12 jam dengan asumsi operasional unit *dewatering* adalah 12 jam, sehingga volume yang dibutuhkan:

Diameter bak (D) **PENAMPUNG LUMPUR CONDITIONING**

- Penampang bak direncanakan berbentuk lingkaran dengan kedalaman 3 m, maka luas permukaan bak adalah

Kedalaman

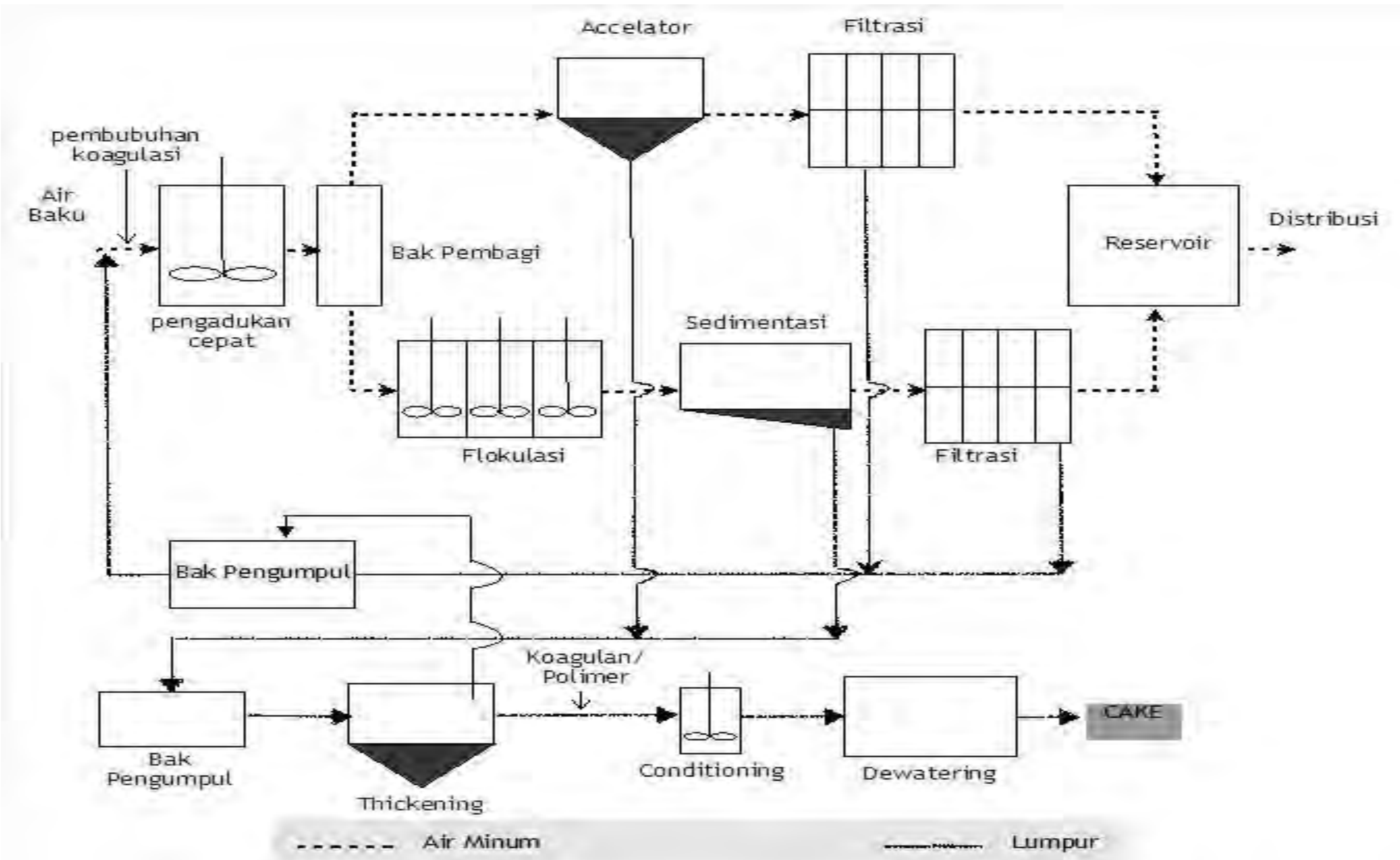
- Kemiringan bak 20 cm/m.
- Kedalaman bagian tengah,

