RECYCLED FIBER MANUFACTURING FOR PAPERMAKING – AN OVERVIEW

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Recycled Fiber Manufacturing for Papermaking – History

- Recovery, Recycling, and Reuse – started in 1600 s to early 1700s
- Industrialization and Innovation fueled growth of recycling centers
- Recycled Cardboard Boxes product: early 1990s
- 20th Century: Awareness on sustainability – Recycled Pulp MAJOR Raw Material

Recoverd Paper

- **Recovered Paper (RP) - Global – Amount: 277 m tons & Utilization Rate: Over 60%**
- **India – 70 – 70% paper and board is based on RP as raw material**
- **India RP: 20 m tons/a requirement & 40% imported**
- **TYPE: Mixed Grades , OCC, ONP&OMG, High grade deinking pulp substitutes**

Recovered Paper Recylability

- **Recycling : Pulp can be allowed 25 cycles of reuse without any problems**
- **Good recyclability: Begnin Chemicals usage, minimal/no impact on water loops, ease of processing, and non-harmful residues**
- **Food Contact: No risk to consumer health**
- **Separation of ink & adhesives through mechanical processing**

Recovered Paper – Collection & Sorting

- **Types:** Household and Industrial/business systems
- **Industrial:** clean, easy to arrange, homogeneous, and economical
- **Systems:** pre- and post: consumer waste

India:

Industrial – Houses, print press, book & manufacturing
Post Consumer (95%): informal, door collectors/vendors, not organized

Recovered Paper – Collection & Sorting

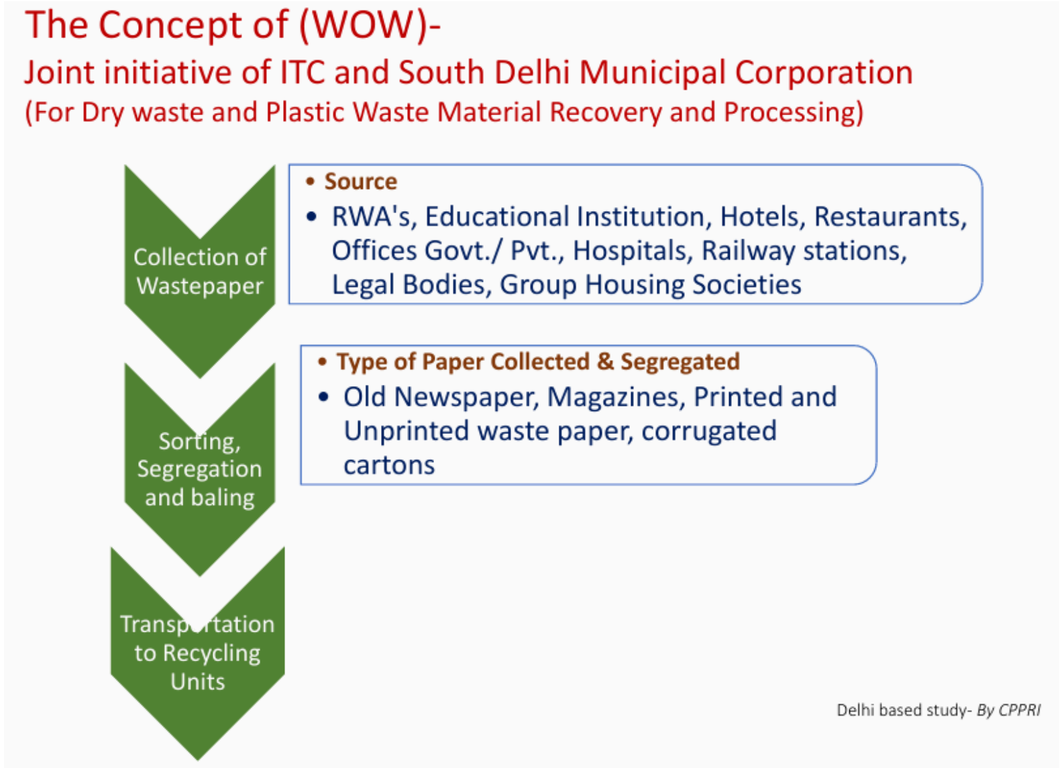
India

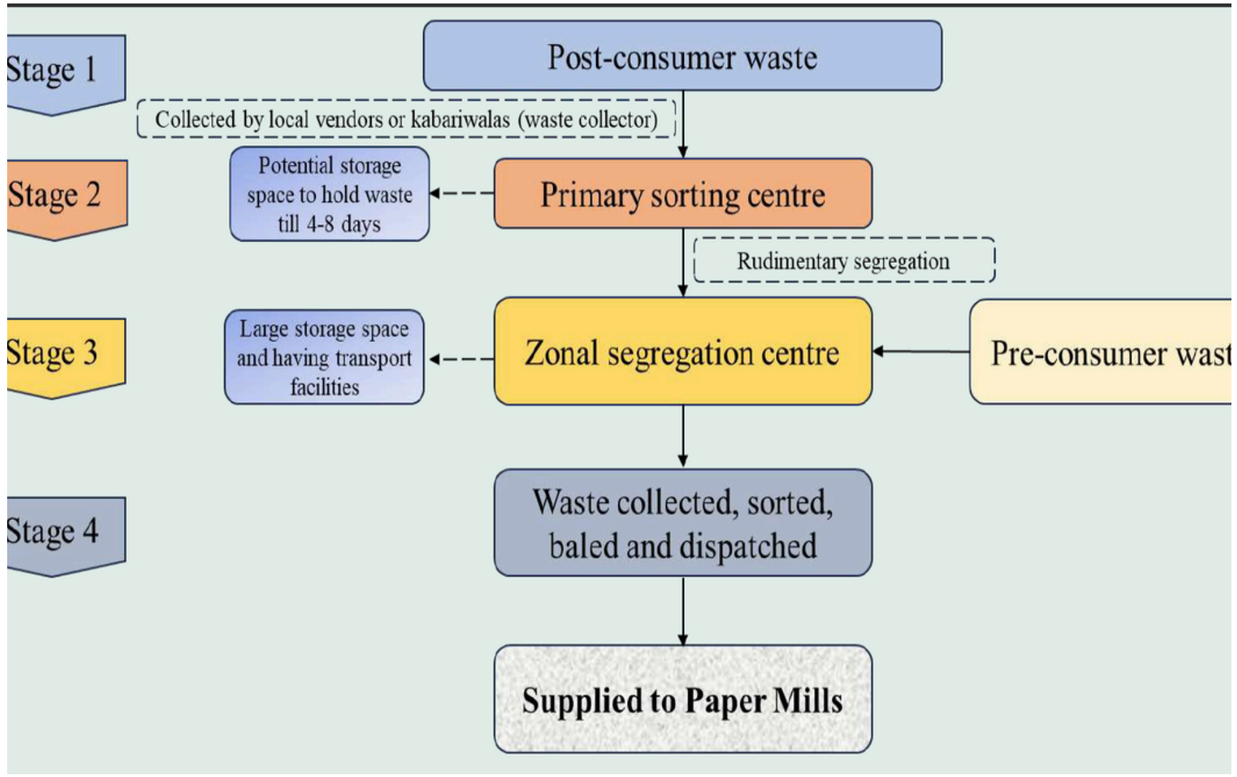
ferent recovery systems in Germar

	1998	2000	2002	
	50.4 %	54.1 %	55.7 %	5
	49.6 %	45.9 %	44.3 %	4
	47 %	41 %	38 %	
	39 %	47 %	51 %	
	6 %	5 %	4 %	
	8 %	7 %	7 %	

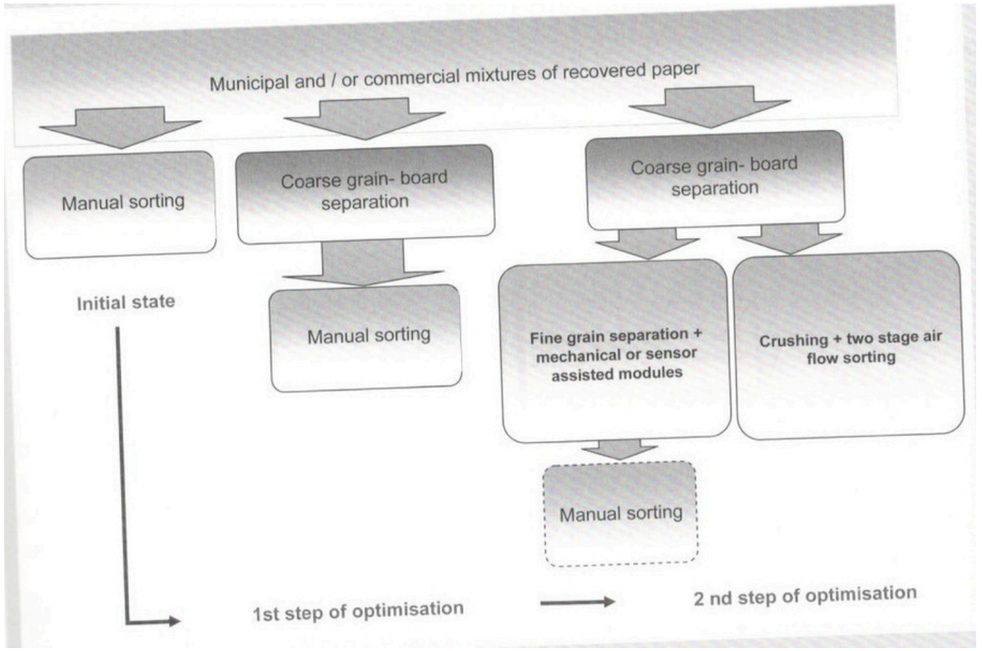
Recovered Paper – Collection & Sorting

India





Recovered Paper – Collection & Sorting

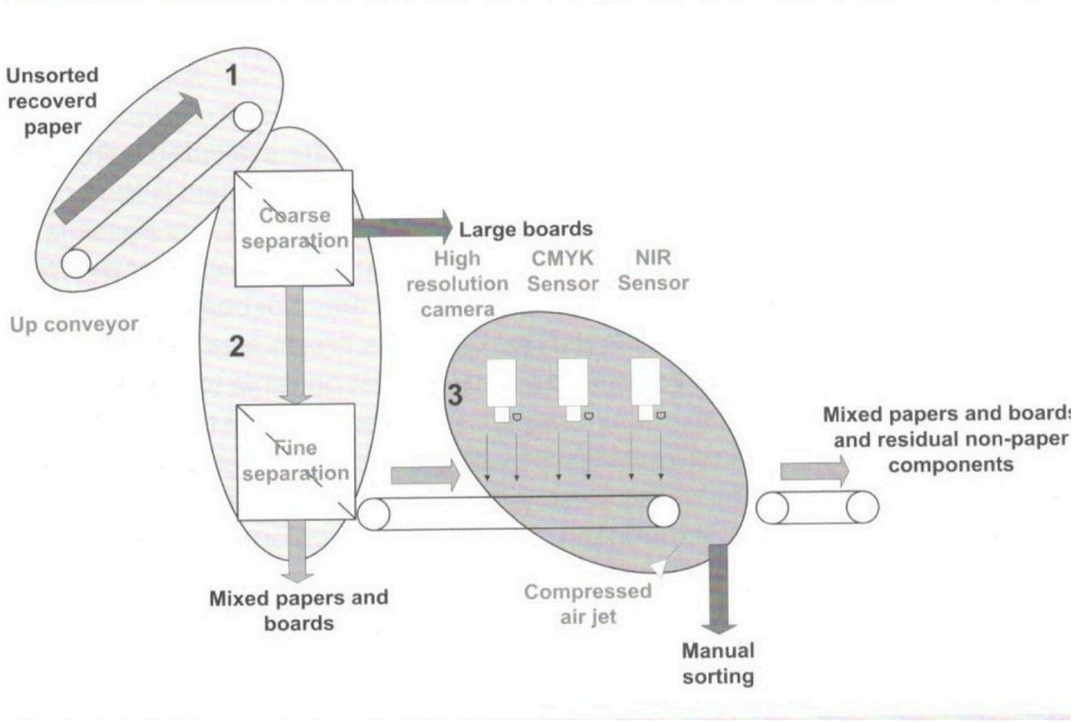


Automated Steps for Efficient Sorting

	Screen classification	Gap technique (vertical adjustment)	Paper spike	Air separator	Colour sensor	CMYK sensor	NIR sensor
	X	X		X			
	X		X				
					X	X	
ion							X
		X		X			

Materials and Separation

Recovered Paper – Collection & Sorting



Shredder

Air Stream Sorting

Automation: Sorting

Performance–Collection & Sorting

	Manually	Coarse screen	Fine screen[I]	Gap technique for fine screen[I]	Deinking screen[II]	Paper spike[II]	Shredding and air stream sorting[I]
Generated RP grades[IV]	1.11 1.04 1.02	1.04	1.02/ 1.02+	-	1.04	1.04 (1.02)	1.11 1.02
Effectiveness in %[III]	-	90–95	90–95	-	n/a	n/a	85–90
Content of 1.11 in the separated fraction in %	-	5–15	50–80	-	2–5	> 10	25–30
Throughput in t/h	0.5	6–30	6–30	-	< 15	7–11	12
Throughput of the subsequent manual sorting in t/(p*h)[V]	-	1.2	> 1.2	-	1.5	3–8	Not to apply

[I] Is only valid with prior coarse separation
[II] Is only valid with prior coarse and fine separation
[III] Refers to the components that should be removed
[IV] Refers to the fractions that are separated from the main product stream of the sorted graphic paper for deinking (1.11)
[V] Tons per person and hour

