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Necessity of Initial Dilution for Sea Outfall Diffusers in Respect to the European Directive on Municipal Discharges

by

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Abstract

The European Directive on municipal discharges prescribes that discharges of sewage to the sea should at least be treated biologically. The author claims that this treatment is an argument for reducing the requirement for initial dilution for sea outfall diffusers. By reducing the costs for the diffusers more emphasise can be laid on solving the bathing water problems rising from storm overflows.

Introduction

Long sea outfalls for the discharge of sewage to the sea is most often provided with diffusers, which have a number of openings (denoted ports) in order to increase the dilution of the sewage. Diffusers with more than 50 ports are often seen. Because of the density difference between the sewage and the seawater the sewage forms a rising plume, which under continuous dilution rises to the sea surface. The dilution in this rising plume is called *initial dilution*.

It should already here be emphasised that this paper only discusses conditions where the plume rises to the surface of the sea. Situations where a proper initial dilution can control how the plume can be trapped below the surface in a stratified recipient will not be mentioned.

Diffusers in long sea outfalls are normally designed on basis of initial dilution requirements. For the specific location these requirements direct lead to the size and number of diffuser ports. This way the actual initial dilution standard is an important factor for the overall economy for a sea outfall project.

Two examples of initial dilution requirements shall be mentioned. The Danish standard is not a formal requirement but a practise followed by all regional authorities (counties). In principle the discharge permit is a political decision to be taken by the county council. The Danish standard require that the initial dilution shall result in a density difference between the plume and the ambient sea water, which is no more than 0,5 kg/m^3. The Spanish requirement described by *Ministerio de Obras Publicas y Transportes* (1993) demands an initial dilution of at least 100 times.

Background for initial dilution requirements

The purpose of having initial dilution requirements is to ensure that the direct environmental conditions like visual impression and odour just near the discharge are acceptable. In most countries the dilution requirement lies in the order of 100 times. However, the origin this value is lost in the past and its relevance seems not clear in the light of the recent decades development in urban drainage in Europe.

The recent literature concerning sea outfalls and initial dilution does not cover any description or discussion regarding experiences with environmental effects versus value of dilution.

The requirement of a dilution in the area of a minimum of 50 to 100 times used in many countries probably dates back to the early sea outfalls from the 50ties and 60ties. Those days the discharge most often took place as raw sewage without any treatment containing a high degree of gross solids. It has been mentioned as a general experience from practise that an initial dilution of 20 – 30 times is far enough to reduce the visual and odour effects for raw sewage discharges. On the other side a dilution of 50 – 100 times seems to remove most of the visual effect leaving only a minor unpleasant smell back. So an initial dilution requirement of at least 100 times looks reasonable in the case of raw sewage.

The above mentioned Danish criterion concerning the density difference goes back to the beginning of the 60ties and is based on the idea of avoiding the formation of a surface plume on the sea surface, which because of the density difference has difficult with mixing with the ambient sea water. As the salinity in the Danish waters from the Baltic Sea to the North Sea varies from 1 to 3,3 percent, the corresponding demand to initial dilution varies from about 15 to 50 times.

Another Danish experience is that all registered problems the recent years with the bathing waters seems clearly connected to storm sewer overflows. A recent review of the international literature by the author confirms this tendency.

In the following the above-mentioned relation between initial dilution requirements and the requirement from the European directive on municipal discharges is discussed in more detail.

Importance of initial dilution for conditions in the bathing zone

In sea outfall design the primary objective is to insure that the bathing water criteria is fulfilled in the bathing zone. This zone can be defined as the area between the 2-m depth contour and the shoreline. The bathing water criterion is based on the concentrations of bacteria like the well-known e.coli., which itself not is a pathogen, but only is an indicator for harmful bacteria and vira. The criterion is formulated as a demand to the exceeding frequency of the concentration. In Larsen (1992) it is described how the bathing water quality can be estimated by a combination of stochastic ad deterministic modelling.

The impact of a discharge of sewage through a sea outfall can be seen as a certain concentration of the indicator bacteria on the border of the bathing zone. For a given outfall this concentration will primarily depend on the following factors:

1. The source strength of bacteria from the diffuser
2. The bacterial decay (die-off)
3. The dilution

In the next sections the influence of these 3 points on the bathing water quality is discussed.

Source strength of pathogens

Source strength of pathogens is the product of flow and concentration of bacteria and vira in discharge from outfalls. In the following concentration of pathogens is for simplicity understood as the concentration of the indicator bacteria E.coli. knowing very well that this is more complex than so.

