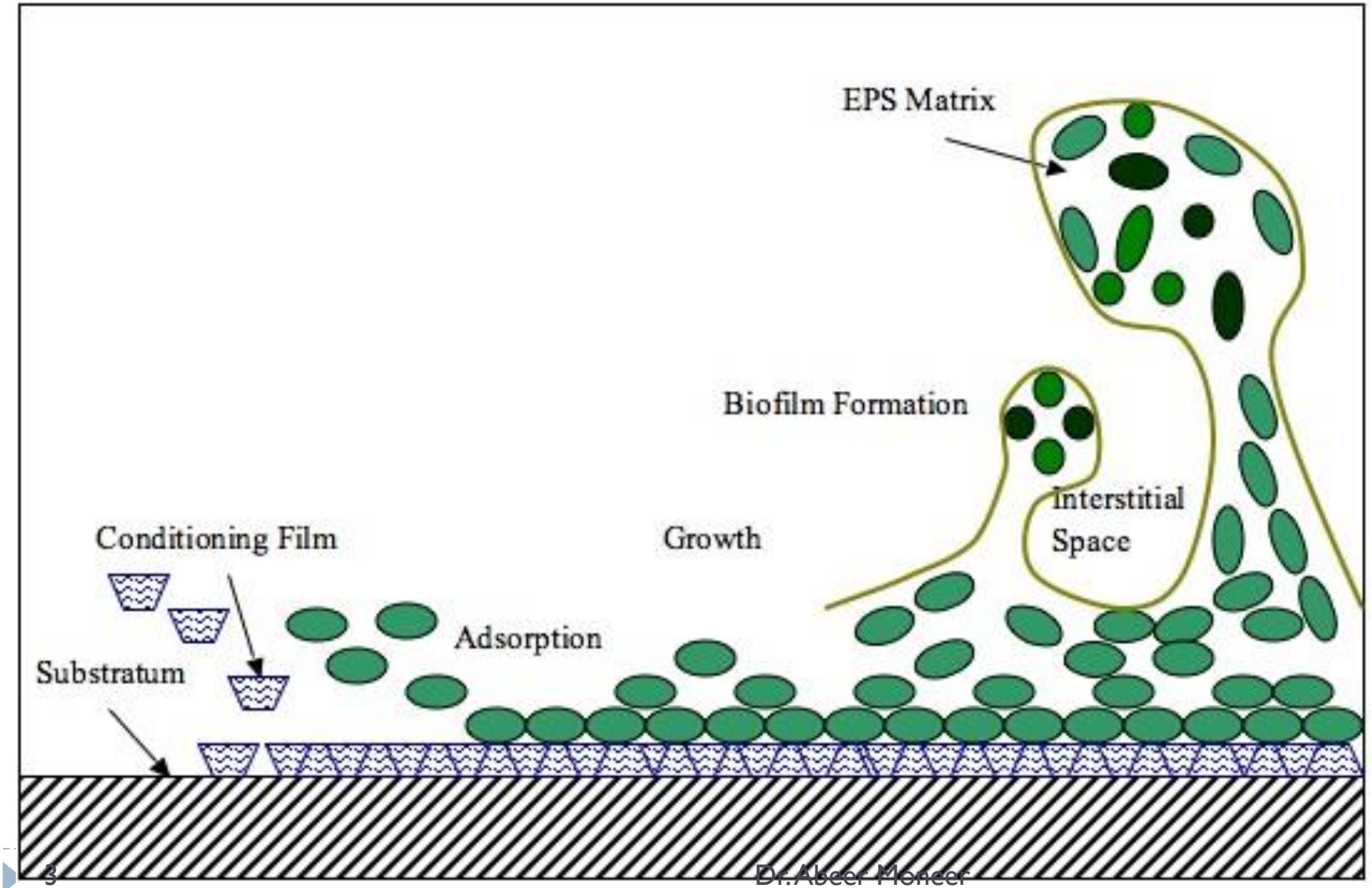
Reverse Osmosis (5)