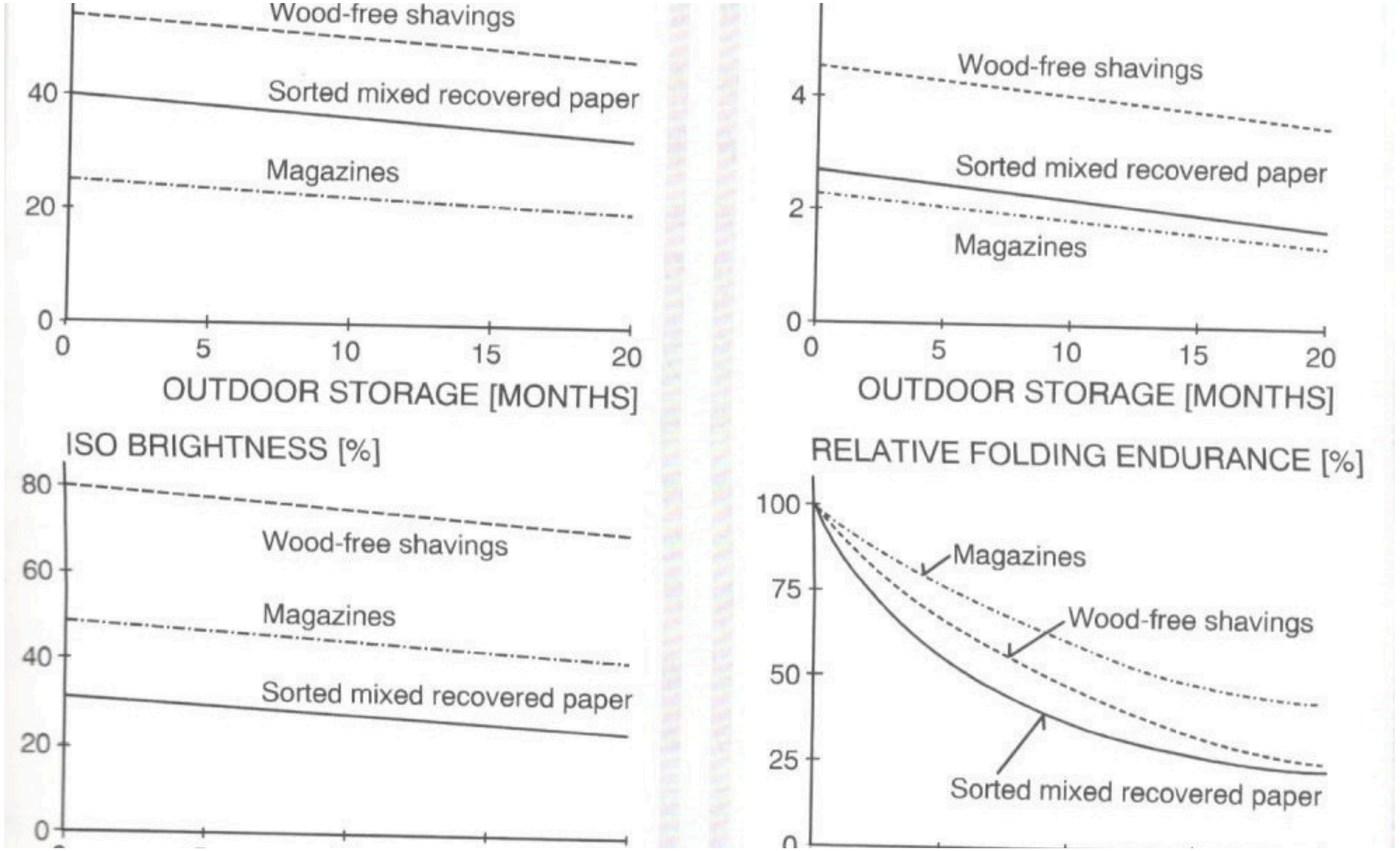
Recovered Paper – Quality

General:
Moisture Content (EN 643: Moisture < 10%)
Ash content and Schopper – Rieger Value
Composition

Brown Paper: Non-paper components, composition, handsheet characteristics

White grades: Non-deinkable paper and board components, composition and age, optical characteristic

Recovered Paper – Storage



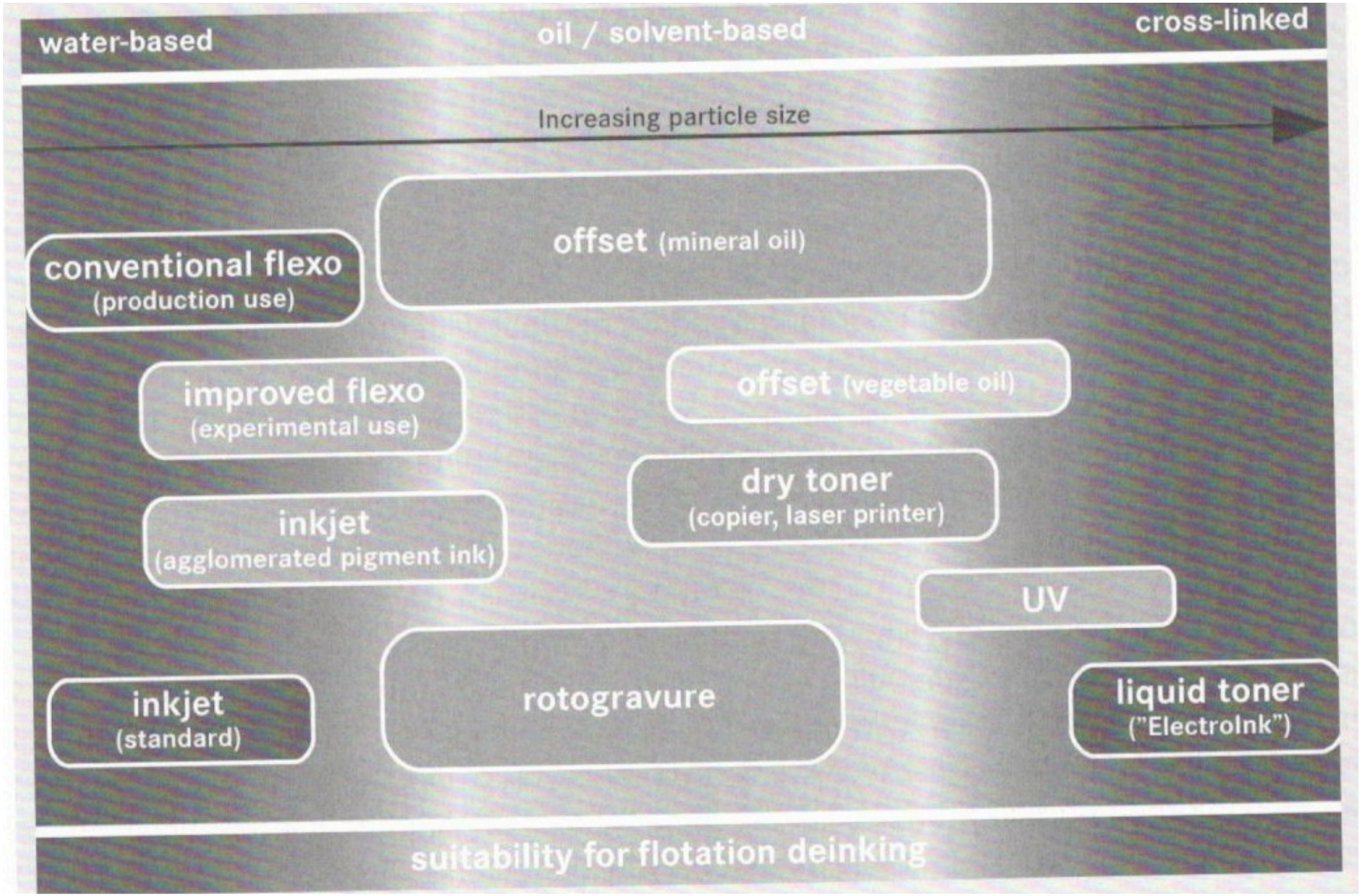
Take Away: Storage – Key properties – Strength & Brightness + Microbial

Recovered Paper – Recyclability

Good Recyclablitiy –

- Non-Paper Components – Low proportion
- Unwanted materials (Inks)
- Benign Chemicals
- Ease of processing
- Environmentally friendly (sludge/residues)
- Food stuff – no risk of contaminants
- Removable adhesives
- Repulpability – wet-strength papers challenging

Recyclability - Deinkability



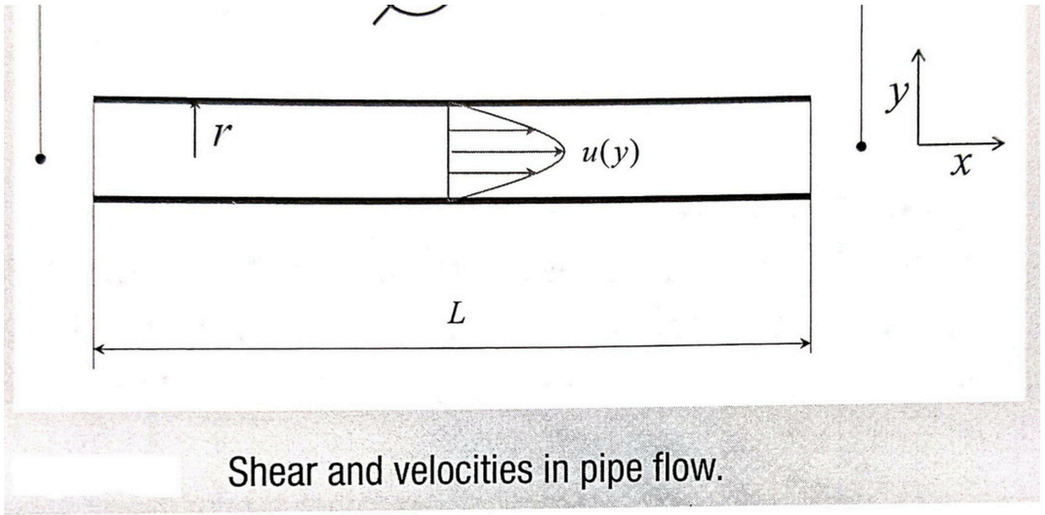
Deinkability Score

- Offset – 81%
- Gravure - > 90%
- Dry Toner: > 90%
- Ink Jet: Speciality>Pigments>dyes>UV – Cured
- Solid Inks - > 80%

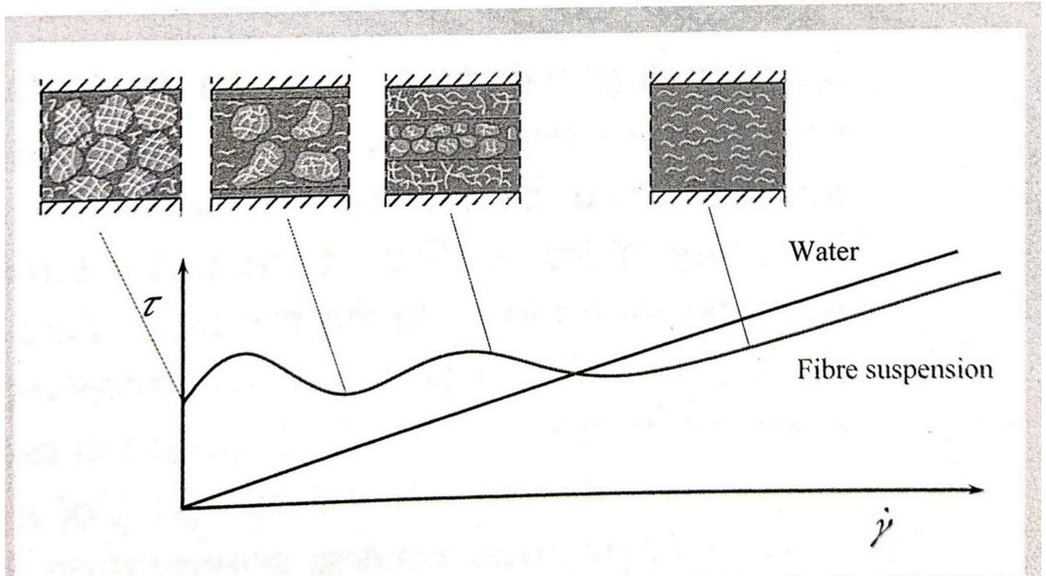
Stickies Removal

- Mechanical screening
- Size - Dia: 1000 to 100,000 µm

Recyclability - Unit Operations

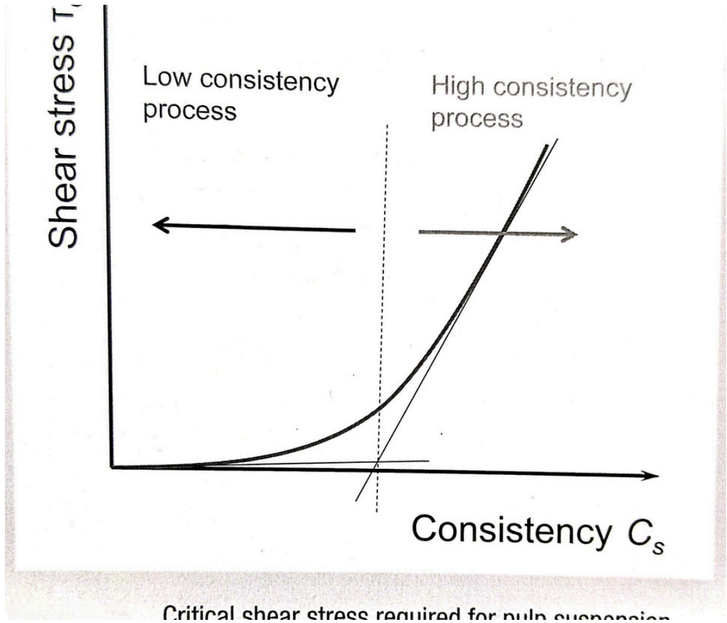


Shear and velocities in pipe flow.



