Chapter IV: Contamination and hygiene of premises

I. Sources of microbial contamination in premises

Microbial contamination in premises stems from interactions among multiple sources. Humans are a primary contributor, shedding microorganisms from skin, hair, respiratory tract, clothing, and poor hygiene; bacteria like Staphylococcus, Micrococcus, or Corynebacterium, along with viruses, spread through coughing, sneezing, or hand contact.

Air and bioaerosols carry particles with bacteria, fungal spores (Aspergillus, Penicillium, Cladosporium), skin cells, or dust, worsened by poor ventilation, movement, or contaminated HVAC systems. Surfaces and fomites—such as door handles, keyboards, or equipment—accumulate microbes from touch or aerosols.

Water and wet areas promote biofilms in sinks, drains, or tanks, harboring pathogens like Pseudomonas aeruginosa or Legionella pneumophila. Improperly cleaned equipment, raw materials, organic waste (used gloves, culture media), and reused cleaning tools spread contamination.

Finally, poor building design (high humidity, cracks, faulty drainage) and pests (insects, rodents) introduce microbes from outdoors.

II. Contamination in hospital settings

Hospital contamination is the presence of microorganisms on patients, healthcare workers, surfaces, medical devices, air, water, linen, waste, or equipment. It becomes dangerous when these microorganisms are transmitted to vulnerable patients and cause healthcare-associated infections.

II.1. Chain of transmission

Hospital contamination usually follows this chain:

Reservoir → Exit route → Transmission route → Entry route → Susceptible host

For example; a patient colonized with *Klebsiella pneumoniae* contaminates a bed rail. A healthcare worker touches the rail, then manipulates a catheter. The microorganism enters the bloodstream of another patient and may cause infection.

II.2. Main sources of contamination

A. Patients

Patients are major reservoirs of microorganisms. They may carry pathogens on the skin, mucous membranes, wounds, respiratory tract, digestive tract, urine, or blood.

examples: *Staphylococcus aureus*, including MRSA; *Enterococcus* spp., including *Escherichia coli*; *Klebsiella pneumoniae*; *Pseudomonas aeruginosa*; *Acinetobacter baumannii*; *Clostridioides difficile*; *Candida* spp. and respiratory viruses.

Patients at higher risk include elderly patients, newborns, surgical patients, burned patients, immunocompromised patients, and patients with invasive devices.

B. Healthcare workers

Hands are one of the most important vehicles of hospital transmission. They may become contaminated after contact with patients, body fluids, wounds, beds, surfaces, equipment, or medical devices. Risk factors include poor hand hygiene, incorrect glove use, long nails, jewelry, and moving from one patient to another without hand disinfection.

C. Surfaces and fomites

Hospital surfaces can act as reservoirs, especially frequently touched surfaces.

Examples: bed rails; bedside tables; door handles; switches; phones; keyboards; monitors; infusion pumps; stethoscopes; blood pressure cuffs and trolleys.

Some microorganisms can survive for long periods on surfaces, especially *Clostridioides difficile* spores, *Acinetobacter baumannii*, *Enterococcus* spp., and *Staphylococcus aureus.*

D. Medical devices

Medical devices are high-risk sources because they can introduce microorganisms directly into sterile 8□ion, construction work, movement of people, and contaminated ventilation systems.

Important airborne or air-associated microorganisms include: respiratory viruses; *Mycobacterium tuberculosis*; *Aspergillus* spp.; and bacteria carried by dust particles.

Air control is especially important in operating rooms, intensive care units, isolation rooms, hematology units, and transplant units.

F. Water and wet environments

Hospital water systems may contain microorganisms, especially when biofilms develop inside pipes, taps, drains, showers, or water-containing equipment. Common water-associated microorganisms include: *Pseudomonas aeruginosa*; *Legionella pneumophila*; *Acinetobacter* spp.; non-tuberculous mycobacteria and environmental fungi.

Sinks and drains are important reservoirs. Splashing from sinks can contaminate hands, gowns, nearby surfaces, and medical equipment.

