BP302T · B.PHARM SEMESTER III

BP302T Environmental Sciences

Unit II — Pharmaceutical Waste & Effluent Management

Final Unit Notes

Pills & Python Notes

From-zero teaching standard: every technical term is defined before use.

Waste types · treatment methods · regulatory requirements

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Chapter 2 — Unit II: Pharmaceutical Waste and Effluent Management

2.1 Learning objectives

After studying this chapter, you will be able to:

1. Classify pharmaceutical waste into chemical, expired drugs, packaging and biomedical waste.
2. Explain the Biomedical Waste Management Rules, 2016 — segregation, colour coding, treatment and disposal.
3. Describe CPCB guidelines for pharmaceutical waste in simple words.
4. Explain the design and functioning of an Effluent Treatment Plant (ETP) stage by stage.
5. Compare water purification methods used in pharma — filtration, RO, UV and distillation.

2.2 Definitions (start from zero)

- **Pharmaceutical waste:** Any unwanted material from making, storing, dispensing or using medicines — expired tablets, spilt chemicals, used packaging, contaminated filters.
- **Biomedical waste:** Waste generated during treatment, diagnosis or research on humans/animals — used syringes, blood-soaked cotton, cultures, body parts.
- **Effluent:** Liquid waste flowing out of a factory — in pharma it may contain solvents, acids, alkalis and drug residues.
- **ETP (Effluent Treatment Plant):** A series of tanks and processes inside a factory that cleans its wastewater step by step before discharge or reuse.
- **Purified water:** Water cleaned to a high standard for making medicines — ordinary tap water is NOT acceptable for drug manufacturing.

2.3 Terminology you must know

Segregation at source: Separating different wastes where they are produced (in the lab/ward itself), not mixing them later.

Colour-coded bins: Different coloured bags/bins for different waste types (Yellow, Red, White, Blue under the 2016 rules).

Barcoding: Putting a barcode label on biomedical waste bags so each bag can be tracked from hospital to treatment facility.

CBMWTF: Common Biomedical Waste Treatment Facility — a central plant serving many hospitals/clinics.

Screening: Removing large floating objects (rags, plastics) at the entry of an ETP.

Equalization: Mixing effluent in a large tank so its flow and strength become uniform before treatment.

Neutralization: Adjusting acidic/alkaline effluent to near-neutral pH by adding alkali/acid.

Activated sludge process: Biological treatment where air + useful bacteria digest dissolved pollutants.

RO (Reverse Osmosis): Forcing water through a very fine membrane under pressure; pure water passes, dissolved salts are rejected.

ZLD (Zero Liquid Discharge): A system where no liquid effluent leaves the factory — all water is treated and reused.

2.4 Explanations

2.4.1 Types of pharmaceutical waste

Technical concept: Pharmaceutical waste is classified by origin and hazard: chemical, expired/rejected drugs, packaging, and biomedical waste.

Simple explanation: A pharma factory and a hospital pharmacy throw out four kinds of "rubbish" — leftover chemicals, out-of-date medicines, empty packs, and infectious hospital waste. Each needs a different dustbin and a different final treatment.

Example: Spent methanol from a synthesis lab (chemical waste) → sent to a solvent-recovery or authorised disposal facility; expired antibiotic strips (expired drugs) → incineration; used syringes from a clinic (biomedical waste) → white puncture-proof container.

Flowchart (draw): Four boxes — "Chemical waste (solvents, reagents)" / "Expired drugs (out-of-date, rejected batches)" / "Packaging waste (blisters, bottles, cartons)" / "Biomedical waste (syringes, cultures, soiled dressings)" — each arrow to its own treatment box.

Key takeaway: Never mix the four streams — mixing makes safe waste hazardous and hazardous waste untreatable.

2.4.2 Biomedical Waste Management Rules, 2016

Technical concept: India's rules for safe handling of biomedical waste — segregation into colour-coded categories, labelling/barcoding, storage, transport, treatment and disposal, with duties for occupiers and operators.

Simple explanation: The 2016 rules are a "traffic-signal system" for hospital waste: each waste type gets a fixed colour bin, a label, and a fixed final treatment, so infectious waste never reaches rag-pickers or rivers.

Example: A nurse drops a used needle into the white translucent puncture-proof container (not the yellow bag); the yellow bag with soiled dressings goes for incineration.

Table (draw as real table in PDF): The four colour categories —

Colour category	Waste and treatment
Yellow	infectious/soiled waste, expired/discarded medicines, chemical waste → incineration or deep burial.
Red	contaminated recyclable waste (plastic bottles, tubing) → autoclaving/microwaving/chemical treatment, then recycling.
White (translucent)	sharps including metal sharps → puncture-proof containers → autoclaving/dry-heat/shredding or encapsulation.
Blue	glassware and metallic body implants → disinfection/autoclaving, then recycling.