Fluid Mechanics – Pulp Suspensions

- Flow – Non-Newtonian
- Absence of laminar flow
- Fibre –free wall layer
- Deflocculation
- Fludized suspension and turbulent flow



Critical shear stress required for pulp suspension

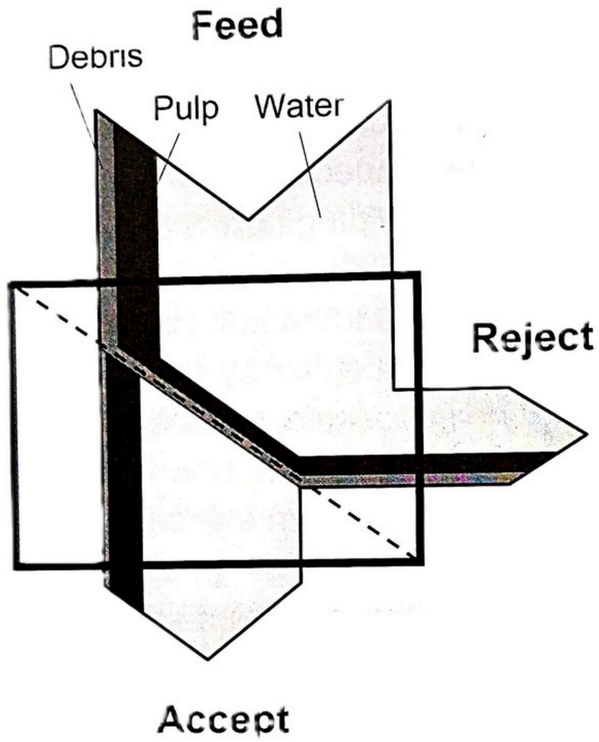
Recyclability - Separation Processes

Basis – Mass balance

Water (W)

Pulp (P)

Contaminants or debris (D)



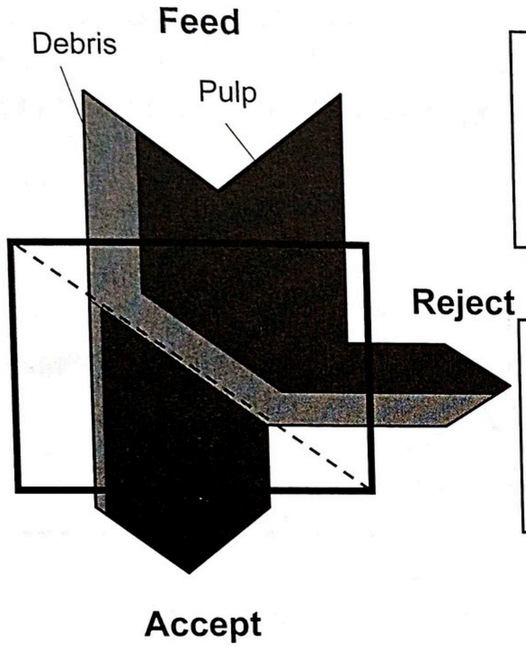
Reject rate

$$R_m = \frac{\dot{m}_r^P + \dot{m}_r^D}{\dot{m}_f^P + \dot{m}_f^D}$$

Thickening factor

$$F = \frac{Cs_r}{Cs_f}$$

Schematic Sankey diagram of a separation process.



Debris reject efficiency

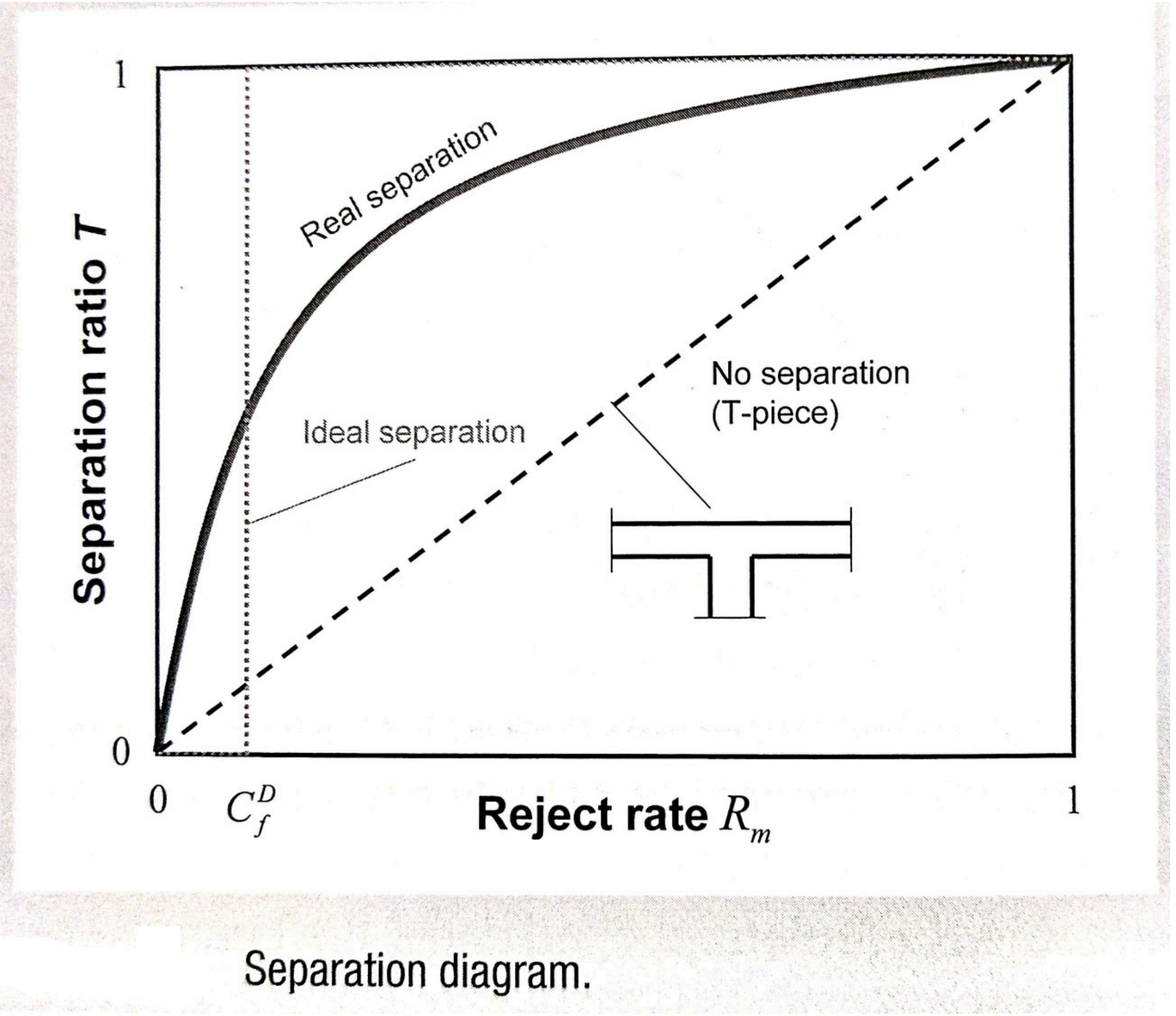
$$T = \frac{\dot{m}_f^D - \dot{m}_a^D}{\dot{m}_f^D}$$

Debris removal efficiency

$$\eta = \frac{C_f^D - C_a^D}{C_f^D}$$

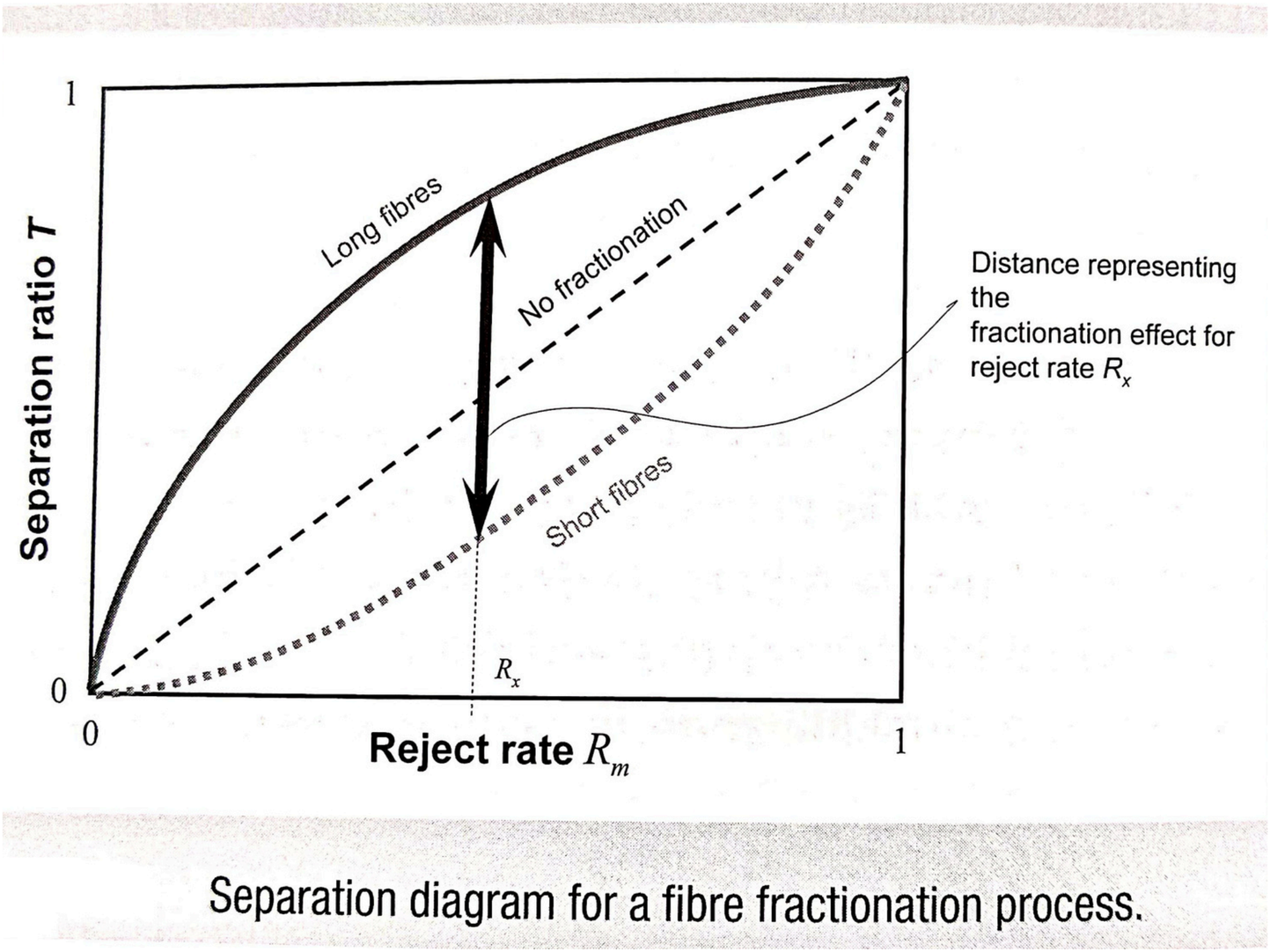
Sankey diagram of a separation process for the solid fractions.

Recyclability - Separation Processes



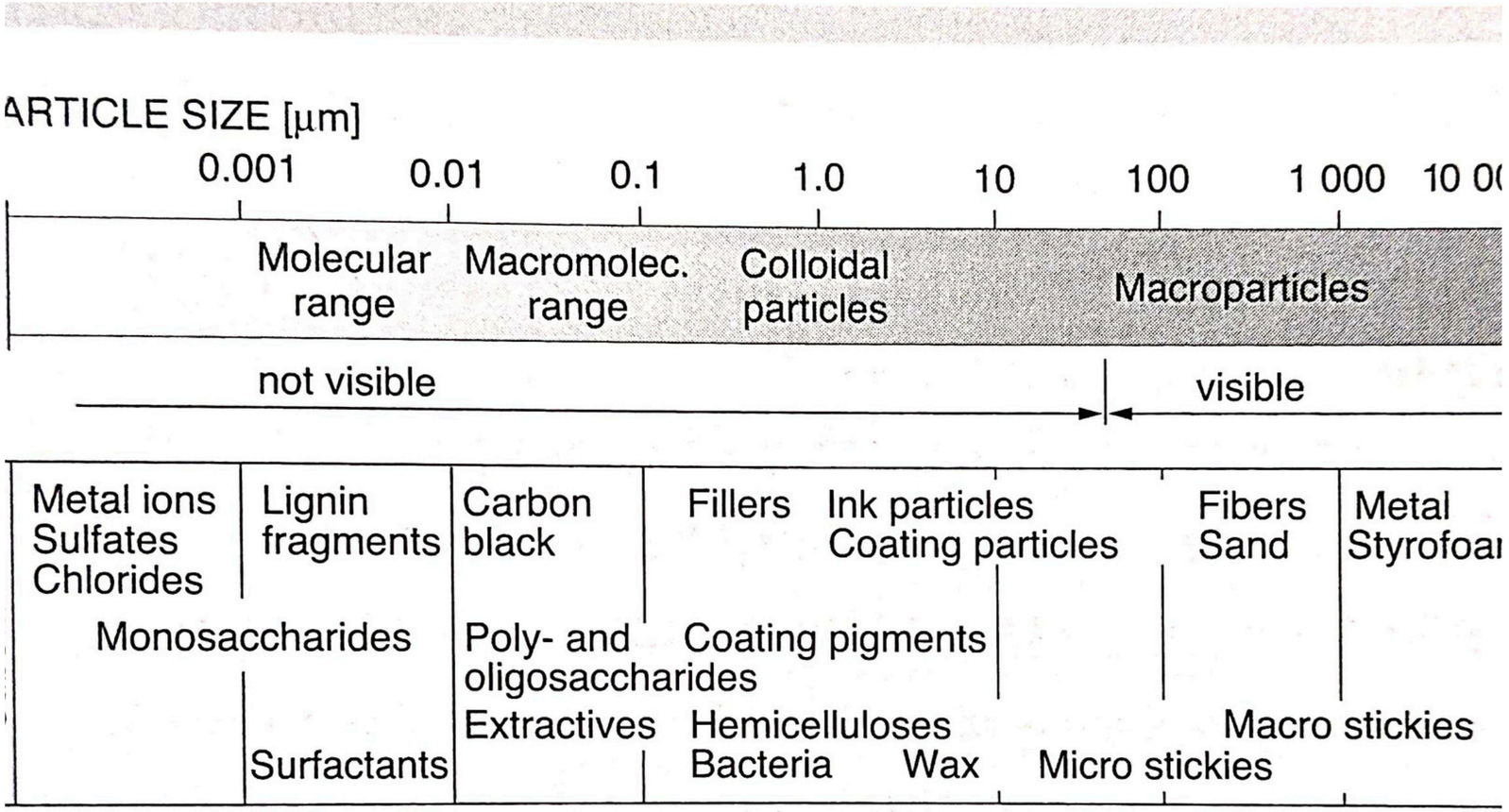
Separation diagram.