DETIL DISAIN PENGOLAHAN LUMPUR
week 15
Genap 2025/2026

TLA 314 PDIPAM

Rachmawati S. Dj

Gambar 1. Skema Rencana Pengelolaan Residu Lumpur IPA Badak Singa



Soal menghitung massa lumpur (Q)

Kapasitas IPA rata2	1.88	m3/s	PDAM, 2014
dosis PAC rata-rata	30.56	mg/l	PDAM, 2014
dosis PAC maksimum	76.67	mg/l	PDAM, 2014
Kekeruhan rata-rata	48.00	NTU	PDAM, 2014
Kekeruhan maksimum	435.00	NTU	PDAM, 2014
rasio suspended solid	1.3	mg/l / mg/l	Kawamura, 2000

menghitung massa lumpur (Q)

SS rata-rata		mg/l
SS maksimum		mg/l
Cornwell (rata2)		kg/hari
Cornwell maks		kg/hari
Qasim (rata2)		kg/hari
Qasim maks		kg/hari
Kawamura (rata2)		kg/hari
Kawamura maks		kg/hari
massa lumpur rata-rata		kg/hari
massa lumpur maks		kg/hari

Soal menghitung volume lumpur

Specific gravity lumpur	1.02	kg/m3	Pengukuran
Solid content lump kimia	0.02		Pengukuran
rho air	997.50	kg/m3	

menghitung volume lumpur

volume rata-rata		m3/hari
volume maksimum		m3/hari

BAK PENGUMPUL

- Bak pengumpul berfungsi sebagai penampung lumpur dari *accelator* pada sistem I dan unit sedimentasi pada sistem II.
- Pada sistem I terdiri dari 4 unit accelator yang masing-masing mengolah 250 liter/detik air, dan 4 buah unit sedimentasi yang masing-masing mengolah 200 liter/detik air.
- Selain sebagai penampung, bak pengumpul juga berfungsi untuk mengatur debit lumpur yang akan mengalir ke *gravity thickener* yang beroperasi secara kontinu 24 selama jam.

Dimensi Bak Pengumpul

- Desain bak pengumpul dihitung berdasarkan kondisi timbulan lumpur maksimum, yaitu saat ke-4 *accelator* dan ke-4 unit sedimentasi melakukan pembuangan lumpur secara bersamaan.
- Pembuangan lumpur dilakukan secara berkala per 2 jam.

BAK PENGUMPUL-
menghitung volume dikumpulkan

pembuangan lumpur/blowdown	2	jam/hari
banyak blowdown/hari		per hari
durasi blowdown	20	detik
volume lumpur sedimentasi		m3/hari
volume dikumpulkan		m3
Bentuk bak	rectangular	

Dimensi Bak Pengumpul

- Volume lumpur yang perlu ditampung = m^3
- Kedalaman bak direncanakan 3 m dan freeboard 0,5 m
- Sehingga luas permukaan (As)= m^2
- panjang bak direncanakan berukuran = m
- dan lebar= m.
- volume aktual = m^3.

BAK PENGUMPUL- menghitung dimensi bak: panjang, lebar, vol aktual

Parameter	Besaran	Satuan	Keterangan
kedalaman	3	m	
luas permukaan		m2	
panjang		m	Vol aktual
lebar		m	
Vol Aktual		m3	

Pompa mixing bak

- Pompa ini berfungsi untuk mencegah terjadinya pengendapan pada dasar bak pengumpul.
- Direncanakan digunakan pompa dengan waktu pengadukan 4 kali dalam 24 jam.
- Setiap kali pengadukan berlangsung selama 4 jam.