Lecture 8

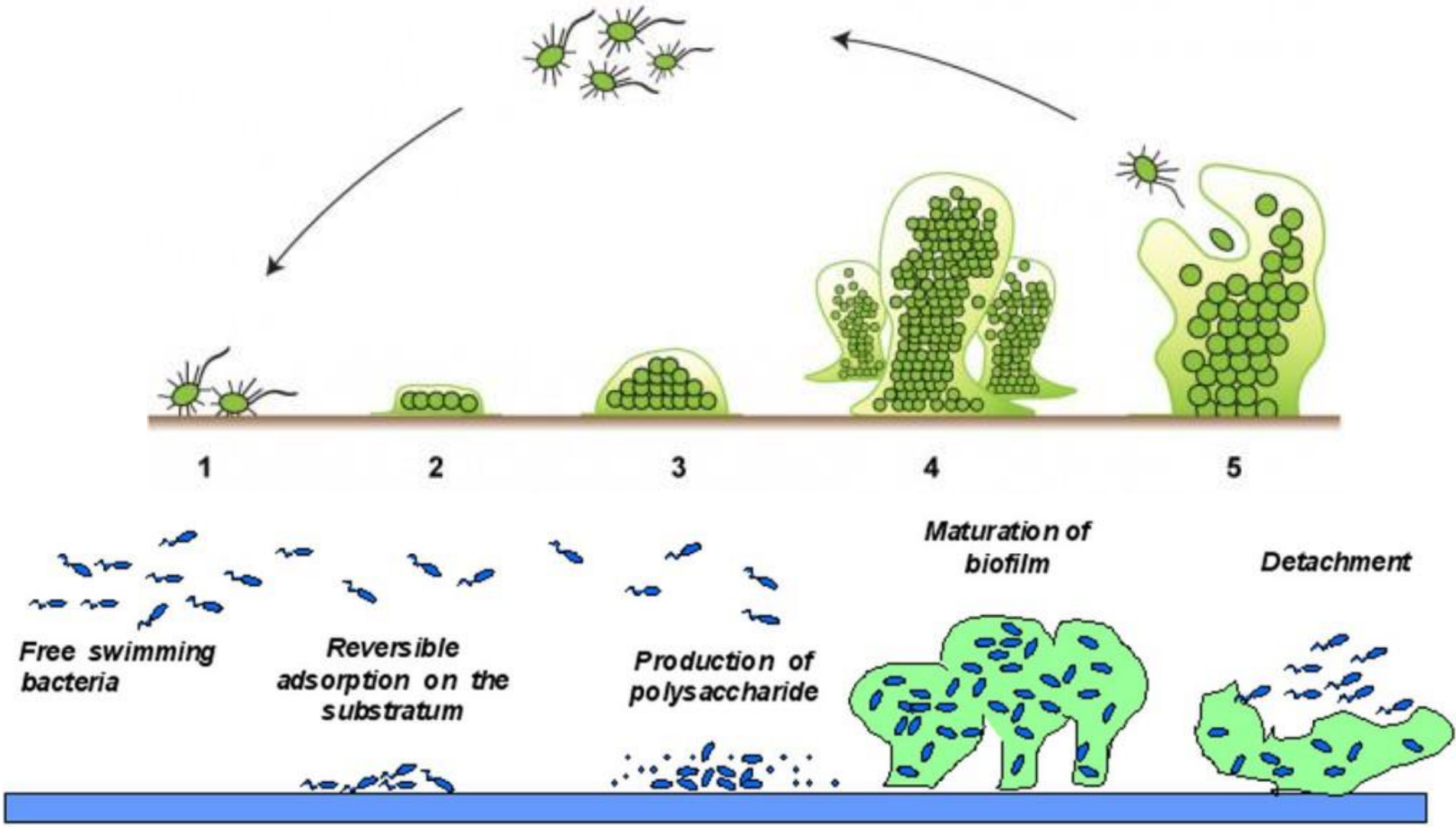
7. Bio-fouling in RO

- Bio-fouling in RO is combined result of the following factors:
- 1. **Presence of microorganisms** in the feed water.
- 2. Availability of the membrane surface area, which can be colonized by the microorganisms.
- 3. The **RO membrane rejects all microorganisms** found in the feed water. As a result, part of the rejected cells remains **adhered** to the membrane and initiates the process of **bio-film formation.**

Bio-film formation



Bio-film formation



7. Bio-fouling in RO

- 4. All **pretreatment operations** prior to the RO module may **provide sufficient surface area for microorganisms and bacterial growth**. For example, the large surface areas found in media filters, activated carbon beds, or even pipelines connecting various units.
- 5. The **bio-film growth mode**, on the membrane surface or any other surface, requires the minimum possible amount of **nutrients** in the feed water.

7.1 Effects of Bio-fouling on RO Performance

- **Bio-fouling** effects on RO performance are characterized by **gradual deterioration** in the system performance.
- Performance deterioration includes the following:
- - Decrease in the permeate flux.
- - Increase in pressure drop.
- - Decrease in salt rejection.

7.1 Effects of Bio-fouling on RO Performance

- The results of the above effects on the overall performance include the following:

1. **Increased cleaning and maintenance costs.**

- This is necessary to **maintain economic operation** that calls for a specific range for production rate and product quality.
- Membrane cleaning restores the system production rate within the specified limits as well as the product quality

7.1 Effects of Bio-fouling on RO Performance

2. Reduction in membrane lifetime.

This is a complex phenomenon, since exposure of the membrane to bio-film formation would result in several side effects, which includes:

- Increase in the pressure drop,
- Exposure of the membrane to extracellular compounds, entrapment of settled solids in the bio-film,
- Precipitation of scaling compounds on the membrane and within the bio-film.