Recyclability - Fractionation Processes



Separation diagram for a fibre fractionation process.

Recyclability - Separation - Substances

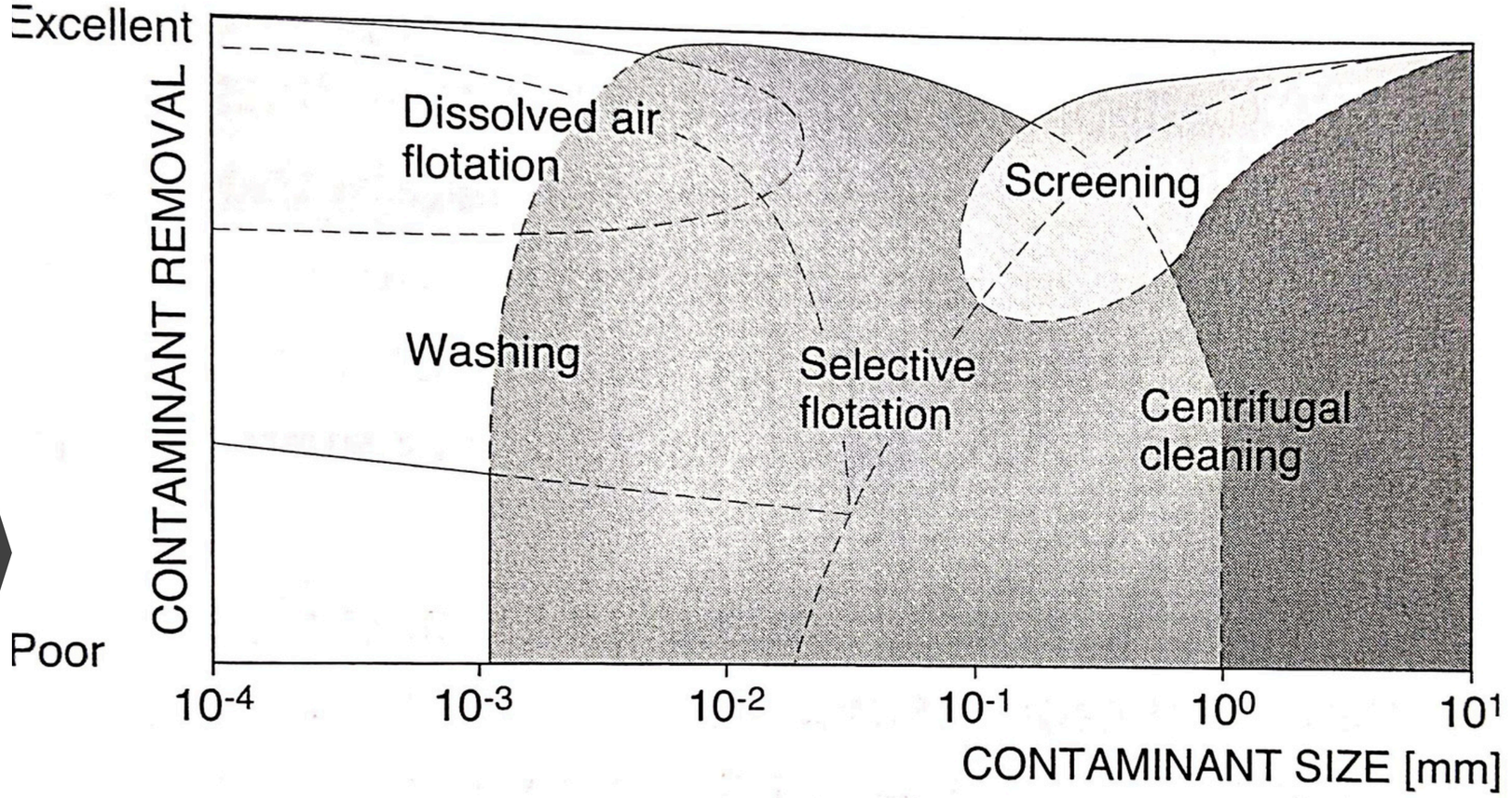


Substances in recycled-fibre processing.

Separation Processes - Classification

Process	Principle	characteristics utilized for	Remarks
Screening	Passage through apertures (Typically small slots or holes) and separation of passing particles from retained particles. Some screening methods involve circular motion or vibrations to aid separation process.	Size, form and shape, deformability	Type of screens: • Based on contaminants (Pressure, Coarse, and Fine) Separation Technology: Pressure, Rotary, vibrating, and centrifugal
Centrifugal Cleaning	Acceleration in centrifugal field and separation of heavy - weight from light- weight fraction	Specific gravity, size and shape	Types: Decanter Centrifuge Disc stack Centrifuge Scroll Separators Hydrocyclones
Flotation	Attachment of hydrophobic particles to air bubbles and separation of foam Probability based stages – collision, attachment, stability, and transport with foam	Surface properties and size	Variable features in flotation cells: aeration stages, type of air supply, foam removal methods, secondary flotation stage, closed or open cells, cell design and arrangement
Washing	Dilution to low consistency and passing of fine particles through small apertures (typically wire mesh)	size	Types: Drum filter, Disk filter, Belt filter, Belt pressure filter, Twin wire press, Screw press, and Belt washer
Fractionation	See screening	Size, geometry (length), flexibility	

Separation Processes - Classification



Efficiency ranges of unit processes for contaminant moval in recycled fibre processing.

Separation Processes - Specific Energy & Consistency

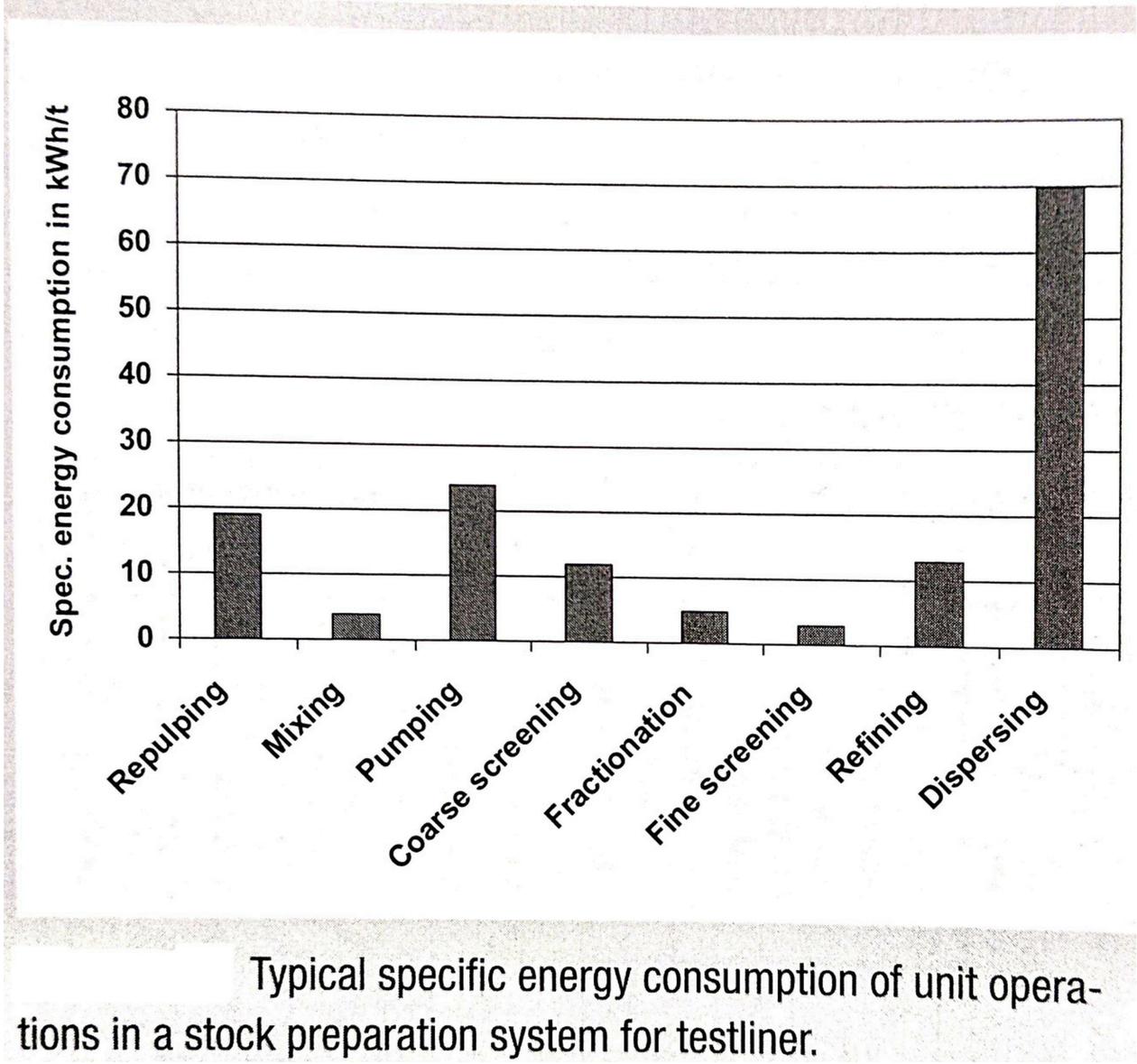
Specific energy consumption and operating consistency of unit processes in recycled-fibre processing.

Unit process	Specific energy demand [kWh/t]	Operating consistency [%]
Slushing pulper	10–40	3–18
Drum pulper (screening)	15–20/40	3.5 – 20/(3.5–6)
Deflaking	20–60	3–6
Screening	5–20	0.5–4
Tailing screen	20–40	1–4
Washing	1.5–20	0.7–1.5 ⇒ 5–12
Dissolved air flotation (DAF)	10–20	< 0.3 ⇒ 0.01
Flotation (selective)	20–50	1–1.3
Centrifugal cleaning	4–8	< 0.5–4.5 (< 6)
Thickening	1–10	0.5 ⇒ 5 (10)
Dewatering-Screw press	10–15	4–10 ⇒ 25–40

Consistency ranges and their different naming in various process stage

eration g	Pulping	Screening	Centrifugal Cleaning	Bleaching	Refi
consistency	< 6 %	< 1.5 %	< 1.5 %	-	3 %
mediate consistency)	-	1.5 % – 2.5 %	1.5 % – 3 %	-	
dium consistency)	< 12 %	2.5 % – 6 %	-	10 % – 15 %	10 %
h consistency)	< 19 %	-	3 % – 6 %	25 % – 35 %	28 %

Recyclability - Stock Preparation (Testliner)



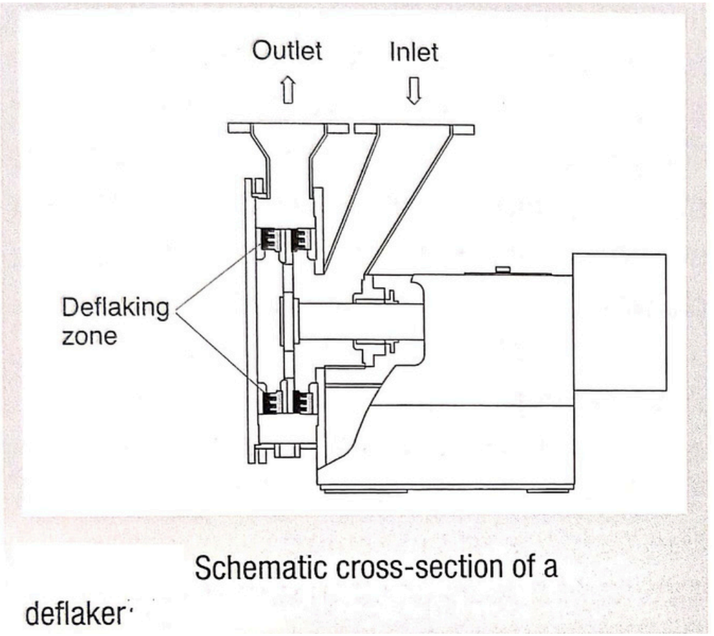
Typical specific energy consumption of unit operations in a stock preparation system for testliner.