Key takeaway: Colour decides the fate of the waste — learn Yellow/Red/White/Blue like traffic lights. (As per the latest rules/notifications — always follow the current official colour schedule displayed in your hospital.)

2.4.3 CPCB guidelines (in brief)

Technical concept: The Central Pollution Control Board issues technical guidelines for handling, treatment and disposal of pharmaceutical and biomedical waste, and standards for effluent discharge.

Simple explanation: CPCB is the national "referee" — it writes the rulebook (how to segregate, label, transport, treat) and the Pollution Control Boards in each state act as on-ground umpires giving permissions (consent to operate) and checking compliance.

Example: A pharma unit must obtain consent from its State Pollution Control Board and send its hazardous waste only to an authorised TSDF with a proper manifest (tracking form).

Key takeaway: CPCB makes guidelines; SPCB gives consent and inspects — a pharma unit needs both.

2.4.4 ETP — design and functioning

Technical concept: An ETP cleans industrial wastewater in stages: preliminary → primary → secondary (biological) → tertiary (polishing), plus sludge handling.

Simple explanation: An ETP is like a water-purification "assembly line" — dirty water enters one end, and each tank removes one type of dirt, until clean water comes out the other end.

Example: A bulk-drug unit's effluent first passes a screen (removes rags), then an equalization tank (evens out flow), then neutralization (pH corrected), then an aeration tank where bacteria eat dissolved organics, then a clarifier where clean water separates from sludge, then carbon filtration + disinfection.

Flowchart (draw): Effluent inlet → Screening → Grit/oil removal → Equalization tank → Neutralization → Primary clarifier → Aeration tank (activated sludge) → Secondary clarifier → Tertiary filtration (sand + activated carbon) → Disinfection (chlorination/UV) → Treated water out (reuse/discharge). Side stream: Sludge → thickener → dewatering → authorised disposal.

Key takeaway: Each stage has one job — screens remove big solids, bacteria eat dissolved organics, filters polish the water.

2.4.5 Water purification in pharma — filtration, RO, UV, distillation

Technical concept: Pharma needs Purified Water and Water for Injection; typical train: pre-treatment → RO → UV/ozone → storage/distribution.

Simple explanation: Tap water is cleaned in steps of increasing "fineness" — first big filters, then RO membrane (removes dissolved salts), then UV light (kills germs), then distillation for the purest grade; the clean water circulates in a loop so it never stagnates.

Example: Sand filter removes mud → activated carbon removes chlorine/smell → softener removes hardness → RO removes 95%+ dissolved salts → UV destroys microbes → storage tank → distribution loop to manufacturing.

Diagram (draw): Left-to-right train: "Raw water → Sand filter → Carbon filter → Softener → RO unit → UV → Storage tank → Loop to plant (return line back to tank)".

Key takeaway: Order matters — coarse to fine; RO removes salts, UV kills germs, distillation gives the purest grade.

2.5 Classifications

Pharmaceutical waste (4 types): Chemical waste; expired/rejected drugs; packaging waste; biomedical waste. **Biomedical waste colour categories (2016 rules):** Yellow, Red, White (translucent), Blue. **ETP stages (4):** Preliminary, primary, secondary (biological), tertiary (polishing). **Water purification methods:** Filtration (sand, carbon, micron), softening, RO, UV, distillation, ozonation.

2.6 Mechanisms / processes

- **RO mechanism:** Pressure greater than osmotic pressure pushes water molecules through a semipermeable membrane; dissolved salts, organics and microbes are held back (reject stream).
- **UV disinfection mechanism:** UV-C light damages microbial DNA, so germs cannot multiply — no chemicals added, no residue.
- **Distillation mechanism:** Water boiled → steam leaves salts/microbes behind → steam condensed → highly pure water (used for Water for Injection).
- **Activated sludge mechanism:** Air blown into tank → aerobic bacteria multiply → they consume dissolved organic pollutants as food → bacteria settle as sludge in clarifier → clean water overflows.

2.7 Diagrams (describe for drawing)

> **Four waste streams:** Four labelled bins (chemical drum, expired strip pack, packaging carton, syringe) each with an arrow to its treatment (solvent recovery / incineration / recycling / colour-coded BMW treatment).

> **ETP layout:** Series of labelled tanks with arrows as in 2.4.4, with the sludge line drawn below in a different shade.

