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BIOCIDES IN THE HEALTHCARE ENVIRONMENT

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LECTURE OVERVIEW

- Background
- Definitions
- Usage of biocides in the healthcare environment
- Factors affecting the efficacy of biocides
- Biocides use, misuse and consequences
- Conclusion

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OBJECTIVES

- Understand the use of biocides in the healthcare environment
- Understand the factors influencing biocidal activity
- Review the important types of biocide and some of their usage

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RATIONALS FOR USING CHEMICAL BIOCIDES

- The control of micro-organisms is of prime importance in hospital and industrial environments but also in domiciliary environment
- In hospital there is the additional consideration of patient care
  - protection from nosocomial infection
  - prevention of cross-infection
- Preservation of pharmaceutical preparations
  - prevention of microbial spoilage
  - minimising risk of consumer/patient acquiring an infection

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DEFINITIONS

- **DISINFECTION**
  - removal of micro-organisms including pathogenic ones from the surfaces of inanimate objects
  - not necessary the destruction of all micro-organisms but the reduction of micro-organisms to an acceptable level
- **ANTISEPSIS**
  - destruction or inhibition of micro-organisms on skin and living tissue
- **CLEANING**
  - removal of all foreign material (e.g. soil, blood)

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DEFINITIONS

- **PRESERVATION**
  - prevention of microbial spoilage of products and decreasing risk of infection when the preparation is administered
  - preservatives should prevent the proliferation of micro-organisms in non-sterile products
  - preservatives should kill micro-organisms in sterile products
- **STERILIZATION**
  - complete elimination of micro-organisms including bacterial spores
  - sterility – "is the absence of viable micro-organisms"

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

- **HIGH-RISK**
  - high-level disinfection
  - contact with sterile body area
  - critical items
- **INTERMEDIATE RISK**
  - intermediate-level disinfection
  - contact with mucous membranes
  - contamination with virulent/transmissible organisms
  - semi-critical items
  - highly susceptible patients
- **LOW RISK**
  - low-level disinfection (cleaning and drying)
  - contact with intact skin
  - non-critical items

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

MAIN WANTED CHARACTERISTICS

- **Antimicrobial activity**
  - broad spectrum
  - rapid activity
  - retain stability / pH
  - retain stability / TC
  - retain activity OL/ HW
  - retain activity / dilution
  - *residual activity*
- **Safety**
  - low toxicity
  - degradable

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

MAIN WANTED CHARACTERISTICS

- **Formulation and usage**
  - no or low corrosiveness
  - no odour
  - non staining
  - good wetting and detergency
  - easily combined with liquid or powder
  - compatible with other chemicals
  - cost-effective

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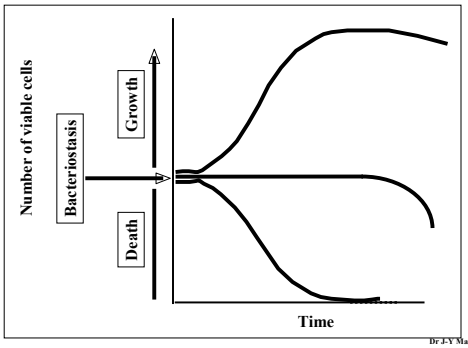
BIOCIDES PROPERTIES

- **INACTIVATION KINETIC**



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BIOCIDES PROPERTIES

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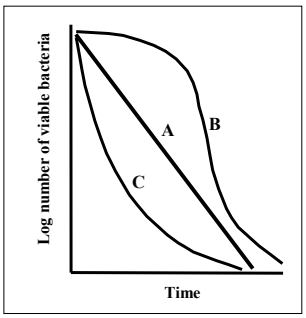

- evaluation of efficacy
- biocide-microbial interactions
- emergence of microbial resistance
- factors influencing activity

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FACTORS INFLUENCING EFFICACY IN PRACTICE

- **Several factors affect the efficacy of disinfection**
  - concentration
  - contact time
  - temperature
  - pH
  - organic load
  - organisms
  - 'conditions'
  - formulation
- **Their practical significance for the end-product and its usage is rarely discussed**