Recyclability - Pulping

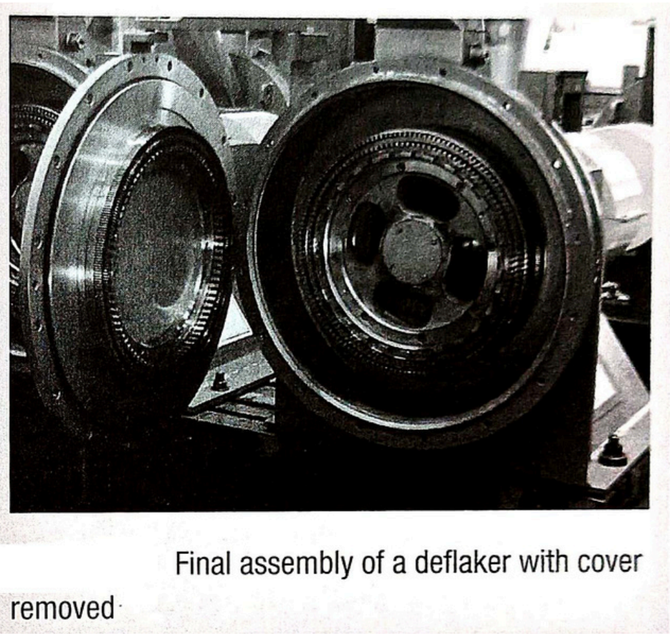
Overview of pulper and drum pulper applications, design features and operating modes.

Type of pulper	Feed		Operating conditions					Machine characteristics				
	Furnish	Condition	Consis-tency [%]	Capacity min [t/d]	Capacity max [t/d]	Slushing time (total) [min]	Operation	Axis	Effective element	Circumf. speed [m/s]	Screening sieve	Pulper diameter [mm]
HC pulper	News Maga-zines	Loose Dewired bales	<19	30	400	15–25	Batch	Vertical	Helical rotor	12–16	No (yes)	<7 100
MC pulper	News Maga-zines	Loose Dewired bales	<12	140	500	20–30	Batch	Vertical	Helical rotor	13–17	No (yes)	<6 000
LC pulper	Fluting Liner High wet strength grades	Loose Opened bales	<6	200	1 600	5–40	Contin. (ragger, Junk separator)	Vertical Horizontal Inclined	Flat rotor with vanes	15–20	Yes	< 8 000
Drum pulper	News Maga-zines Fluting Liner	Loose	<20 (<5)	100	1 600	20–40	Contin.	Horizontal	Drum	1.5–2	Yes (drum)	<4 250

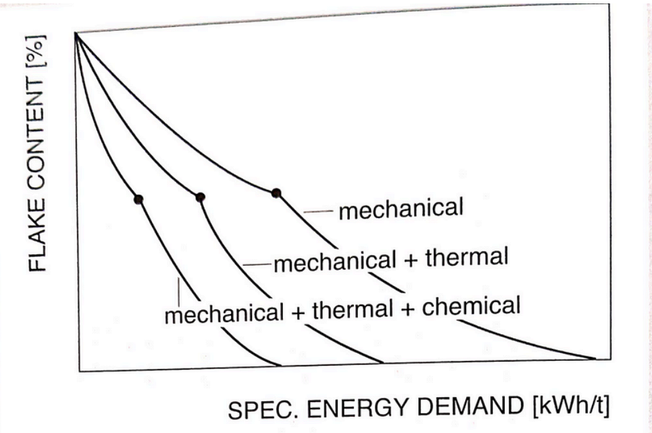
Recyclability - Deflaking



Schematic cross-section of a deflaker

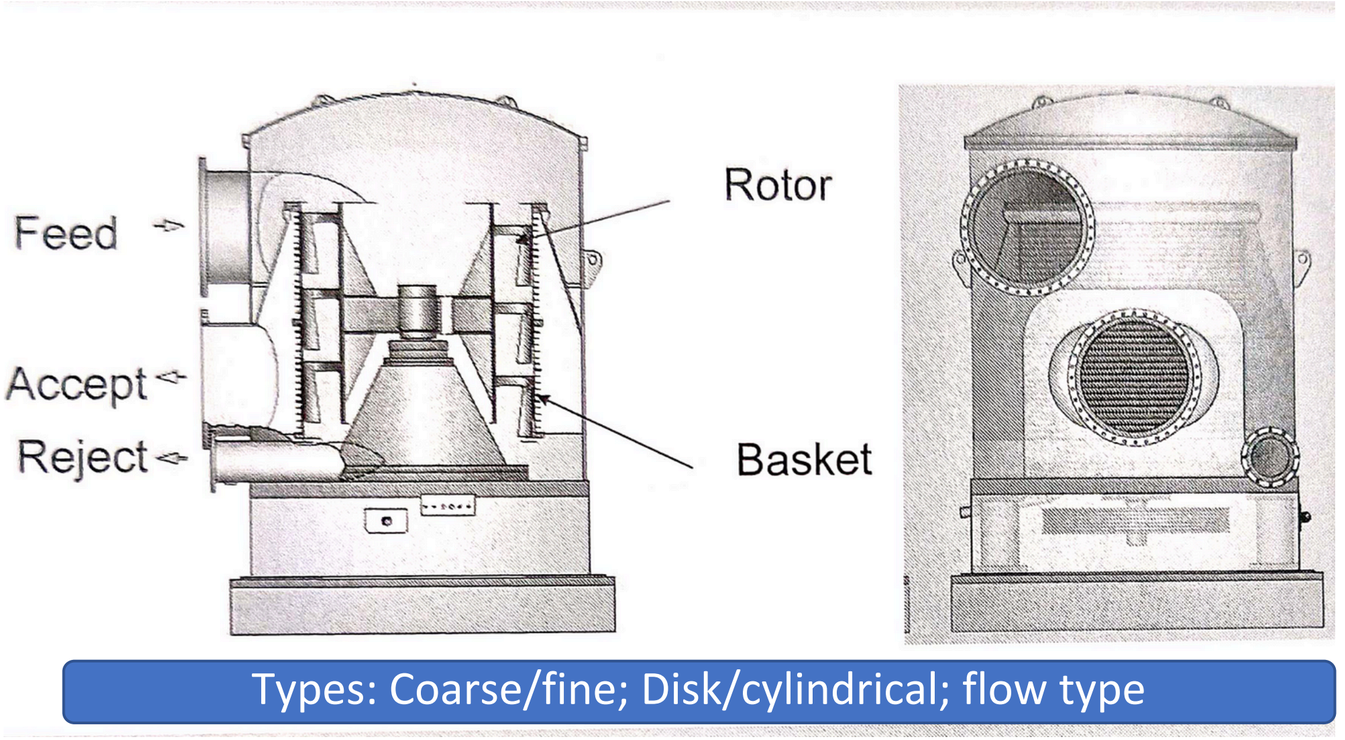


Final assembly of a deflaker with cover removed

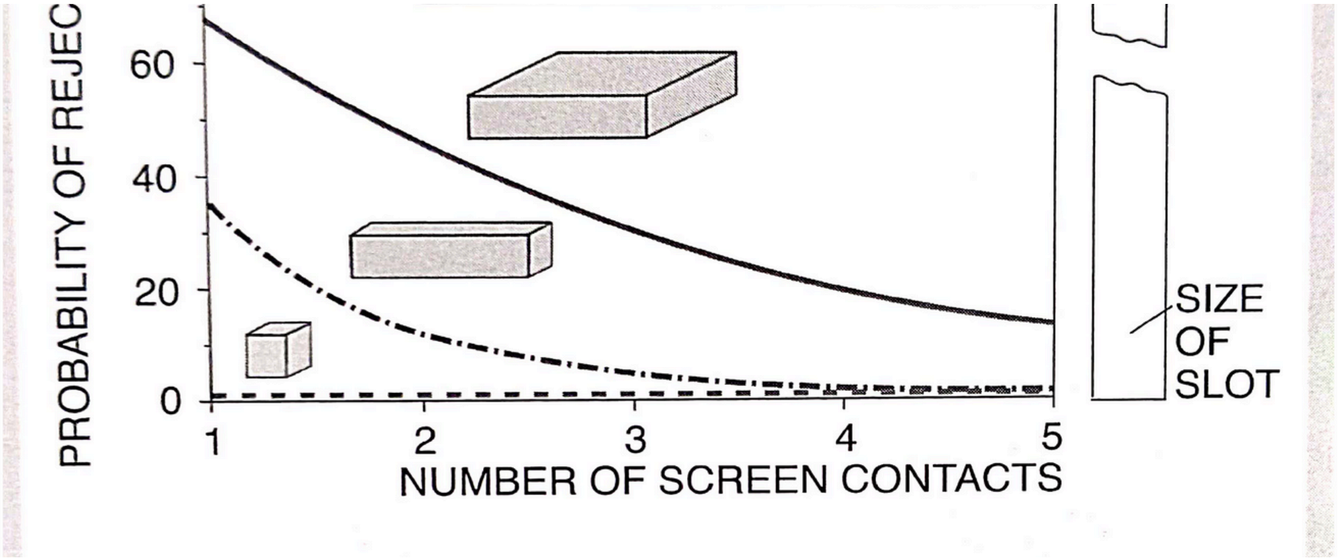


Flake reduction of wet-strength grades by mechanical, mechanical-thermal, and combined mechanical-thermal-chemical treatment.

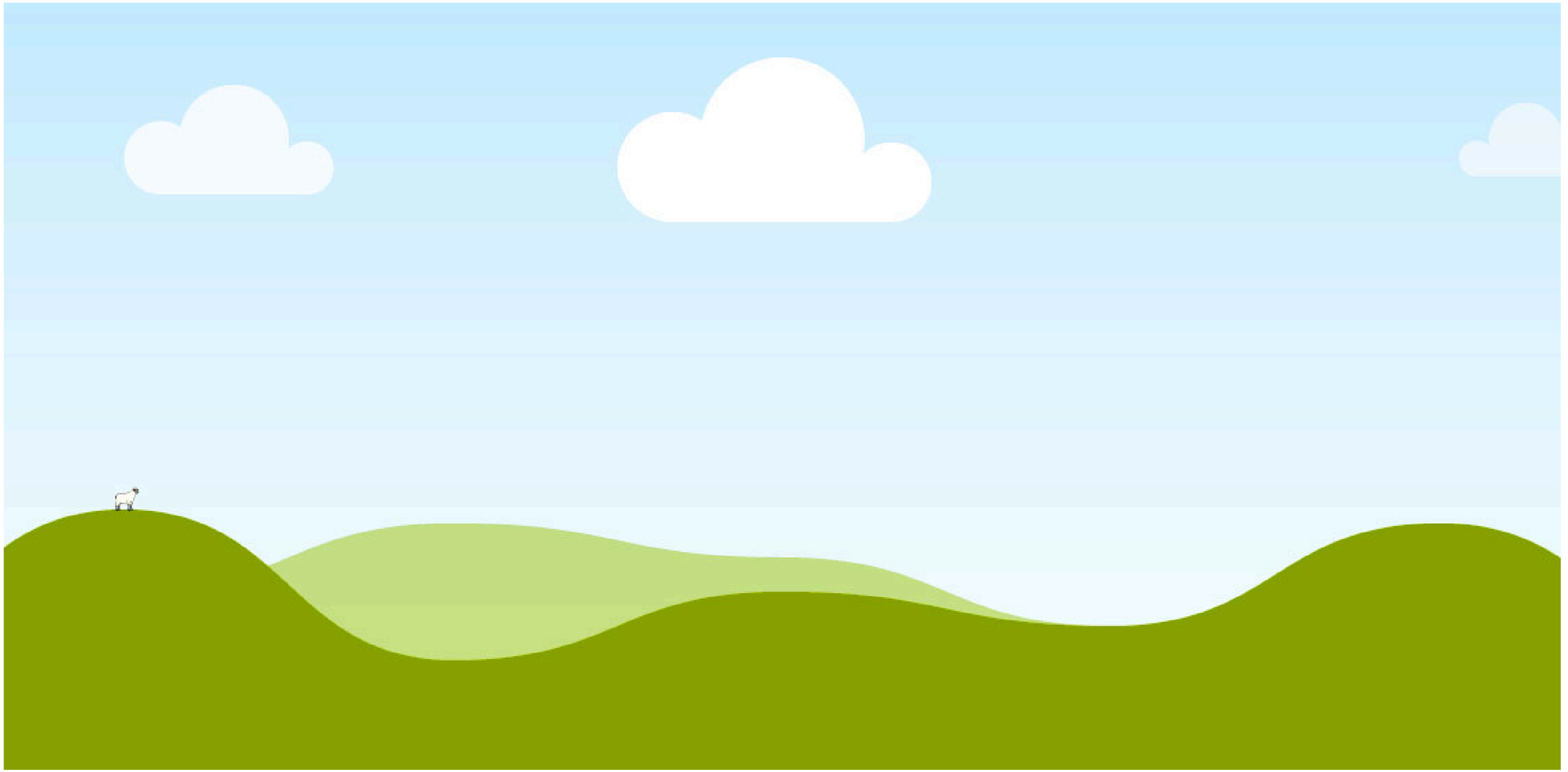
Recyclability - Screens



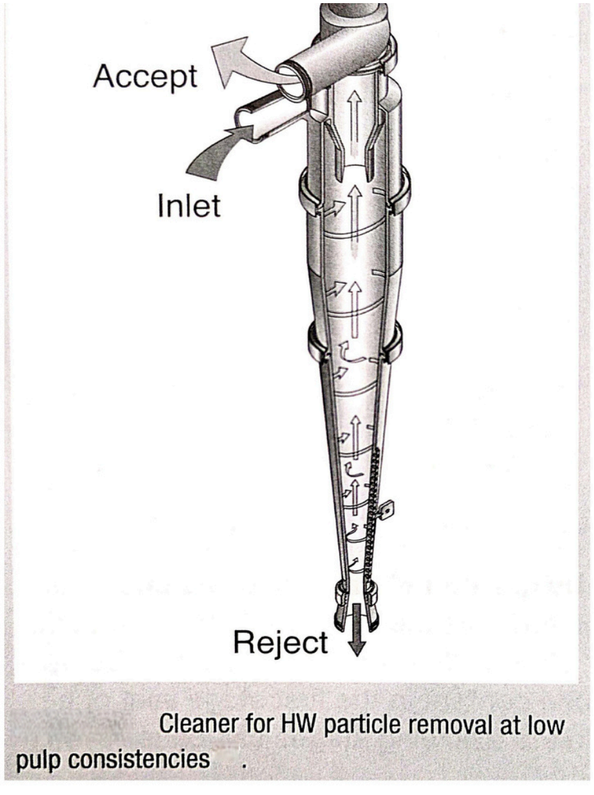
Types: Coarse/fine; Disk/cylindrical; flow type