7.1 Effects of Bio-fouling on RO Performance

3. **Other than reducing the flow area, the bio-film may increase friction and drag.**

- Both factors **increase the pressure drop** within the system, which in turn increase the demand load on the high pressure feed pumps. This is necessary to maintain **sufficient feed pressure and permeation rate.**
- 4. **Uneven growth of the bio-film** is also quiet common and that results in **uneven flow within the system**. As results, **sections with lower flow rate may result in enhancement of scaling and settling of solids.**

7.2 Bio-fouling Mechanism

- The bio-fouling mechanism is formed of the following elements:
- **1. Bio-fouling potential** depends on **feed water conditions**, system design, and operating conditions.
- Feed water **temperature is a very important parameter**; where in the Gulf and equatorial regions the seawater temperature during the long summer period remains close to **30°C**.
- Such condition would highly **favor bacterial growth** and **bio-film formation**. In addition, presence of dead ends, piping, or non-disinfected water tanks in the system would enhance the bio-film formation process.
- **Poor cleaning** may also contribute to microbial contamination and formation of the bio-film.

7.2 Bio-fouling Mechanism

- 2. **Formation of the conditioning film,** which involves adsorption of macromolecules on the membrane surface.
- This step may last for **few seconds to minutes** after the membrane is exposed to the feed water.
- The conditioning film has **different surface properties** than the original membrane surface.
- Therefore, the **electrostatic charge** of the conditioning film may considerably **affect microbial adhesion**.

7.2 Bio-fouling Mechanism

- 3. **Microbial adhesion is achieved by hydrodynamic forces, motility, and diffusion.**

The **microbial layer** is **protected** to a large extent **from** the **shearing forces** of the bulk flow **because of the small thickness** of the bio-film in comparison with the boundary layer thickness.

In addition, the RO membranes reject all the bacterial cells and microorganisms arriving at membrane surface.

The adhesion process is also affected by the number of cells in the bulk, nutrient concentration, temperature, pH, flow hydrodynamics, and surface charge.

Recent membrane development focus on construction of membranes with surface charge that inhibit microbial adhesion and formation of the conditioning film.

7.3 Bio-fouling Assessment

- 4. **Bio-fouling is recognized by indirect effects on the system performance:**
- Permeate decline,
- Decrease of salt rejection,
- Increase of the pressure drop on the feed-side.

7.3 Bio-fouling Assessment

- Further assessment of membrane bio-fouling is achieved by any of the following techniques:
- **Analysis of the pretreatment filter media for bio-fouling**. Presence of bio-fouling in these systems may give strong indication for membrane bio-fouling.
- **Use of on-line membrane testing elements**, which have smaller size than the actual membrane module. These elements can be removed and replaced on frequent basis. The removed elements are then dismantled and properly tested for bio-fouling and other forms of scaling.

7.4 Bio-fouling Treatment

- **Addition of biocides to the feed water** at an appropriate dosing rate would kill the microorganisms and bacterial cells suspended in the water and forming the bio-film on various parts of the system.
- Biocide treatment would prevent further growth of existing bio-films or formation of new bio-films.
- However, **existing bio-films, formed of dead bacterial cells**, would remain to affect the system performance in various aspects, i.e., higher pressure drop, lower recovery, lower salt rejection, etc.

7.4 Bio-fouling Treatment

- In other words, **biocide** treatment **kills** the **microorganisms and bacteria** forming the bio-film, **but has no effect on removal of the bio-film**. Moreover, a dead bio-film might become a substrate for new bacterial cells, which may get attached to the dead bio-film and consume its nutrient content.
- The same concept applies for the dead and suspended cells in the feed stream, which may ends up being attached to the membrane surface and causes reduction in recovery rate and salt rejection.

7.4 Bio-fouling Treatment

- **Effectiveness of the biocide** depends on several operating and design factors, which includes;
- type of biocide,
- concentration of biocide,
- side-reactions of biocide and compounds other than bacteria or microorganisms,
- pH,
- temperature,
- residence time,
- type of microorganism,
- growth state,
- physical nature of the bio-film.

7.4 Bio-fouling Treatment

- Increase in the biocide concentration, temperature, and residence time would increase the percent kill of the microorganisms.
- Chlorine is one of the most effective and common biocide agents.
- However, it requires a de-chlorination unit placed ahead of the RO to protect membranes sensitive to chlorine attack.
- Another disadvantage of chlorine use is the safety precautions required for storage and handling.

7.4 Bio-fouling Treatment

- Other biocides include formaldehyde, ozone, hydrogen peroxide, etc.
- Use of these is found much smaller scale than chlorine.
- In addition, some of these have lower efficiency than chlorine and have harmful effects on the environment.

Questions

- **<u>Complete the following statements with the proper word (s):</u>**

1. The bio-film growth mode, on the membrane surface or any other surface, requires the minimum possible amount of ----- in the feed water.
2. From the bad effects of Bio-fouling on RO Performance is the increase --------- and -------- costs.
3. Sections of the membrane with lower flow rate may result in enhancement of ------- and --------.
4. Feed water -------- is a very important parameter in the formation of bio-film.

Questions

- **Answer the following questions:**
- 1. Explain the bio-fouling mechanism and the factors affecting it.