> **RO membrane cross-section:** Feed water on left, membrane in middle, "pure water (permeate)" arrow through, "concentrate (reject)" arrow deflected — label "applied pressure > osmotic pressure".

> **Pharma water loop:** Storage tank → pump → UV → points of use → return line back to tank (continuous circulation).

2.8 Flowcharts

> **Biomedical waste journey (2016 rules):** Generation (ward/lab) → segregation into colour-coded bins at source → barcoded labelling → in-house storage (as per latest time norms) → authorised transport → CBMWTF/TSDF treatment → safe disposal → records maintained.

2.9 Infographic concept box

"From Drain to Reuse — the ETP Story" — five tank icons in a row (Screen → Balance → Bugs eat waste → Settle → Polish), each with one-line job description; side box "Sludge also treated!"; footer: "Treat at source — the river is not a dustbin."

2.10 Tables

Table 2.1 — Pharmaceutical waste types and handling

Waste type	Examples	Handling/disposal
Chemical waste	Spent solvents, reagents, lab chemicals	Segregate, label, solvent recovery or authorised TSDF
Expired drugs	Out-of-date tablets, rejected batches	Incineration (yellow category discipline)
Packaging waste	Blisters, bottles, cartons	Segregate; recycle clean material
Biomedical waste	Syringes, cultures, soiled dressings	Colour-coded bins per 2016 rules → CBMWTF

Table 2.2 — ETP stages

Stage	What happens	Removes
Preliminary	Screening, grit/oil removal	Large solids, oil, grit
Primary	Equalization, neutralization, coagulation, settling	Suspended solids, pH imbalance
Secondary	Aeration + bacteria (activated sludge)	Dissolved organics (BOD/COD)
Tertiary	Sand/carbon filtration, disinfection	Fine particles, colour, germs

Table 2.3 — Water purification methods compared

Method	Removes	Notes
Filtration (sand/carbon)	Suspended particles, chlorine, odour	Pre-treatment step
Softening	Hardness (Ca, Mg)	Protects RO membranes
RO	Dissolved salts, most organics/microbes	Core purification step
UV	Microorganisms	No chemicals, no residue
Distillation	Almost everything (salts, microbes, pyrogens)	Highest purity; energy-intensive

2.11 Examples

1. Methanol recovered from a reaction by distillation and reused — chemical waste reduced at source.
2. A hospital ties a barcode label on every yellow bag before handing it to the CBMWTF vehicle.
3. An ETP operator checks pH after the neutralization tank every shift.
4. A pharma plant reuses ETP-treated water for cooling towers and gardening — moving towards ZLD.
5. UV unit installed after RO as a final germ-killing guard before the storage tank.

2.12 Analogies

> **ETP is like a school:** screening is the gate (keeps outsiders out), primary treatment is primary school (basic learning), secondary is high school (deep learning by bacteria), tertiary is college (polishing for the real world).

> **RO membrane is like a very fine sieve for sugar in tea:** water passes, sugar (salts) stays back — except the holes are molecular-size and pressure pushes the water through.

> **Segregation at source is like sorting clothes before washing:** whites, coloureds and delicates washed separately — mixed washing ruins everything, just like mixed waste.

2.13 Pharmacy relevance

- Every pharma manufacturing and hospital pharmacy must manage waste legally — pharmacists supervise disposal of expired drugs and chemical waste.
- ETP operation is a routine compliance duty; treated-water quality decides consent renewal.
- Purified water quality directly affects medicine quality — water is the most-used raw material in pharma.
- Pharmacists train staff in colour-coded segregation — one wrong bin can fail an inspection.

2.14 India context

- The Biomedical Waste Management Rules, 2016 apply across India; SPCBs enforce them through consents and inspections.
- CPCB categorises industries (including pharma) and pushes cleaner technologies; many Indian pharma clusters now work towards Zero Liquid Discharge.
- Common treatment facilities (CBMWTF) serve clusters of hospitals in Indian cities, so even small clinics can dispose of waste legally.

2.15 Key points

1. Four pharma waste streams: chemical, expired drugs, packaging, biomedical — segregate at source.
2. BMW Rules 2016: Yellow (incinerate), Red (treat then recycle), White (sharps), Blue (glass/metal) + barcoding and authorised transport.
3. CPCB frames guidelines; SPCB grants consent and inspects.
4. ETP = preliminary → primary → secondary (bacteria) → tertiary (polish) + sludge handling.
5. Pharma water train: filtration → softening → RO → UV → storage loop; distillation for the purest grade.
6. Goal: treat at source, reuse water, ZLD where required.

2.16 Common confusions

Yellow vs Red bag: Yellow = infectious to be destroyed (incineration); Red = contaminated plastic to be treated then recycled — not the same bin.