Recyclability - Separation - Screens



Recyclability - Separation - Cleaner



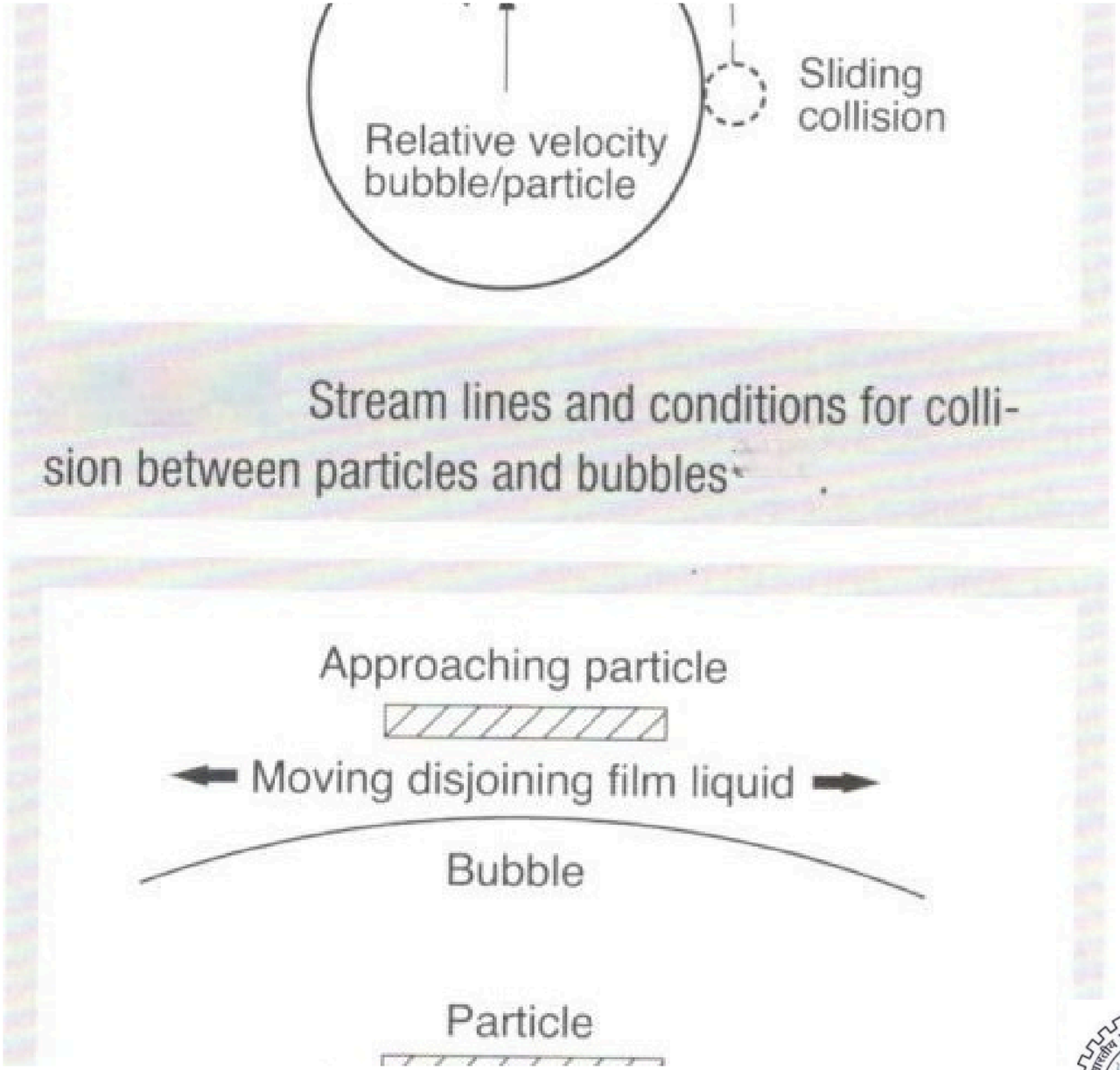
Cleaner for HW particle removal at low pulp consistencies .

Primary features of cleaners for various pulp consistency ranges.

ıner type		HC Cleaner		MC Cleaner	LC Cleaner	
racteristic		with rotor	without rotor		HW	LW
ɛrred flow iple	–	Countercurrent	Countercurrent	Countercurrent	Countercurrent	Unidirecti
istency range	%	2–4.5 (6)	(1–5) 2–6	1–2	0.5–1.5	0.5–1.
ughput per ıer	l/min	100–10 000	80–10 000 (20 000)	600–3 000 (10 000)	100–1 000 (2 000)	100–50 (5 000
. energy umption/stage	kWh/t	0.5–3	0.5–3	1–4	2–10	2–50
sure drop – accept	bar	0.1–1.0	0.4–2 (3)	1–2	0.7–2 (4)	0.8–2
ox. g-factor	–	< 60	< 60	< 100	< 1 000	< 1 00
th ıeter (max) ɛt opening	mm mm mm	3 000 300–700 80–120	2 000–5 000 100–500	3 000–5 000 100–700 40–80	 75–300 10–40	 110–45 40–60
ɛt rate ass/stage	%	0.1–1.0	0.1–1.0	0.1–1.0	5–30	3–20 (0.2)
ɛt discharge inal stage)	–	Batch / continuous	Batch / continuous	Continuous / Batch	Continuous	Continuo
ɛt thickening inal stage)	–	–	–	–	1.5–7	0.2–1.
stage reject ıarge	–	(if any) Batch	(if any) Batch	Batch	Continuous / Batch	Continuo

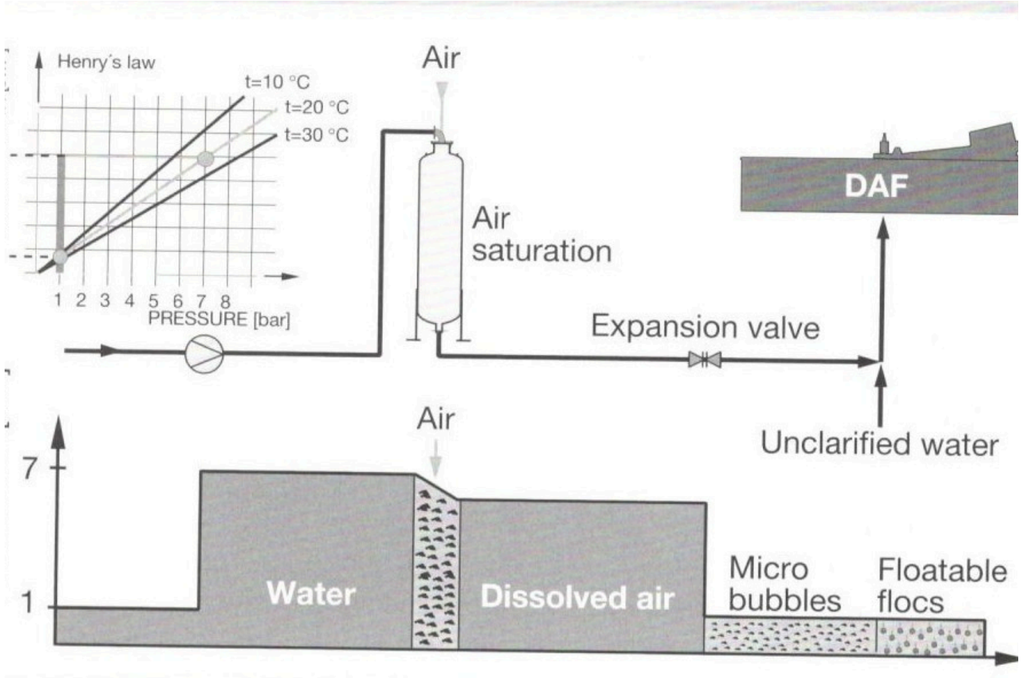
pecial cases

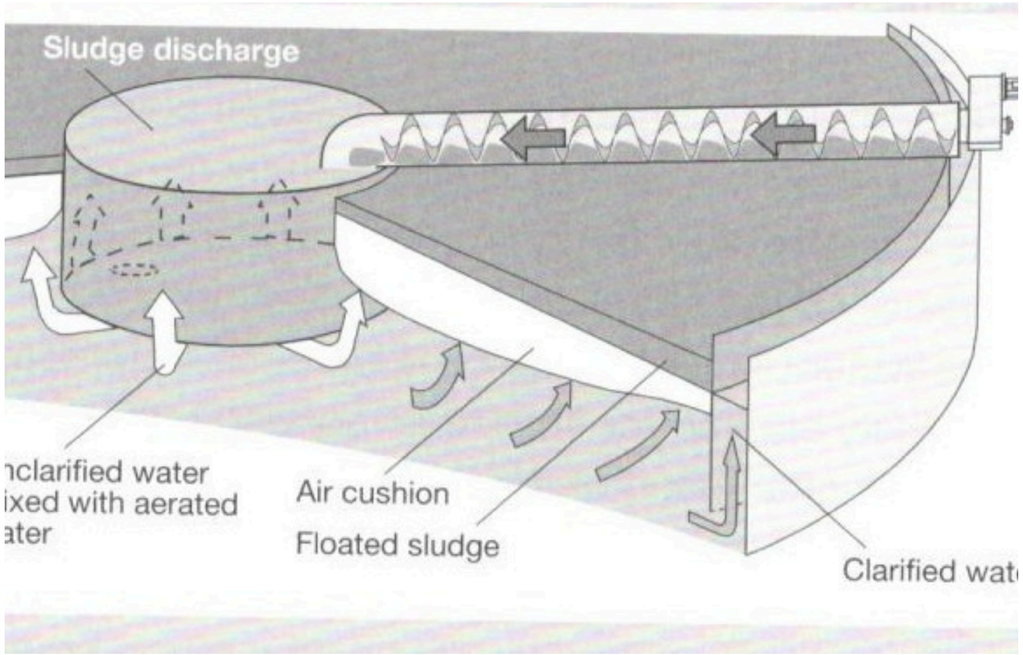
Recyclability - Separation - Flotation



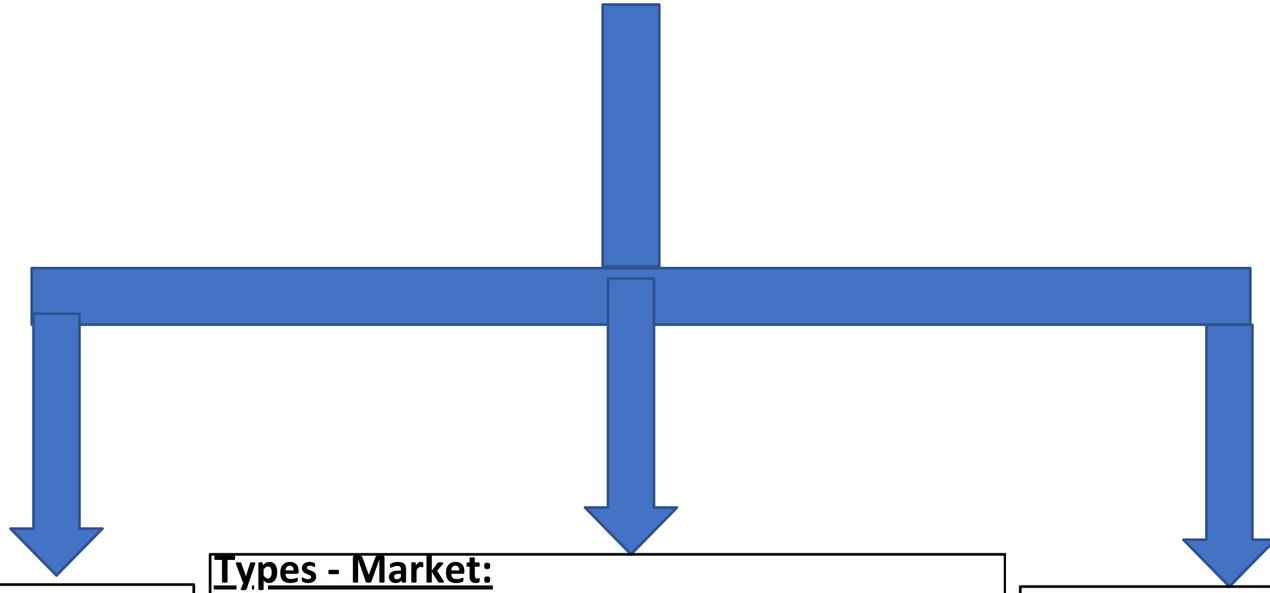
Stream lines and conditions for collision between particles and bubbles

Dissolved Air Flotation - Principle





Recyled Pulp - Flotation



Features:

- Number of Aeration Stages
- Type of Air Supply
- Foam removal methods
- Secondary Flotation
- Closed/Open Cells
- Multiple cell units