G. Waste, linen, and cleaning tools

Medical waste may contain blood, body fluids, dressings, gloves, needles, cultures, or contaminated materials. Poor waste management can contaminate floors, hands, surfaces, and air. Dirty linen and cleaning tools can also spread microorganisms if they are not handled correctly. Contaminated mops, cloths, buckets, and poorly prepared disinfectant solutions can turn cleaning into a source of dissemination.

II.3. Classification of hospital areas according to infection risk

Hospital premises can be classified into different risk zones according to the probability of microbial transmission. This classification depends on the type of patients, their immune status, the type of care provided, the presence of invasive procedures, and the required level of environmental hygiene.

1. Low-risk areas

These are areas where there is usually no direct patient care and where the risk of infection transmission is minimal. Examples: administrative offices; meeting rooms; archives; non-clinical corridors; technical rooms not directly linked to patient care; public administrative areas.

In these areas, cleaning mainly aims to maintain general cleanliness and prevent dust accumulation.

2. Moderate-risk areas

These areas receive patients, but invasive procedures are limited. The infection risk exists but remains moderate if standard hygiene measures are respected.

Examples: conventional hospital wards; long-term care units; rooms of non-infectious and non-immunocompromised patients; outpatient consultation rooms; psychiatry wards; some maternity areas, excluding delivery rooms and neonatal intensive care.

3. High-risk areas

These areas involve fragile patients, complex care, or procedures that may facilitate the entry of microorganisms into the body.

Examples: intensive care units; resuscitation units; rooms of immunocompromised patients; hematology units; oncology units with neutropenic patients; hemodialysis units; endoscopy units; delivery rooms; emergency rooms where invasive procedures are performed; isolation rooms for infectious patients.

4. Very high-risk areas

These areas require strict environmental control because patients are extremely vulnerable or because procedures require maximal asepsis. Examples: operating rooms; surgical intervention rooms; transplant units; protected hematology units; sterile or protected rooms; burn units; neonatal intensive care units; bone marrow transplant units.

Hygiene Rules in Hospital Settings

1. Perform hand hygiene before and after patient contact, before aseptic procedures, after exposure to body fluids, and after touching the patient's environment.
2. Use personal protective equipment correctly: gloves, masks, gowns, and eye protection when needed.
3. Clean and disinfect surfaces regularly, especially high-touch surfaces such as bed rails, door handles, tables, switches, and medical equipment.
4. Respect aseptic technique during invasive procedures, wound care, catheter insertion, injections, and surgical acts.
5. Sterilize or disinfect medical devices according to their use and infection risk.
6. Separate clean and dirty circuits to avoid cross-contamination between sterile material, waste, linen, patients, and staff.
7. Manage waste safely, especially biological waste, sharps, contaminated dressings, and used gloves.
8. Control air and water quality in high-risk areas such as operating rooms, intensive care units, transplant units, and burn units.
9. Apply isolation precautions for patients with transmissible infections: contact, droplet, or airborne precautions.
10. Train healthcare workers regularly and monitor compliance with hygiene and infection-control procedures.

III. Contamination in industrial settings

Industrial contamination is the unwanted presence of microorganisms, chemical residues, physical particles, or allergens in a product, raw material, environment, or production equipment.

2. Main sources of contamination

- **Raw materials:** Raw materials may already contain microorganisms before entering the factory (milk, meat, water; animal-derived products; packaging materials…) . Raw materials can introduce bacteria, spores, yeasts, molds, viruses, toxins, dust, and foreign bodies.
- **Personnel**

Workers are a major source of contamination through:hands; skin; hair; respiratory droplets; clothes; shoes and poor hygiene practices.

Common microorganisms from humans include *Staphylococcus spp.*, *Micrococcus spp.*, *Corynebacterium spp.*, and respiratory viruses.

Good personal hygiene, hand washing, protective clothing, and training are essential.

- **Equipment and surfaces**

Industrial equipment can retain microorganisms if it is badly designed, difficult to clean, damaged, or wet. Risk areas include: tanks; pipes; valves; filling machines; conveyor belts; mixers; cutting machines; packaging lines; drains and dead zones in equipment.

These areas can support biofilm formation, which protects microorganisms from disinfectants.