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FACTORS INFLUENCING EFFICACY IN PRACTICE

CONCENTRATION

- An effective concentration is needed - safety
- Concentration depends on - biocide (type)
  - usage
- Effective concentration - reduce microbial load to a 'safe' level
- Failure to be aware of the 'concentration' factor - improper usage
  - misleading claims

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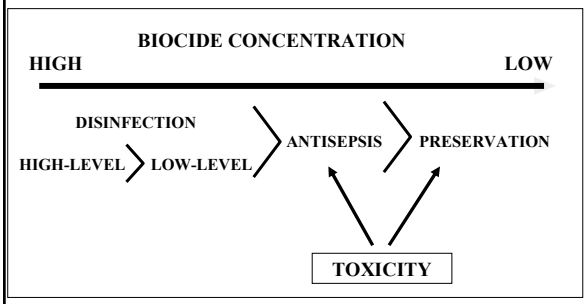
FACTORS INFLUENCING EFFICACY IN PRACTICE

CONCENTRATION



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FACTORS INFLUENCING EFFICACY IN PRACTICE

CONCENTRATION

- Understanding the concentration exponent (η) - $C_1^{\eta}T_1 = C_2^{\eta}T_2$
  - predicting efficacy
- Practical meaning
  - phenol has a concentration exponent of 6
  - its activity reduced by the power of 6 upon dilution
  - two-fold dilution means a decrease in activity of $2^6 = 64$!
- Practical applications
  - use of effective and safe concentrations of biocides
  - evaluation of biocidal activity
  - effective quenching (neutralisation) of biocides

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FACTORS INFLUENCING EFFICACY IN PRACTICE

CONTACT TIME

- The period of treatment is important
  - compliance
  - hand washing
  - "sterilization"
  - Manufacturers
- No straight relationship with concentration - longer contact time = better efficacy
- Length [duration] of survival

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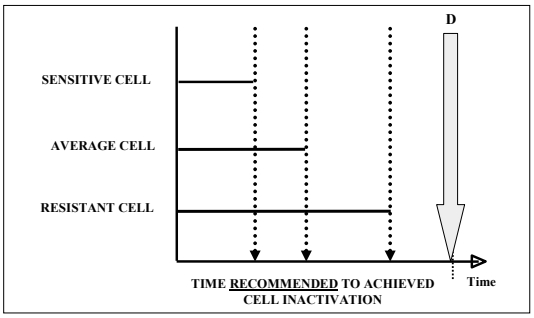
FACTORS INFLUENCING EFFICACY IN PRACTICE

CONTACT TIME



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FACTORS INFLUENCING EFFICACY IN PRACTICE

TEMPERATURE

- Temperature efficacy relationship (Q_{10} value)
  - phenol 4
  - butanol 28
  - ethanol 45
  - ethylene glycol mono-ethyl ester 300

$$Q_{10} = \frac{\text{Time to kill at T°C}}{\text{Time to kill at (T + 10)°C}}$$

- Practical meaning
  - Q_{10} for phenol is 4
  - a 10ºC decrease in temperature reduces the activity by a factor of 4
- Practical applications
  - activity upon storage (preservative)
  - enhanced activity (combining heat + biocide)

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FACTORS INFLUENCING EFFICACY IN PRACTICE

pH

- A change of pH affects
  - biocide activity
  - micro-organisms
- pH affects the degree of ionization (acid or base)
  - if the active species is the non-ionized molecule
    - phenols, acetic acid, salicylic acid
    - increase pH= decrease activity
  - if the active is the ionized molecules
    - dyes
    - increase pH = increase activity

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FACTORS INFLUENCING EFFICACY IN PRACTICE

pH

- Stability of the molecules
  - thiomersal (degradation pH<7)
- Usage
  - glutaraldehyde
- Micro-organisms
  - surface charge
  - growth

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FACTORS INFLUENCING EFFICACY IN PRACTICE

pH

- Increasing activity as pH rises
  - increase in degree of ionization compounds and changes in bacterial surface groups
    - QACs
    - chlorhexidine
  - competition with H^+ for anionic sites
    - diamines
    - acridines
    - triphenylmethane dyes
  - increase reactivity (with –amino group)
    - glutaraldehyde