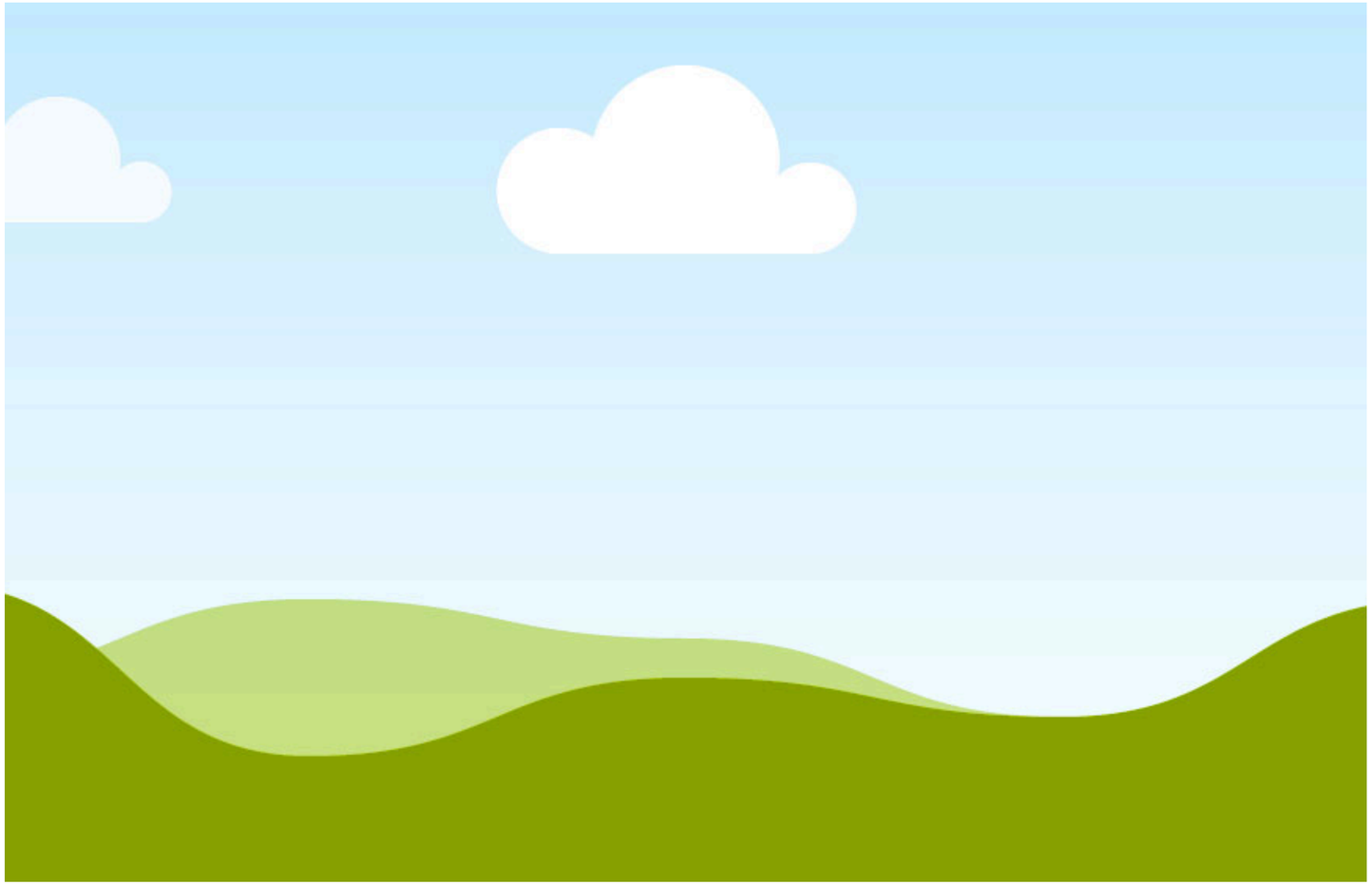
Types - Market:

- **Ahlstrom** – Self-aspiring
- **Comer** – Static mixer & mechanical agitator
- **Kaverner** – Closed system, compressed air injection
- **Lamort** – circular enclosed & pressurized cell –divided into superimposed elementary cells
- **Voith** – self-aspiration static mixing, foam treated in secondary stage

Quality of DIP:

- **Brightness - around 60% (Lab)**
- **Dirspec reduction: around 85%**
- **Solids removal $\propto$ foam removal**

Recyclability - Flotation – Particle Size



Recyclability - Dewatering – Processes

rocesses involved in dewatering.

	Dewatering/Washing	
rocess	**Solid/liquid separation**	**Solid/solid separ**
	Increasing consistency	Fractionation (particl
	Enabling next process step Loop separation Web (sheet forming)	Fines/ash vs. Fibres
	Filtration Pressing	Filtration (Pressing)
	No solids in filtrate	High particle size Separation purity
chinery	Disk filter Belt filter Twin wire press	Washer Recovery filter

Recyclability - Dewatering – Operating Conditions

Operating conditions of different types of dewatering machine.

chine	Separation		Consistency range [%]					Separation efficiency Solids/liquids	Dewatering by			
			Inlet		Outlet							
	Solid/liquid	Solid/solid	< 2.0	> 3.5	5–10	10–20	20–> 30		Gravity	Vacuum	Wire pressure	Pressing
n Filter	■		■		■			→	■			
Filter	■		■		■			↑	■			
Filter	■		■		■			→	■			
pressure Filter	■		■	■	■			→	■		■	
wire press	■		■	■			■	→	■		■	■
w press	■			■			■	↘	■			■
washer		■	■		■			↗			■	