Pompa mixing bak

- Kapasitas pompa=   L/det
- Jumlah pompa diperlukan 2 unit:
- 1 beroperasi dan
- 1 sebagai cadangan secara bergantian

Kapasitas pompa mixing

$$Q = \frac{72\ m^3}{1\ pompa\ \times 4\ jam} = 18\ m^3/jam = 5\ liter/detik$$

POMPA MIXING- menghitung kapasitas & jumlah pompa

1X pengadukan	4	jam

Parameter	Besaran	Satuan	Keterangan
Kapasitas pompa		m3/jam	
		liter/detik	
jumlah pompa	2	unit	

Pompa lumpur (*sludge feed*)

- Lumpur dari bak pengumpul dialirkan ke unit *gravity thickener* menggunakan pompa
- Perhitungan pompa dilakukan berdasarkan debit maksimum = m^3/detik.
- Pada saat pengoperasian pompa akan dioperasikan pada debit rata-rata = m^3/detik.
- Jumlah *Gravity thickener* direncanakan sebanyak 2 unit

Pompa lumpur (*sludge feed*)

- Jumlah pompa direncanakan 2 unit: 1unit dioperasikan, 1unit cadangan.
- Pompa dioperasikan secara kontinu
- Q_{maks} = m^3/detik ~
- Q_{pompa} = m^3/detik
- diperlukan 2 buah pompa *non-clogging submerisble pump* dengan kapasitas = liter/detik.

POMPA sludge feed –menghitung kapasitas & jumlah pompa

Parameter	Besaran	Satuan	Keterangan
jumlah pompa	4	unit	2 operasi 2 cadangan
kapasitas pompa		m3/detik	
		liter/detik	

Struktur inlet dan outlet

- Inlet bak berupa saluran dari unit sedimentasi dan accelerator.
- Saluran *outlet* ke *gravity thickener* menggunakan pipa berdiameter = inch.

GRAVITY THICKENER

Kriteria desain

Parameter	Besaran	Satuan	Keterangan
Kedalaman	3.0 - 4.0	m	USEPA, 2003
	4.5 - 6.5	m	Qasim, 1985
diameter max	25.000	m	USEPA, 2003
slope	1:6 - 1:3		USEPA, 2003
waktu detensi primary	24 - 48	jam	USEPA, 2003
waktu detensi secondary	18 - 30	jam	USEPA, 2003
solid content efluen	2.0 - 10	%	Qasim, 1985
Hydraulic loading	2.0 - 33	m3/m2.hari	Qasim, 1985
Solid loading	10.0 - 144	kg/m2.hari	Qasim, 1985
SVR	0.5 - 2	hari	Qasim, 1985

GRAVITY THICKENER – Data Perencanaan

Perencanaan *thickener* dilakukan berdasarkan kondisi maksimum IPA sehingga timbulan lumpur berada pada kondisi maksimumnya.

Parameter	Besaran	Satuan	Keterangan
solid loading	120.000	kg/m2/hari	jkt palyja
solid content influen	0.020		
solid content effluen	0.040		
slope	1.0 : 4.0		

Dimensi thickener

Surface area yang dibutuhkan masing-masing *thickener* untuk berat lumpur = kg/hari dengan *solid loading* = kg/m^{2}hari:

$$A = \frac{(16.731{,}652\ kg/hari\ /2\ unit)}{120\ kg/m^2.hari} = 69{,}715\ m^2$$

diameter (D) masing-masin g*gravity thickener*

$$D = \sqrt{\frac{4\ A}{\pi}} = \sqrt{\frac{4 \times 69{,}715}{\pi}} = 9{,}4\ m$$

Diameter aktual = 9,5 m, sehingga A = 70,85 m

Pengecekan *hydraulic loading rate* *(HLR)*

- Saat beban rata-rata:

$$HLR = \frac{395,487\ m^3/hari}{141,70\ m^2} = 2,791\ m^3/m^2.hari$$

(memenuhi)

Saat beban maksimal

$$HLR = \frac{822,235\ m^3/hari}{141,70\ m^2} = 5,803\ m^3/m^2.hari$$

(memenuhi)

Pengecekan *solid loading rate (SLR)*

- Saat beban rata-rata:

$$Solid\ loading = \frac{8.047,759\ kg/hari}{141,70\ m^2} = 56,79\ kg/m^2.hari$$

(memenuhi)