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FACTORS INFLUENCING EFFICACY IN PRACTICE

pH

- Decreasing activity as pH rises
  - increased dissociation of molecule
    - phenols
  - dissociated molecule makes only a minor contribution to antimicrobial activity
    - benzoic acid
    - sorbic acid
  - active factor is the un-dissociated molecule
    - hypochlorites
    - iodine

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FACTORS INFLUENCING EFFICACY IN PRACTICE

pH

- Practical applications
  - activity upon storage (preservative)
  - formulations
  - activation

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FACTORS INFLUENCING EFFICACY IN PRACTICE

ORGANIC MATTER (INTERFERING SUBSTANCES)

- Interfering substances decrease biocide activity (blood, pus, soiling, milk etc.)
  - decreasing amount available (absorption)
  - protection
- Practical applications
  - cleaning process
  - biocide properties
  - some biocides may exert a detergent action
  - some detergents may exhibit some biocidal activity

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FACTORS INFLUENCING EFFICACY IN PRACTICE

INOCULUM SIZE AND TYPES OF MICRO-ORGANISMS

- Extent of microbial contamination is important
  - higher concentrations
  - longer contact time
- Different micro-organisms have different susceptibility to biocides
  - High-level
    - prions
    - bacterial spores
    - protozoal oocysts
    - mycobacteria
  - Intermediate-level
    - naked viruses
    - protozoal cysts
    - vegetative Gram$^-$
  - Low-level
    - fungi
    - protozoa
    - vegetative Gram$^+$
    - enveloped viruses

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FACTORS INFLUENCING EFFICACY IN PRACTICE

INOCULUM SIZE AND TYPES OF MICRO-ORGANISMS

- Practical applications
  - extent of microbial contamination difficult to assess
  - should represent the worst case scenario
    - efficacy *vs.* toxicity
  - in laboratory-based inactivation experiments, the inoculum size should be controlled and clearly stated
  - highly infectious or virulent micro-organisms should be eliminated
    - Hepatitis B virus
    - *E. coli* O157

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FACTORS INFLUENCING EFFICACY IN PRACTICE

MICROBIAL GROWTH CONDITIONS

- The association of bacteria with solid surface leads to the formation of biofilms
  - less sensitive to disinfection
- Biofilms and resistance
  - low metabolism
  - dormant cells
  - penetration
  - biofilm phenotype
- Biofilms and infections
  - catheters
  - heart valves
  - implanted ocular lenses
  - intrauterine devices

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FACTORS INFLUENCING EFFICACY IN PRACTICE

MICROBIAL GROWTH CONDITIONS

- Growth conditions
  - physical conditions
  - chemical conditions
  - suspension *vs.* biofilm
- Practical significance
  - highly resistant microbial communities
  - testing protocols

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FACTORS INFLUENCING EFFICACY IN PRACTICE

'CONDITIONS'

- Surface
  - porous
  - non-porous
  - animate
- Practical significance
  - reduction of adhesion
  - 'facilitated' disinfection

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FACTORS INFLUENCING EFFICACY IN PRACTICE

'CONDITIONS'

- Water activity
  - hard water
  - divalent cations
- Relative humidity
  - gaseous disinfectants ethylene oxide, ß-propiolactone, formaldehyde
- Incompatibility
  - neutralisation
- Practical significance
  - preparation of disinfectants
  - pre-humidification
  - knowledge of product

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FACTORS INFLUENCING EFFICACY FORMULATION

SURFACE ACTIVITY

- Surface activity and biocide efficacy
  - surface active agents
- Practical significance
  - potentiation of activity
  - delivery of active
  - incompatibility

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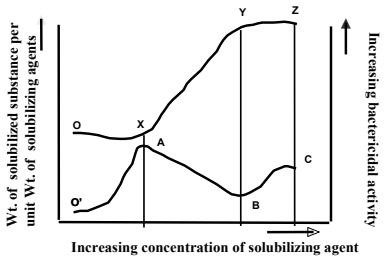
FACTORS INFLUENCING EFFICACY FORMULATION



OXYZ: Solubilization curve

O'ABC: Bactericidal activity

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

LIMITATIONS

- Toxicity
  - end user
  - environment
  - the use of high concentrations might not be acceptable because of the high toxicity for the environment
- Alteration of the surface/equipment
  - corrosiveness
  - colour formation
- Incompatibility with other components of a formulation
- Overall efficacy against a given predicted micro-organism