conditions ■

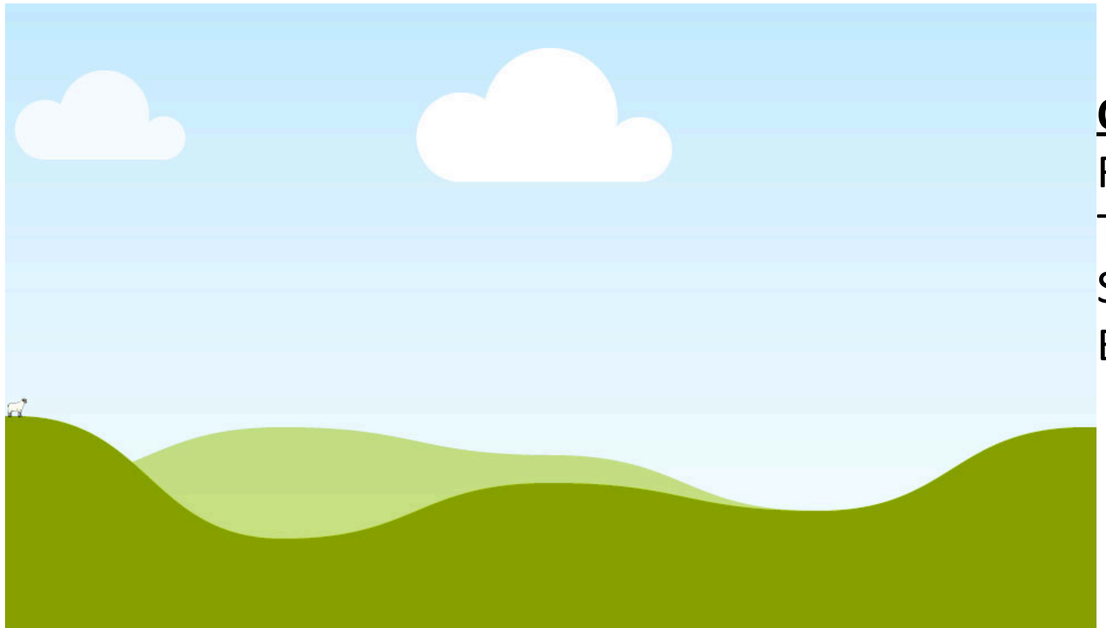
al conditions

↑ Good

→ Average

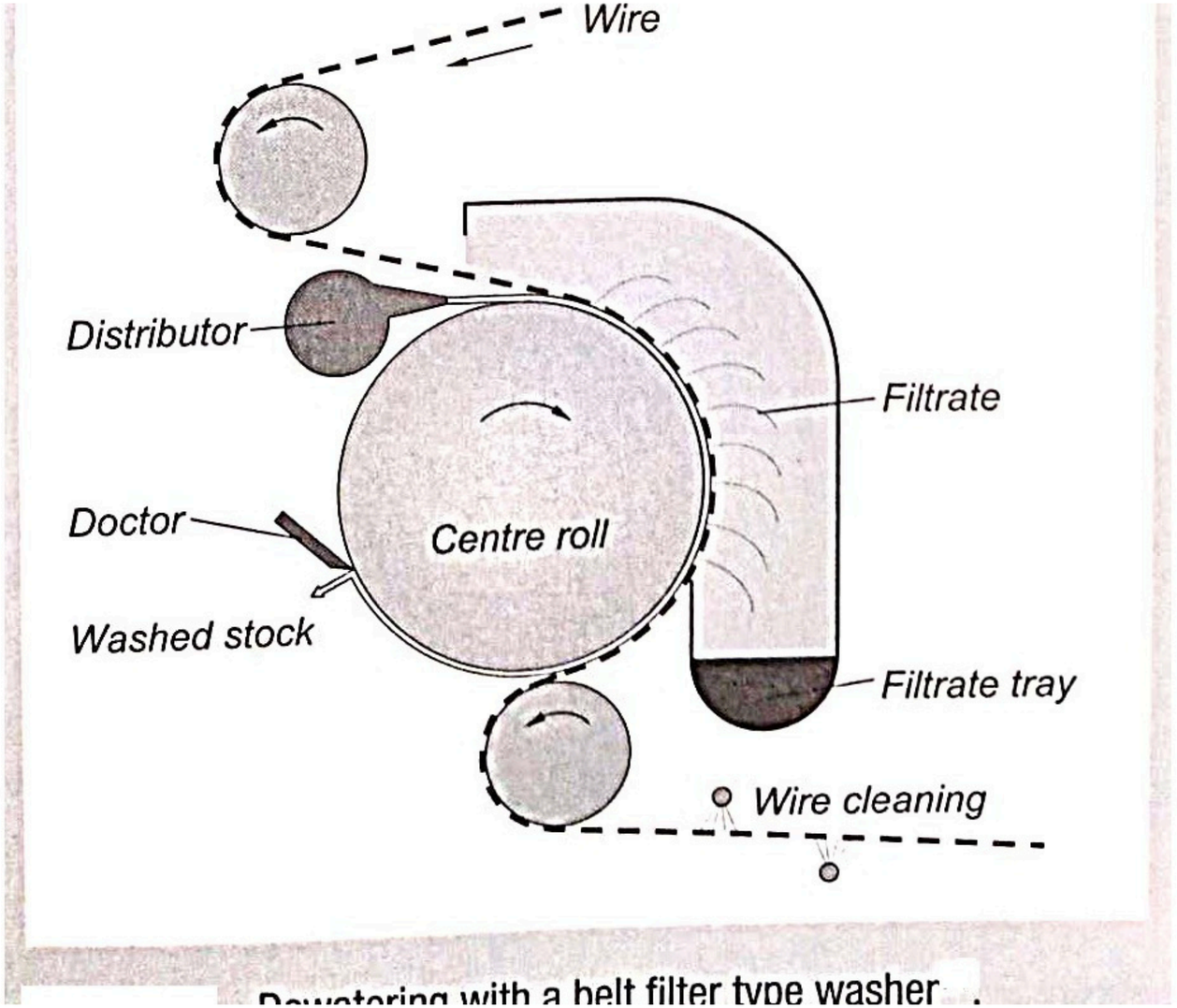
↓ Poor

Flotation - Chemistry



<u>Chemicals</u>:
Fatty Acid
Triglyceride
Silicates
Ethoxylated fatty acids

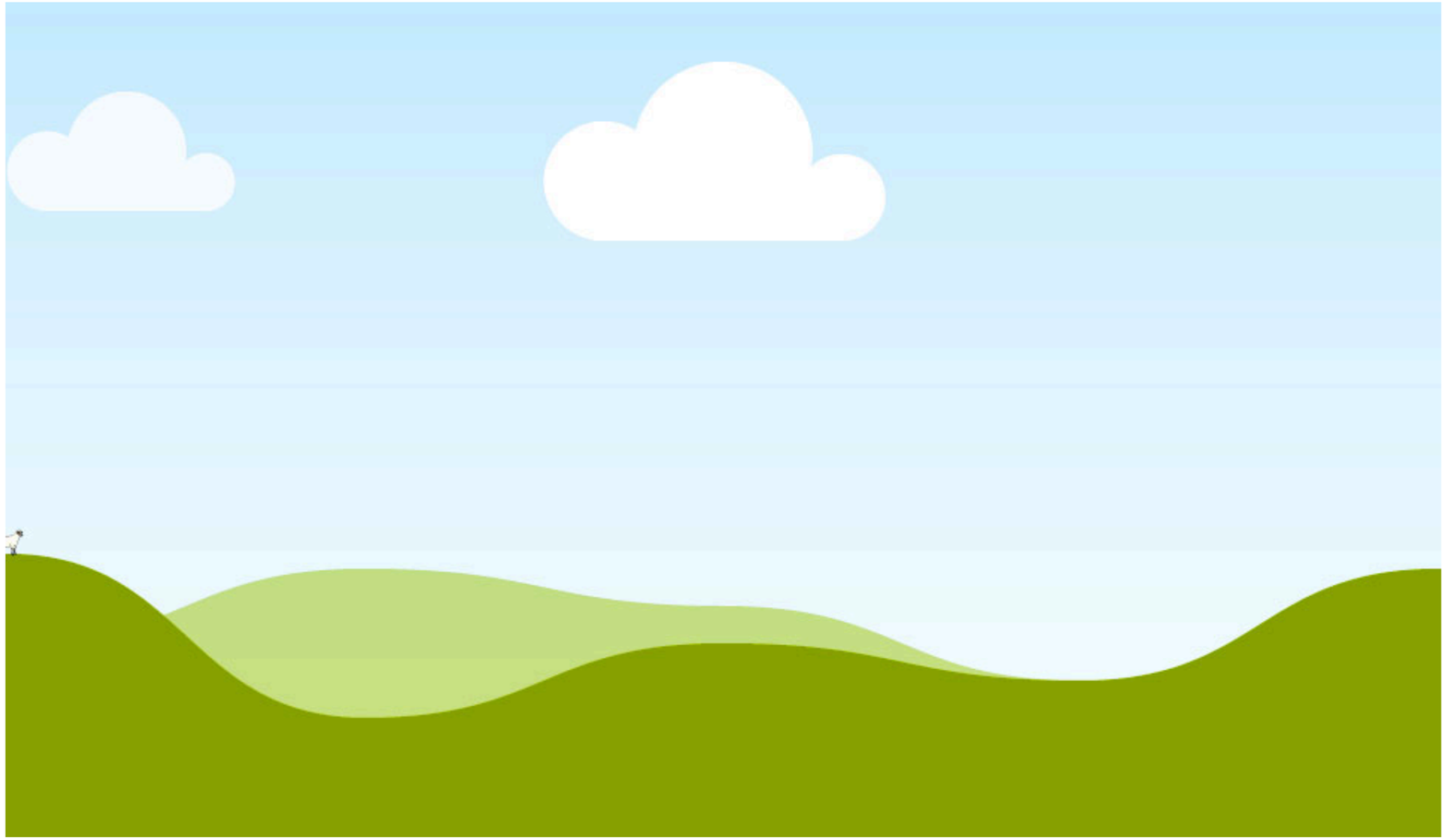
Flotation Chemistry- Ink Removal



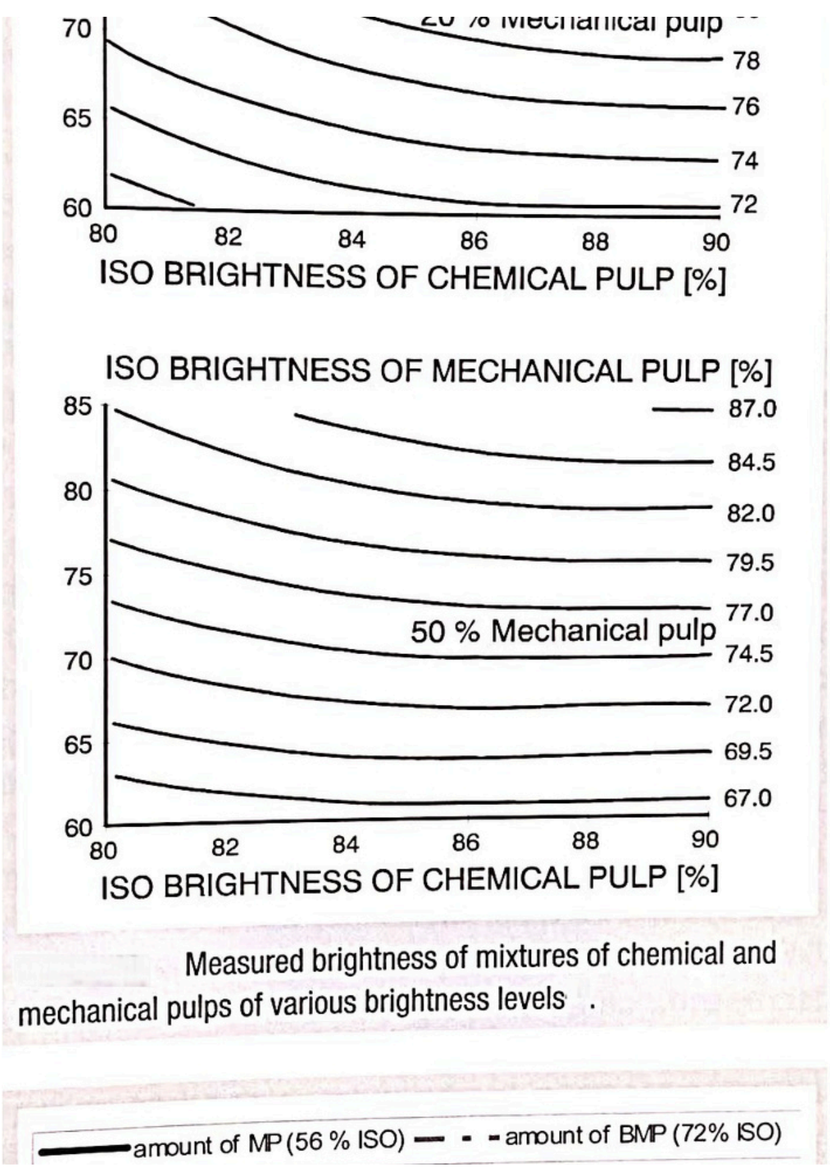
Dewatering with a belt filter type washer

Principle: Vario – Split Washer

Recyclability - Flotation - Defoamer



DIP - Bleaching - Brightness



Measured brightness of mixtures of chemical and mechanical pulps of various brightness levels .

amount of MP (56 % ISO) — - - amount of BMP (72% ISO)

<u>Chemicals</u>: Peroxide, Dithionate, FAS, Oxygen, hypo, ClO_2

<u>Stage</u>: Single/Multiple

Recyclability - Water Treatment

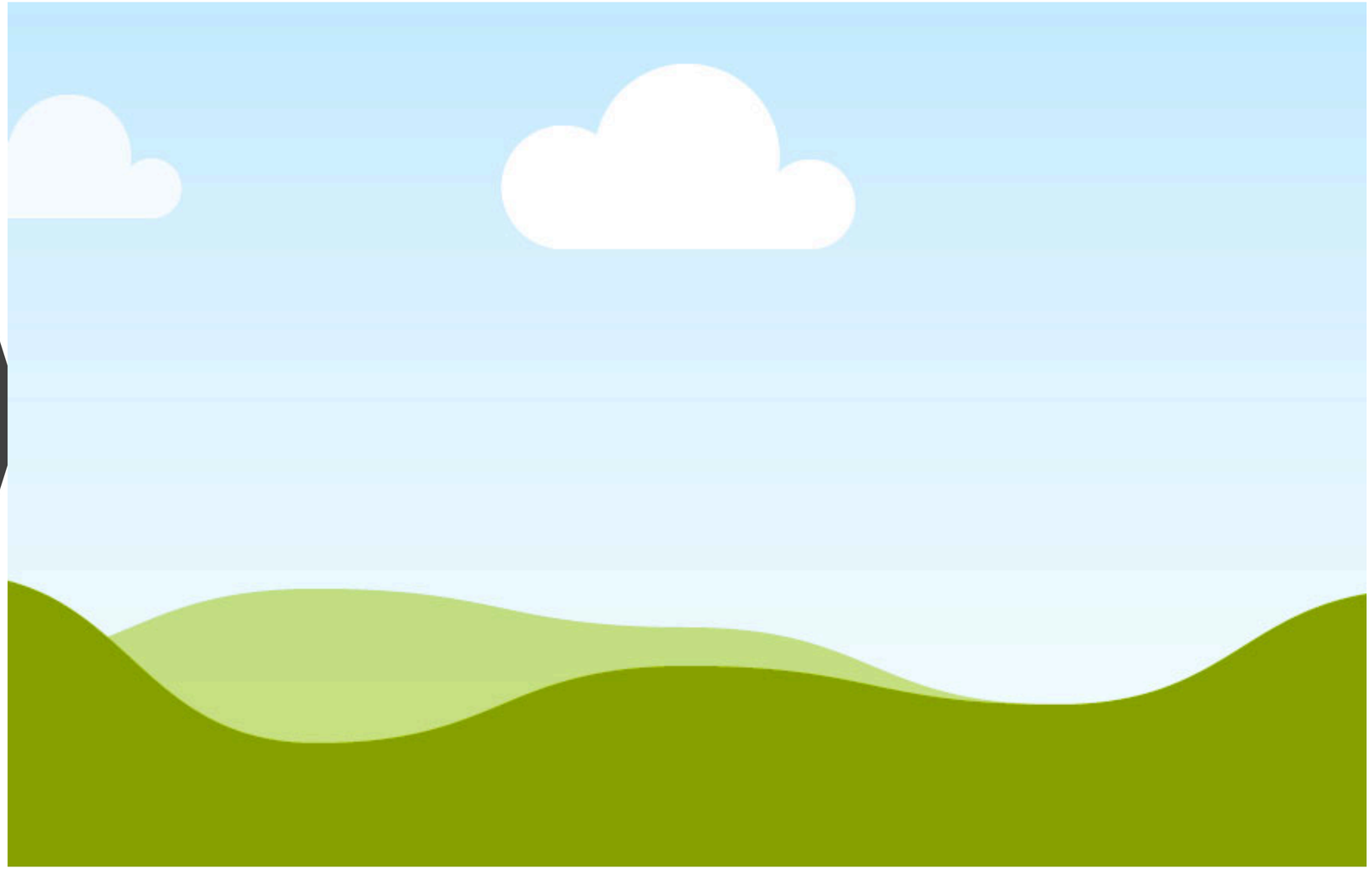
	Sedimentation	Filtration	Dissolve
	big	very low	
ime	big	very low	
rades changing	low	big	
t	moderate	no	
o load kicks	low	low	
rvice	low	low	m
o disturbances	low	low	m
iciency			
Long fibers	good	very good	ve
Short fibers	good	moderate	
Fillers	very good	moderate	m
quality [mg/l]	10–100	10–300	1
	low	very big	
n of reject [%]	1–2.5	8–30	
costs	low	big	m
costs	low	moderate	
umption	very low	low	m
onsumption	low	low	m

Recycled Pulp Manufacture – Layout Design

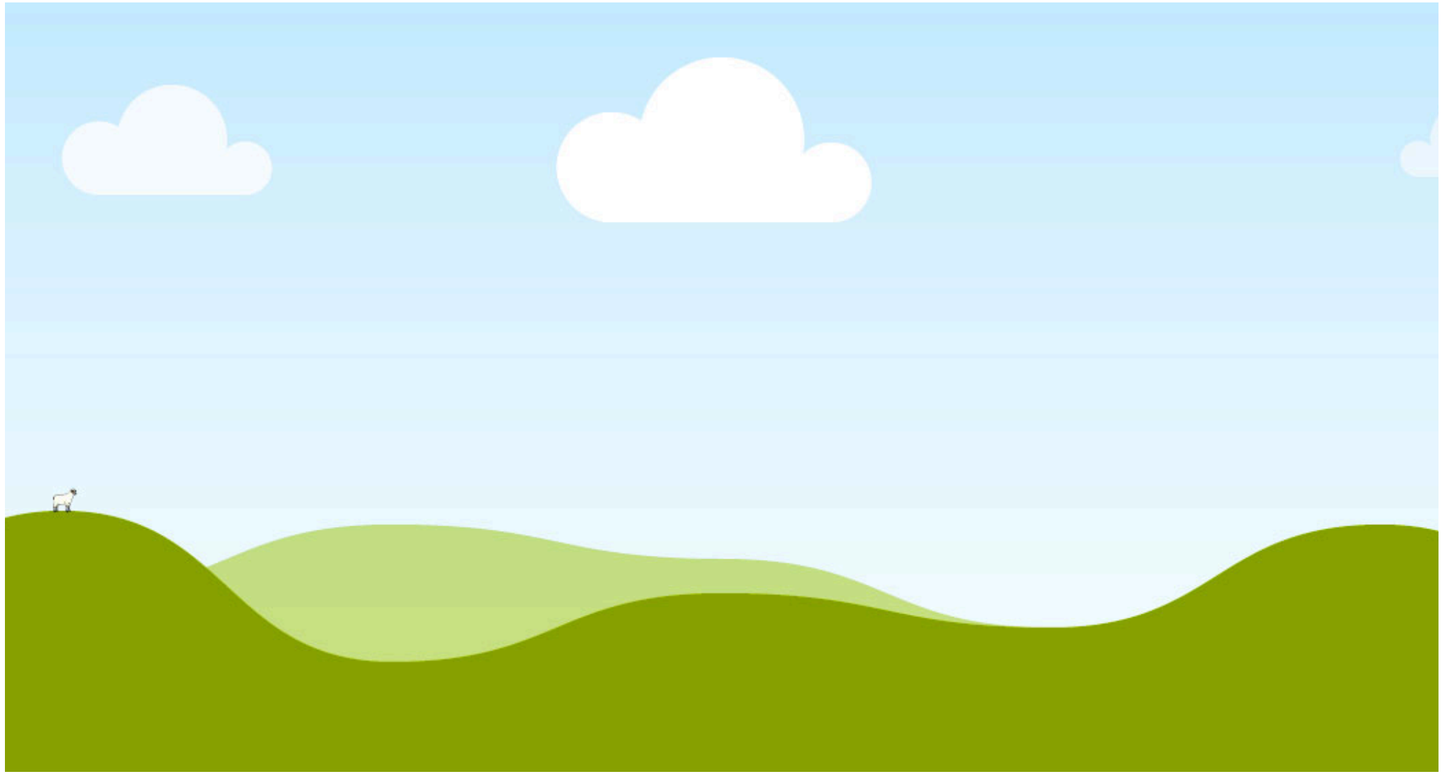
RULES TO PRACTICE

1. Combine Process Steps with Similar consistency
2. Lay out preferable with decreasing consistency
3. Efficiency – Particle size & Fragmentation
4. Avoid – “ Separation Gaps”
5. Combine – Separation with different active principles
6. Optimization (Unit) – Separation efficiency and yield
7. Standardize

DIP –
Layout Design – Newsprint/SC/LWC



DIP
-
LAYOUT DESIGN
-
MARKET PULP



Recycled Pulp Manufacture – Design for Success

Key Design data	Capacity Yield Type/variety of RCF grade to be used
Runnability	Operational availability (over time)
General Targets	Specific effluent volume Overall specific energy demand (heat, power)


ANY
QUESTIONS
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