Wastewater treatment using Sand Mounds

Treatment Mechanisms in Mound Systems

- Mound Systems, like Sand Filters, are essentially aerobic, fixed-film bioreactors
- They rely on several physical, chemical and biological processes to treat effluent effectively
- The following section reviews these processes

Mound Systems Physical Processes

- Filtration - whereby larger organic and
  - inorganic particles are retained with the pore spaces of the media via mechanical straining, and
  - contact with bio-film surfaces
- Filtration by media - in conjunction with bio-films is also an effective mechanism for pathogen removal within fixed media systems

Mound Systems Physical Processes

- Larger pathogens found in effluent (algae, protozoa and helminths) are able to be strained by the media but, bacteria and viruses are generally too small to be removed by this mechanism and require sufficient bio-film growth for effective removal

Mound Systems Chemical Processes

- Oxidation - facilitates the conversion of carbonaceous material into energy and cell mass by aerobic bacteria (bio-chemical process)
- Also allows nitrification, the chemical conversion of ammonia (NH_4) to nitrate (NO_3), to occur
- De-nitrification also takes place in anoxic micro-sites within the media filter

Mound Systems Chemical Processes

- Adsorption - can occur throughout the media bed. Dependant upon the pH and mineralogy of the media used (e.g.; sands - low, iron oxides - high)
- Involves the attachment or ‘sorbing’ of chemical constituents (principally P in wastewater) onto the media surfaces; but sand sorbs little P
- Adsorption specifically relates to media properties such as surface area and polarity

Mound Systems Biological Processes

- Respiration - bacteria within the bio-film use elements (nutrients, carbon, etc.) contained within effluent by absorption and solubilisation to produce fresh cell mass and end products. Endogenous phase necessary for effective operation
- De-nitrification - conversion of nitrate (NO_3) to atmospheric nitrogen (N_2) also occurs as a biological process performed by both aerobic and anaerobic bacteria within the bed media

Mound Systems Biological Processes

- Predation - micro-flora within the bed media will prey upon organisms (pathogens, native bacteria) within the wastewater stream
- In mound systems this process is continued within the native soil profile where predation plays a major role in reducing the pathogen numbers

Treatment Performance of Mound Systems and Sand Filters

	BOD_5 (% removal)	TSS (% removal)	TN (% removal)	FC (% removal)
Mound and Intermittent Sand Filter	90 - 98	90 - 95	14 - 50	97 - 99
Recirculating Sand Filter	95 - 99	81 - 95	45 - 82	97 - 99

cited in Crites and Tchobanoglous (1998) "Small and Decentralized Wastewater Management Systems"

Sand Filtration Design Principles

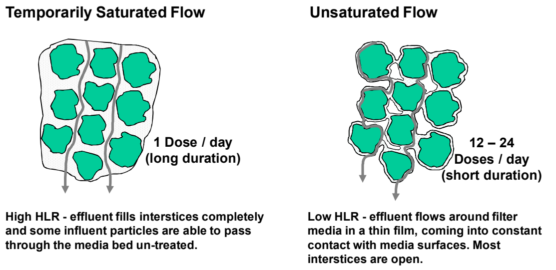
Hydraulic Considerations for Mound Systems

- System hydraulics is of critical importance when designing a media filter bed
- Parameters that require consideration when designing a system include:
  - Hydraulic Loading Rate
  - Hydraulic Conductivity of the bed media (unsaturated)
  - Size and Consistency of the bed media

Hydraulic Loading Rate

- The Hydraulic Loading Rate (HLR) is the rate at which effluent is added to the surface of the bed media (L/m^2) per time period
- This parameter has a significant effect on the treatment effectiveness of the system
- If the HLR is too high, conditions will move from unsaturated to temporarily saturated hydraulic flow and effluent may by-pass treatment by moving too rapidly through the bed

Hydraulic Loading Rate



Hydraulic Conductivity of the Bed Media

- Hydraulic Conductivity (K_{sat}) or 'permeability' is the rate (L/t) at which water moves through a porous medium
- Under unsaturated flow conditions this rate is controlled by grain size (media property) and the degree of saturation (hydraulic property)
- The relationship between K_{sat} and the degree of saturation is non-linear, meaning that as media saturation increases, the rate that water flows through that media increases greatly

Hydraulic Conductivity of the Bed Media

- The degree of saturation can be controlled by 'dosing' effluent evenly over the surface of the media bed intermittently for short durations
- To achieve this result a pressurised effluent distribution system is used and ensures that all available surface area of the filter bed is utilised as a wastewater treatment medium
- Short circuiting and 'dead zones' are likely to occur in systems that are gravity fed, incorrectly designed, or have poor distribution networks

Hydraulic Conductivity of the Bed Media

- The grain size is a specific property of the media selected for the filter bed and as such requires more consideration during the early phase of any sand filter or mound system design
- An ideal filter media has both a large surface area, permitting maximum effluent contact with the developing bio-film surfaces and sufficient pore space to allow aeration and unsaturated flow

Size and Consistency of the Bed Media

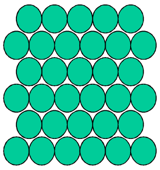
- Sands, along with most other gradational filter media, contain a variety of grain sizes. The proportion of each grain size has a significant control over the hydraulic conductivity and treatment efficiency of the media
- Media with a diverse range of grain sizes will pack much more tightly, providing a large surface area for bio-film growth, but the hydraulic conductivity and aeration potential of the media may be extremely low

Size and Consistency of the Bed Media

- Alternately, media with a narrow range of grain sizes will pack in a loose uniform manner, providing less surface area for bio-film growth, but increasing the hydraulic conductivity and aeration potential of the media significantly
- Most natural sands and industrial by-products fit the first description to varying degrees and require additional sorting (screening) to achieve the appropriate characteristics

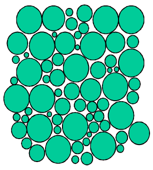
Size and Consistency of the Bed Media

Highly Uniform



Lower Surface Area
Higher Hydraulic Conductivity

Loosely Uniform



Higher Surface Area
Lower Hydraulic Conductivity

Comparison of Unit Operations

Parameter	Single pass sand filter / Mound	Recirculating gravel filter	Packaged media biofilter
Medium	Sand	Gravel	Peat, foam or textile
Bed depth	600mm	600-900mm	600-1,500mm
Hydraulic loading rate	50L/m^2/day	200L/m^2/day	200-1,000L/m^2/day
Organic loading rate	25g/m^2/day	100g/m^2/day	150-500g/m^2/day
Recirculation ratio	N/A	3-5	0-5
Doses	12-24/day	48-72/day	48/96/day

Filter Media Properties

- A Single Pass Sand Filter (SPSF) design is required to have a sufficiently low hydraulic conductivity such that retention time within the bed media is adequate to provide all the necessary treatment with only one pass through the medium
- However, if the hydraulic conductivity of the bed media is too low, unsaturated flow conditions will be difficult to maintain and treatment efficiency will be significantly decreased

Filter Media Properties

- Mounds too, have their own particular bed media requirements. If the hydraulic conductivity of the media is too high the effluent loading rate may exceed the infiltration capacity of the native soil resulting in surcharge
- Mounds also require that the media “holds up” the effluent in the mound to be available for evapotranspiration