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

HIGH-LEVEL DISINFECTION

- Aldehydes
  - pH >7
  - *soiling*
  - non corrosive
  - toxic
  - glutaraldehyde
  - ortho-phthalaldehyde
  - formaldehyde
    - fumigation

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

HIGH-LEVEL DISINFECTION

- Peroxygens
  - pH<7
  - *soiling*
  - degradable
  - hydrogen peroxide
  - peracetic acid
- Hypochlorites (CRAs)
  - pH<7
  - soiling
  - corrosive to metal
  - sodium hypochlorites

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

INTERMEDIATE/LOW-LEVEL DISINFECTION

- Biguanides
  - pH >7
  - *soiling*
  - incompatible with soap and anionic detergents
  - inactivated by hard water, some materials and plastic
  - chlorhexidine
  - polyhexamethylene biguanide (contact lenses)

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

INTERMEDIATE/LOW-LEVEL DISINFECTION

- **Quaternary ammonium compounds (QACs)**
  - **cetrimide**
    - **pH>7**
    - ***soiling***
    - **incompatible with soap and anionic detergents**
    - **absorbed by rubber/plastic**
    - **absorbed by fabric**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

INTERMEDIATE/LOW-LEVEL DISINFECTION

- **Halogen realising agents (HRAs)**
  - **iodine**
    - **pH<7**
    - **soiling**
    - **staining**
    - **may corrode metals**
    - **long term toxicity**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

INTERMEDIATE/LOW-LEVEL DISINFECTION

- **Phenolics**
  - **triclosan (fabrics, surface)**
    - **pH >7**
    - ***soiling***
    - **activity greatly reduced by dilution**
    - **absorbed by rubber/plastic**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

INTERMEDIATE/LOW-LEVEL DISINFECTION

- **Alcohols**
  - ***soiling***
  - **poor penetration**
  - **good cleansing properties**
  - **combination**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

ANTISEPSIS

- **Phenolics (triclosan)** — **surgical soap**
- **Alcohols** — **combination**, **hand rub products**
- **Biguanide (chlorhexidine)** — **solution for wounds and burns**
- **QACs**
- **Iodine (povidone iodine)** — **skin and wound**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

ANTISEPSIS

- **CRAs (hypochlorites)** — **skin and wounds**
- **Hydrogen peroxide** — **solution for wounds and ulcers**
- **Aldehyde (glutaraldehyde)** — **warts**

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BIOCIDES USAGE IN THE HEALTHCARE ENVIRONMENT

PRESERVATION

- **Acids and esters (parabens)**
- **Biguanides**
- **QACs**

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USE AND MISUSE

• **Inappropriate disinfection regimens**	
- inappropriate concentrations	**- microbial survival**
- incompatibility	**- contamination**
- absorption	**- infection**
	- resistance
• **Failure of a disinfection process**	**- non-respect / no understanding factors affecting activity**
• **Overuse**	
- systematic disinfection of low-risk surfaces	**- concentrations?**
- incorporation into fabrics and surfaces	**- commercial benefit**

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CONCLUSION DISINFECTION IN THE HEALTHCARE ENVIRONMENT

• **Appropriate usage**	**- ESSENTIAL**
	- prevention
• **Understanding factors affecting activity**	**- training**
• **Training of end user**	
• **Respect of manufacturer's instructions**	**- training**
	- documentation
	- appropriate testing
• **Compliance**	**- training**

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FURTHER READING

- **Chemical Disinfection in Hospitals (1996) Eds GAJ Ayliffe, D Coates & PN Hoffman. Public Health Laboratory Service. Blackmore Press: Shaftesbury ISBN 0-901144-34-7**
- **Principles and Practice of Disinfection, Preservation and Sterilization – 4th edn (2004) Eds AP Fraise, PA Lambert & J-Y Maillard. Blackwell Publishing: Oxford. ISBN 1-405-101999-7**
- **Disinfection, Sterilization and Preservation (2001) ed SS Block. Lippincott Williamd & Wilkins: Philadelphia. ISBN 0-683-30740-1**

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