Diffusers and pollution discharge to receiving waters

Diffusers

Small flow rates: discharge through pipe end (one jet)

Large flow rates: discharge through diffuser arrangement (a series of jets)

Simple diffuser
Definitions

Outfall: underwater pipeline that discharges wastewater into a receiving water

Diffuser: a section of the outfall (usually the most seaward portion) with relatively small holes or ports

Outfall and Diffuser System
Outfall Design Process

Major components of design process:

- site selection
- outfall hydraulics
- dilution and mixing
- diffuser port design
- pipe design
- pipe support system
- construction methods

Four Design Stages

- feasibility study
- predesign
- preliminary design
- final design
Site Selection

Discharge point normally located close to treatment plant etc.

Outfall siting criteria:

- bottom topography and surf zone
- physical oceanography
- water quality
- underwater soils and geology

Bottom Topography and Surf Zone

- Hydrographic survey required
- Desirable to locate the diffuser on a relatively flat slope
- Try to achieve equal discharge from each diffuser port.

Difficult to penetrate the surf zone (breaking waves). Problems during construction and long-term structural integrity.
Physical Oceanography

Parameters to measure:
• water mass movement (currents):
  Eulerian and Lagrangian measurements
  recordings over appropriate period (cover all relevant conditions)
• salinity and temperature
  needed to determine density (stratification)
• diffusion
  dye, tracer studies
• wave height and period
  important for design

Water Quality

Predict changes in the water quality due to pollution discharge.

Determine existing water quality (monitoring program for baseline condition)

Parameters of interest for domestic sewage outfall:
• dissolved oxygen
• pH
• conductivity/salinity
• temperature
• oil and grease
• fecal coliform bacteria
• nutrient content
• heavy metals
• BOD/COD
  In water column and benthic area.
Outfall Hydraulics

Determine design flows, pipe diameters for outfall and diffuser section, and port size and spacing.

Discharge through a gravity system, if possible. Pumping sometimes required.

Diffuser Hydraulics

Size and spacing of diffuser ports determined through iterative hydraulic calculations considering:

- design flows
- pipe diameter
- pipe slope
- frictional resistance
- effluent density
- receiving water density
- discharge depth
- operating head
Guidelines for Diffuser Design

Flow distribution: uniform distribution between ports

Velocity in diffusers: velocity high enough to prevent deposition of sludge, grease etc

Prevention of seawater intrusion: full flow in all ports to avoid seawater intrusion

Dilution and Mixing

A diffuser changes a point source to a line source.

Mixing is due to:

- kinetic energy (initial discharge velocity)
- buoyant forces (density difference between effluent and receiving water)
- receiving water currents
Diffuser Port Design

**Orientation:** determined by flow direction of receiving water currents

Diffuser should be located perpendicular to the net current to maximize dilution.

**Port types:** two basic types, *pipe wall port* and *riser tube*

Holes in the wall of the pipe

Tubes project upward from the pipe
Pipe Design

The following pipe design components should be considered:

- foundation requirement
- pipe forces
- hydraulic flow properties
- corrosion resistance
- pipe material selection
- pipe anchoring
- construction method

Pipe Forces

The pipe must resist both external and internal forces.

Internal force: pressure from water flow

External forces: waves, currents, impact from foreign bodies
External Forces on Pipes

- **Current**
  - Figure 1: Current Forces

- **Waves**
  - Figure 2: Wave Forces

- **Impact forces**
  - Figure 3: Impact Forces

Pipe Support System

- bottom exposure
- bottom exposure with armor
- buried trench section
- pile-supported system
- semi-floating outfall
Construction Method

Three different zones: onshore, surf, and offshore.

Commonly used construction methods:

• barge lay
• trestle lay
• string float
• bottom pull
**String float**

**Effect on Dilution of the Diffuser Number**

- Incoming flow rate: $Q_o$
- Opening area: $A_o$

\[ A_n = A_o / n \]

Diameter for opening: \[ D_n = \frac{D}{\sqrt{n}} \]

Flow rate from opening: \[ Q_{on} = Q_o / n \]
Flow rate after distance $x$ in one jet:

$$Q_n(x) = 0.32Q_0\frac{x}{D_n} = 0.32\frac{Q_0}{n}\frac{x\sqrt{n}}{D} = \frac{0.32Q_0}{\sqrt{n}}\frac{x}{D}$$

Flow rate after distance $x$ in all jets:

$$Q(x) = nQ_n(x) = 0.32\sqrt{n}\frac{x}{D}$$

Dilution increases with a factor $\sqrt{n}$

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**Effect of Density on Required Energy for Discharge to Receiving Water**

Energy equation (reservoir to just outside pipe exit):

$$H_b = -y_i + \frac{p}{\rho_0 g} + u_0^2 + f \frac{L}{D} \frac{u^2}{2g}$$
Pressure at pipe exit (hydrostatic pressure):

\[ p = y_i g \rho_r \]

Yielding:

\[ H_k = -y_i + \frac{y_i \rho_r}{\rho_0} + \frac{u_0^2}{2g} + f \frac{L}{D} \frac{u^2}{2g} = y_i \frac{\rho_r - \rho_0}{\rho_0} + \frac{u_0^2}{2g} + f \frac{L}{D} \frac{u^2}{2g} \]