Saat beban maksimal

$$Solid\ loading = \frac{16.731,652\ kg/hari}{141,7\ m^2} = 118,08\ kg/m^2.hari$$

(memenuhi)

Kedalaman Thickener

- Kebutuhan kedalaman:

$$H = \frac{Volume\ lumpur}{Jumlah\ unit\ x\ A_s} = \frac{Volume\ lumpur}{Jumlah\ unit\ x\ \frac{1}{4}\pi D^2} = m$$

kedalaman tengah:

$$H_t = \frac{D_{aktual}}{2/slope} = \frac{D_{aktual}}{2/4} = m$$

Kedalaman Thickener

kebutuhan Kedalaman		m
freeboard		m
zona jernih		m
zona pengendapan		m
zona thickening		m
kedalaman tengah	-	m
Total kedalaman aktual	-	m

Keliling thickener

- Saat rata-rata:
- Saat maksimum:

Lumpur keluaran *gravity thickener*

- Kuantitas lumpur pada thickener dengan solid content 4%, solid capture 90%
-

$$\text{Q lumpur max} = \frac{15.058,487\ (\frac{kg}{hari})}{0,04\ \times 1.02\ \times\ 997,5\ kg/m^3)} = \ 370,00\ \text{m3}$$

Dimensi thickener

Parameter	Besaran	Satuan	Keterangan
jumlah unit	2	unit	
berat lumpur per unit		kg/hari	
volume lumpur per unit		m3/hari	
luas area per unit		m2	
diameter		m	
diameter aktual		m	
cek HLR		m3/m2.hari	
cek SLR		kg/m2.hari	
kebutuhan Kedalaman		m	
freeboard		m	
zona jernih		m	
zona pengendapan		m	
zona thickening		m	
kedalaman tengah		m	
Total kedalaman aktual		m	
solid capture 90%		kg/hari	
Q lumpur		m3/hari	
Keliling thickener		m	

SOLID VOLUME RATIO

the volume of the sludge blanket held into the thickener divided by the volume of the thickener sludge removed per day

$$SVR = \frac{\left[\frac{\pi}{12}\, x D\ aktual^2\ x\ H_{tengah}\right] + \left[\frac{\pi}{4}\, x D\ aktual^2\ x\ H_{thickening}\right]}{volume\ lumpur\ hasil\ proses/jumlah\ unit}$$

Supernatan

$Q_{supernatan}$=Q lumpur influen – Q lumpur efluen

$M_{supernatan}$=M lumpur influen – M lumpur efluen

$$SSsupernatan = \frac{M_{supernatan}}{Q_{supernatan}}$$

Ketika Debit maksimum

Ketika Debit Rata-rata

Lumpur dan supernatan

Parameter	Besaran	Satuan	Keterangan
volume lumpur hasil proses		m3/hari	solid capture 90%
cek SVR			
Supernatan		m3/hari	
solid yang terbuang		kg/hari	
Solid dalam supernatan		kg/hari	
konsentrasi solid		mg/l	
Keliling thickener		m	

Struktur inlet dan Outlet

- Struktur inlet dan outlet *gravity thickener* merupakan pipa dengan diameter = 6 inch
- Outlet supernatan berupa weir dengan panjang sama dengan keliling bak gravity thickener = m
- Efluen supernatan ditampung pada saluran efluen dengan lebar 0,5 m (asumsi)
- Ketebalan gravity thickener 0,3 m (asumsi)
- Kedalaman total saluran adalah 0,5 m (asumsi)

BAK PENAMPUNG LUMPUR CONDITIONING

- Lumpur dari *gravity thickener* dikumpulkan pada bak penampung sebelum dialirkan ke unit *dewatering*.
- Pada unit ini juga dilakukan *conditioning* dengan pembubuhan bahan kimia.
- Perhitungan dimensi bak penampung dilakukan berdasarkan debit maksimum.