RO vs UV: RO removes dissolved salts; UV kills germs — they do different jobs and are used in series, not as alternatives.

ETP vs water purification plant: ETP cleans outgoing dirty water; the purification plant makes incoming clean water for manufacturing.

Disinfection vs sterilization: Disinfection (UV/chlorine) reduces germs to safe levels; sterilization kills all — different targets.

CPCB vs SPCB: Central board = national standards/guidelines; State board = state-level consent and enforcement.

2.17 Common mistakes

Putting sharps in yellow bags instead of white puncture-proof containers.

Mixing chemical waste with general waste, making everything hazardous.

Believing RO alone gives injection-grade water — distillation/validated steps are needed for the highest grade.

Running an ETP only "during inspection" — continuous operation and records are legally required.

Storing biomedical waste beyond permitted time without authorisation.

2.18 Mnemonics

BMW colours: "**Y**ellow = **Y**uck, burn it; **R**ed = **R**ecycle after treatment; **W**hite = **W**ounding sharps; **B**lue = **B**ottles/glass" → "Y-R-W-B: Yuck, Recycle, Wound, Bottle".

ETP stages: "**P**lease **P**repare **S**oup **T**oday" → **P**reliminary, **P**rimary, **S**econdary, **T**ertiary.

Water train: "**F**ilter, **S**often, **R**O, **U**V, **S**tore" → "FSRUS — First Sieve, Remove, Ultraclean, Zap, Store".

2.19 Exam summary

Pharmaceutical waste has four streams — chemical, expired drugs, packaging and biomedical waste — which must be segregated at source. The Biomedical Waste Management Rules, 2016 prescribe colour-coded segregation (Yellow for incineration, Red for treatment-then-recycling, White for sharps, Blue for glass/metal), barcoded labelling, authorised transport to common treatment facilities and record-keeping, with CPCB guidelines and SPCB consents enforcing compliance. An ETP cleans effluent in four stages — preliminary (screening), primary (equalization, neutralization, settling), secondary (activated-sludge biological treatment) and tertiary (filtration, disinfection) — with separate sludge handling, moving towards Zero Liquid Discharge. Pharma water purification follows a coarse-to-fine train: filtration, softening, RO (removes dissolved salts), UV (kills germs) and distillation for the purest grade, stored and distributed in a circulating loop.

2.20 One-minute revision

Four waste streams: chemical, expired, packaging, biomedical. BMW 2016 colours: Yellow-burn, Red-recycle, White-sharps, Blue-glass + barcode + CBMWTF. ETP: screen → balance → neutralize → bacteria eat → settle → polish → disinfect. Water train: filter → soften → RO → UV → store → loop. CPCB guides, SPCB permits. Goal: treat at source, reuse water.

2.21 Exam questions

Short/long questions:

1. Classify pharmaceutical waste and describe the handling of each type.
2. Explain the colour-coded segregation under the Biomedical Waste Management Rules, 2016.
3. Describe the design and functioning of an ETP with a neat flow diagram.
4. Compare RO, UV, filtration and distillation for pharmaceutical water purification.
5. Write a note on CPCB guidelines for pharmaceutical waste management.

MCQs:

1. Expired medicines under BMW Rules, 2016 go into: (a) Red bag (b) Yellow bag (c) White container (d) Blue bag — **Ans: (b)**
2. Sharps are collected in: (a) Yellow bag (b) Red bag (c) White translucent puncture-proof container (d) Blue bag — **Ans: (c)**
3. In ETP, the activated sludge process belongs to: (a) preliminary (b) primary (c) secondary (d) tertiary stage — **Ans: (c)**
4. RO mainly removes: (a) germs only (b) dissolved salts (c) large rags (d) noise — **Ans: (b)**
5. UV treatment kills microbes by: (a) heating (b) damaging DNA (c) filtration (d) chlorination — **Ans: (b)**

Viva questions:

1. What are the four colour categories under the BMW Rules, 2016?
2. Why is segregation at source important?
3. What is the function of the equalization tank in an ETP?
4. Why is water circulated in a loop in pharma plants?
5. What does ZLD mean?

Application-based questions:

1. Your hospital pharmacy has 200 expired antibiotic strips and 50 used syringes. Describe step-by-step how you will dispose of them legally.
2. An ETP's secondary clarifier shows poor settling. List probable causes and corrective actions.
3. Design the water purification train for a new tablet unit and justify the order of units.

2.22 References

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2. Rajagopalan, R. *Environmental Studies*. Oxford University Press.
3. Joseph, B. *Environmental Studies*. Tata McGraw Hill.