- **Air and dust**

Air can carry microorganisms, spores, dust, droplets, and particles. It is especially important in pharmaceutical, cosmetic, dairy, bakery, and cleanroom industries. Air contamination is favored by: poor ventilation; open doors; excessive personnel movement; dust-generating powders; poor filtration and construction or maintenance work.

- **Water**

Water is one of the most important sources of industrial contamination. It may be used for washing, formulation, cooling, steam, cleaning, or rinsing.

Water can carry: *Pseudomonas aeruginosa*; coliforms; *Legionella*; non-tuberculous mycobacteria; yeasts and molds; biofilm organisms.

Water systems must be monitored because biofilms can develop in pipes, tanks, filters, and dead legs.

- **Environment and pests**

The production environment can be contaminated by: floors; walls; drains; waste areas; condensation; humidity; insects and rodents. Pests can introduce bacteria, fungi, parasites, and physical contamination.

4. Industrial risk zones

1. Low-risk zones: These areas do not usually contain exposed products (offices; administrative areas; external storage…)

2. Moderate-risk zones: These areas handle raw materials or packaged products, but direct exposure of sensitive products is limited raw-material reception; dry storage; packaging storage; weighing rooms)

3. High-risk zones: These areas contain exposed products or direct product-contact surfaces (mixing rooms; cutting or grinding areas; filling lines; cooling areas; open tanks; packaging of ready-to-use products; clean production rooms; cold rooms).

4. Very high-risk zones These areas require very strict control because the product is highly sensitive or sterile (aseptic filling areas; sterile pharmaceutical production; cleanrooms; production of injectable medicines; infant formula production; ready-to-eat food after heat treatment; high-care food areas; biotechnology production areas). These zones require controlled air, restricted access, validated cleaning, environmental monitoring, and strict personnel hygiene.

IV. Management of contamination

Contamination management is based on prevention, monitoring, and corrective action.

A. GMP and GHP

Good Manufacturing Practices and Good Hygiene Practices include:

- personal hygiene;
- clean clothing;
- controlled raw materials;
- equipment maintenance;
- pest control;
- water quality control;
- cleaning and disinfection;
- waste management;
- documentation.

B. HACCP

HACCP means Hazard Analysis and Critical Control Points. It is used to identify hazards, determine critical control points, define limits, monitor production, and apply corrective actions.

Examples of critical control points:

- pasteurization;
- sterilization;
- cooling temperature;
- metal detection;
- filtration;
- aseptic filling;
- water treatment.

6. Cleaning and disinfection

A. Cleaning

Cleaning removes visible dirt, organic matter, grease, dust, and residues. It must always come before disinfection. Main steps:

1. remove gross dirt;
2. rinse;
3. apply detergent;

4. scrub or circulate cleaning solution;
5. rinse again;
6. inspect cleanliness;
7. disinfect if required.

Organic matter can protect microorganisms and reduce disinfectant activity.

B. Disinfection

Disinfection reduces microorganisms to an acceptable level. It does not always destroy bacterial spores.

Common disinfectants:

- chlorine compounds;
- peracetic acid;
- hydrogen peroxide;
- alcohols;
- quaternary ammonium compounds;
- aldehydes;
- steam or hot water.

C. Cleaning-in-place and sterilization-in-place In closed industrial systems, cleaning may be done by:

- **CIP**: Cleaning-in-place;
- **SIP**: Sterilization-in-place.

These methods are common in dairy, beverage, pharmaceutical, and biotechnology industries.

Indicative spectrum of activity of common disinfectants

The role of disinfectants is to destroy or reduce microorganisms present on surfaces, equipment, materials, and industrial premises.

- **Alcohols** are effective against vegetative bacteria and many enveloped viruses, but they are not sporicidal**.**
- **Quaternary ammonium compounds** are more active against Gram-positive bacteria than Gram-negative bacteria and are generally ineffective against spores.
- **Chlorine compounds** have a broad spectrum and may act on spores at suitable concentration and contact time.
- **Aldehydes**, especially glutaraldehyde and formaldehyde, have broad antimicrobial activity and may be sporicidal under correct conditions.
- **Peroxides and peracetic acid** are strong oxidizing agents and can be useful against bacteria, fungi, viruses, and spores depending on formulation.