Volume

- Waktu detensi direncanakan 12 jam dengan asumsi operasional unit *dewatering* adalah 12 jam, sehingga volume yang dibutuhkan:

$$V = \frac{370\, m^3/hari \times 12\, jam}{24\, jam/hari} = 185{,}00\, m^3$$

Dimensi

- Penampang bak direncanakan berbentuk lingkaran dengan kedalaman 3 m (asumsi), maka luas permukaan bak = m^2

$$D = \sqrt{\frac{4 \times 61,67\ m^2}{\pi}} = 8,86\ m$$

Kedalaman

- Kemiringan bak 20 cm/m.
- Kedalaman bagian tengah,

$$h = \frac{20\ cm/m}{100\ cm/m} \times \frac{9\ m}{2} = 0{,}9\ m \sim 1{,}0\ m$$

- Total kedalaman=

kedalaman bak + kedalaman bag tengah+ *freeboard*

- Volume aktual bak penampung lumpur,

$$V = \left(\frac{\pi}{4} \times 9^2 \times 3\right) + \left(\frac{\pi}{12} \times 9^2 \times 1{,}0\right) = 211{,}95\, m^3$$

- Dengan volume bak tersebut, waktu detensi aktual pada kondisi maksimum = jam
- dan pada kondisi rata-rata = jam.
- Struktur outlet berupa pipa dengan diameter 8 inch

UNIT DEWATERING

- Terdapat tiga alternative unit yang akan digunakan untuk mekanisme dewatering:
- (1) Sludge drying bed,
- (2) Belt filter press, dan
- (3) centrifuge.

Sludge Drying Bed

- Sludge drying bed mengeringkan lumpur dengan melalui mekanisme penguapan dan perkolasi.
- Perhitungan luas area *sludge drying bed* dilakukan berdasarkan volume lumpur yang dihasilkan dari gravity thickener dengan asumsi waktu pengeringan tipikal 10 hari.

Dimensi

- *Volume lumpur = 10 x 370 m3/hari = 3.700 m3*
- Kedalaman lumpur direncanakan 30 cm, sehingga luas permukaan yang dibutuhkan = m2
- Dimensi unit adalah
- P = m
- L = m

Belt Filter Press

- Belt Filter Press memiliki kelebihan antara lain efluen lumpur memiliki solid content yang lebih tinggi (20%) dalam waktu yang lebih singkat.
- Proses *dewatering* menggunakan belt filter press terdiri atas tiga tahap, yaitu:
  (1) *conditioning* secara kimia,
  (2) Pengeringan kandungan air berlebih, dan
  (3) penekanan lumpur untuk memisahkan solid dengan air.
- *Conditioning* menggunakan polimer kationik dengan dosis 6 kg/ton (Palyja, 2008).

Kriteria Desain

Kriteria Desain Belt Filter Press (Metcalf & Eddy, 1991)

Parameter	Besaran	Satuan
Lebar Belt	0,5 - 3,5	m
Sludge Loading	90 - 680	kg/m/jam
Hydraulic Loading	1,6 - 6,3	L/m/detik

Data perencanaan

Keterangan	Besaran	Satuan
Debit lumpur maksimal	370,00	m^3/hari
Debit lumpur rata-rata	177,97	m^3/hari
Solid lumpur maksimal	15.058,487	kg/hari
Solid lumpur rata-rata	7.242,983	kg/hari
Solid capture	95	%
Solid loading	450	kg/m.jam
Waktu operasi	12	jam/hari
	7	hari/minggu
Konsentrasi padatan efluen	20	%

Perhitungan Kapasitas *Belt Filter Press*

- Padatan yang diolah oleh unit belt filter press merupakan lumpur dari *gravity thickener* yang ditambahkan dengan polimer.
- Kebutuhan polimer
- $$Dosis\ polimer = massa\ solid\left(\frac{kg}{hari}\right) \times dosis\ polimer\left(\frac{6\ kg}{ton}\right) \times 10^3\ kg/ton$$

Perhitungan Kapasitas *Belt FilterPress*

Jumlah padatan yang diolah

$$Padatan\ diolah\ \left(\frac{kg}{jam}\right) = \frac{massa\ solid\ +\ polimer\ (\frac{kg}{hari})}{Waktu\ Operasi\ (\frac{jam}{hari})}$$

Lebar belt yang dibutuhkan

$$Lebar\ (m) = \frac{jumlah\ padatan\ \left(\frac{kg}{jam}\right)}{solid\ loading\ (\frac{kg}{m.jam})}$$

Sludge flow

$$Lumpur\ diproses\ (m3/hari) = \frac{debit\ lumpur\ \left(\frac{m^3}{hari}\right)}{waktu\ operasi\ \left(\frac{jam}{hari}\right)}$$

Spesifikasi Belt Filter Press di pasaran

Untuk memenuhi kebutuhan tersebut perlu dilihat salah satu spesifikasi Belt Filter Press di pasaran pada Tabel 5.1

Tabel 5.1. Spesifikasi Produk Belt Filter Press

Model	N-PD11L	N-PD16L	N-PD21L	N-PD26L
Lebar belt (m)	1,1	1,6	2,1	2,6
Luas penyaringan efektif (m^2)	10,1	14,8	19,5	24,2
Sludge Flow (m^3/jam)	5-12	8-20	15-35	20-50
Kapasitas pengolahan (kg/jam)	150-400	250-600	400-1000	700-1500
Dimensi (panjang m x lebar m)	3,4 x 1,9	3,4 x 2,4	3,4 x 2,9	3,4 x 3,4
Power (kW)	0,5	0,8	1,47	1,47

Sumber: Dewaco Ltd., 2013

- Dengan membandingkan kebutuhan pengolahan dewatering dan spesifikasi di atas (tabel 5.1), pemilihan Belt Filter Press adalah 2 unit model **N-PD21L.**
- Saat kondisi rata-rata hanya 1 unit dioperasikan secara bergantian dan saat kondisi maksimal keduanya dioperasikan.

Cake lumpur

- Direncanakan solid capture sebesar 95%, maka massa lumpur dari belt filter press :
- Berat Cake Lumpur:
- M_{Cake}=95% x 12 (jam/hari) x padatan diolah (kg/jam)

- Kondisi rata-rata
- Kondisi maksimum

Cake lumpur

- Specific gravity lumpur hasil dewatering = 1,105
- specific gravity air pada suhu 30^0C = 995,68.
- Dengan demikian debit cake lumpur:
- pada kondisi rata-rata = m^3/hari
- pada kondisi maksimum = m^3/hari

Kuantitas Filtrat

- Debit filtrat dari unit Belt Filter Press
- $Q_{filtrat} = Q_{inlet} - Q_{cake}$
  - Kondisi Maksimum = m^3/hari
  - Kondisi rata-rata = m^3/hari

$$\text{Kandungan TSS} = \frac{\text{Massa padatan filtrat}}{\text{Volume padatan filtrat}}$$

Jumlah padatan

- Padatan = 5% x padatan diolah (kg/jam) x 12 jam
- Kandungan TSS =
  - Kondisi Maksimum
- Massa = kg/hari
- TSS = kg/m^3 = mg/L
  - Kondisi rata-rata
- Massa = kg/hari
- TSS = kg/m^3 = mg/L

bak penampung filtrate

- Untuk menampung filtrate yang dihasilkan, dibuat bak penampung pada masing-masing unit belt filter press sesuai dengan dimensi unit yang digunakan.

Centrifuge

Tabel 5.1. Kriteria desain centrifuge

Keterangan	Besaran	Satuan
Bowl diameter	800	mm
Kapasitas hidrolik	180	m^3/jam
Panjang	5,3	m
Lebar	3	m
Tinggi	1,75	m
Berat	11.200	kg

Sumber: Pieralisi Decanter Centrifuge catalog; Giant III, 2011

Data perencanaan Centrifuge

Tabel 5.1. Data Perencanaan Centrifuge

Keterangan	Besaran	Satuan
Debit lumpur maksimal	370,00	m^3/hari
Debit lumpur rata-rata	177,97	m^3/hari
Solid lumpur maksimal	15.058,487	kg/hari
Solid lumpur rata-rata	7.242,983	kg/hari
Ssl Influen	1,02	-refrensi
Solid capture	95	%
Konsentrasi padatan efluen	25	%

Perhitungan Jumlah Centrifuge

- Unit centrifuge akan mengolah padatan yang berasal dari unit gravity thickener dan polimer yang digunakan pada proses conditioning adalah sebesar 4 kg per ton lumpur.
- Kebutuhan polimer

$$Dosis\ polimer = massa\ solid\left(\frac{kg}{hari}\right) \times dosis\ polimer\left(\frac{4\ kg}{ton}\right) \times 10^3\ kg/ton$$

Perhitungan Jumlah Centrifuge

- Jumlah padatan yang diolah

$$Padatan\ diolah\ \left(\frac{kg}{jam}\right) = \frac{massa\ solid\ +\ polimer\ (\frac{kg}{hari})}{Waktu\ Operasi\ (\frac{jam}{hari})}$$

- Sludge flow

$$Lumpur\ diproses\ (m3/hari) = \frac{debit\ lumpur\ \left(\frac{m^3}{hari}\right)}{waktu\ operasi\ \left(\frac{jam}{hari}\right)}$$

- Kapasitas beban hidrolik unit centrifuge adalah sebesar 180 m^3/jam, sehingga diperlukan hanya 1 unit.

Cake lumpur

- Direncanakan solid capture sebesar 95%, maka massa lumpur dari *centrifuge:*
- Berat Cake Lumpur
- M_{Cake} = 95% x 12 (jam/hari) x padatan diolah (kg/jam)
  - Kondisi rata-rata
- M_{Cake} = kg/hari
  - Kondisi maksimum
- M_{Cake} = kg/hari

Kuantitas Cake Lumpur

- Specific gravity lumpur hasil dewatering = 1,136
- specific gravity air pada suhu 30^0C = 995,68.
  Debit cake lumpur:
- kondisi rata-rata = m^3/hari
- kondisi maksimum = m^3/hari.

Kuantitas Filtrat

- Debit filtrat dari unit Centrifuge
- $Q_{filtrat} = Q_{inlet} - Q_{cake}$
  - Kondisi Maksimum = m^3/hari
  - Kondisi rata-rata = m^3/hari

Jumlah padatan

- Padatan = 5% x padatan diolah (kg/jam) x 12 jam
- Kandungan TSS =
  - Kondisi Maksimum
- Massa = kg/hari
- TSS = kg/m^3 = mg/L
  - Kondisi rata-rata
- Massa = kg/hari
- TSS = kg/m^3 mg/L

bak penampung filtrate

- Untuk menampung filtrate yang dihasilkan, dibuat bak penampung pada masing-masing unit centrifuge sesuai dengan dimensi unit yang digunakan.

BAK PENGUMPUL *DRY CAKE*

- Lumpur dari unit mechanical dewatering dikumpulkan dalam bak pengumpul cake sebelum dikelola lebih lanjut.
- Perhitungan dimensi dilakukan berdasarkan debit lumpur maksimum.
- Dengan adanya dua alternatif dewatering, maka terdapat dua alternatif dimensi bak sebagai berikut.

Belt Filter Press -Dimensi Unit

- Volume lumpur yang dihasilkan unit belt filter press pada kondisi maksimum = m^3/hari
- dan saat kondisi rata-rata = m^3/hari.
- Waktu detensi bak direncanakan = 5 hari volume yang harus ditampung pada kondisi maksimum = m^3.
- dimensi bak ditetapkan: kedalaman = 2 m, panjang = m, dan lebar = m.

Pengecekan waktu penyimpanan

- Kondisi maksimum = hari
- Kondisi rata-rata = hari

Centrifuge -Dimensi Unit

- Volume lumpur yang dihasilkan unit belt filter press pada kondisi maksimum = m^3/hari
- dan saat kondisi rata-rata = m^3/hari.
- Waktu detensi bak direncanakan = 5 hari volume yang harus ditampung pada kondisi maksimum = m^3.
- dimensi bak ditetapkan: kedalaman = 2 m, panjang = m, dan lebar = m.

Pengecekan waktu penyimpanan

- Kondisi maksimum = hari
- Kondisi rata-rata = hari

BAK PENGUMPUL AIR PENCUCIAN UNIT FILTRASI DAN SUPERNATAN UNIT PENGOLAH LUMPUR