The average production of E.coli. bacteria is about 10^{13} bacteria per person per day. Correspondingly the concentration of bacteria in raw sewage lies in order of magnitude of 10^{10} to 10^{11} per. 100 ml.

In Denmark all sewer plants have tertian treatment (sedimentation, organic matter removal and nutrients removal) corresponding to the European requirements for discharges to sensible waters. A side effect of the tertian treatments is that the concentration of suspended solids is reduced to practical nil and the concentration of pathogens (bacteria and vira) is considerably reduced, often with a factor of more than 100. Furthermore, also the smell of raw sewage has practically disappeared from the sewage after the treatment. The reduction of bacteria concentrations for sewage passing Danish treatment plants can be summarised in table 1.

Table 1 Reduction of E.coli. concentration through treatment plants

Degree of treatment	Reduction factor
No treatment, raw sewage	1
Mechanical treatment	1,5 - 3
Biological treatment	100 - 1000
Tertian treatment	1000 – (10.0000)

From this table it is obvious that concerning the bacterial concentrations in the bowl just above the diffuser a lower initial dilution should be accepted if a higher degree of treatment is used.

It should be mentioned that sewage that leaves a tertian treatment has high concentration of oxygen, looks almost clear with only a insignificant turbidity and has an odour that is orders of magnitudes lower than the odour from raw sewage. Accordingly the authorities in several cases in the recent years have accepted lower initial dilution and corresponding more simple diffusers with reference to the high degree of treatment.

From the Danish experiences it is the authors point of view that an initial dilution of 30 times should be sufficient in most cases in respect to odour and visual effects when the sewage is either biological or tertian treated.

Decay of pathogens

Very little is known about how treatment influences the bacterial decay (die-off of pathogens) in seawater. Accordingly it is assumed in the following argumentation that the decay is constant and independent of other conditions.

Dilution

As an introduction to the discussion on how important the initial dilution is for the total dilution from the diffuser to bathing zone we will consider a simplified example with a single point source discharging bacteria at the sea surface where we have a constant current with velocity *U* creating a simple passive plume. The concentration of bacteria *C* in this plume is (see for example Fisher et al, 1979)

$$c(x,y,z) = 2\frac{M}{4\pi x\sqrt{D_y D_z}}\exp\left(-\left(\frac{y^2}{4\frac{x}{U}D_y} + \frac{z^2}{4\frac{x}{U}D_z}\right)\right)$$

where *x, y* and *z* are Cartesian co-ordinates, D_y and D_z are dispersion coefficients. The discharged mass of bacteria per unit time *M* is given by

$M = C_0 Q_0$

where C_0 is initial concentration, Q_0 is the discharged flow.

The point is now that the concentration only depends on the discharged mass per unit time and not the initial concentration as long as Q_0 so little compared to the flow in the plume downstream at the point we are interested in. So we can see that in this case we will not reduce the concentration by reducing C_0 because this will only increase Q_0 so *M* will remain the same.

From this example we can see that initial dilution in principle does not improve the overall dilution. As shown by Larsen (1995) the initial dilution only have an insignificant influence on the far field dilution in respect to the effect of density differences.

Please notice that it is of course still important, especially in respect to larger outfalls, to use a diffuser, that can give the surface plume a large initial geometric width. The argument is only related to the dilution.

Discussion

Compared to other coastal structures like breakwaters, groins etc. diffusers are rather complex and sensible structures, and they are often situated at location on coasts with high waves, strong currents and sediment transport. Accordingly a diffuser frequently is in danger of failure, which can lead to serious environmental impact to the nearest beaches and expensive reconditioning. One can argue that the high initial dilution requirements indirectly increase this risk by increasing the size of the diffuser.

Minimum port diameter

The initial dilution depends on the port diameter, the water depth, the flow velocity in the port, the density difference and to some degree on the spacing between the ports.

On a shallow coast with a limited water depth it can be difficult to satisfy the initial dilution criterion without having a very small port diameter. On the other hand it is good engineering practise not to use very small cross-sections in sewer systems. Accordingly a minimum port diameter is often defined. For that reason this minimum port diameter more or less directly leads to a minimum water depth where the diffuser can be placed on a shallow coast. This leads again to the overall length of the outfall.

A diffuser is especially sensible for blockage primarily because a diffuser consists of pipes that decrease in size in the flow direction. Therefore there exists in the various countries a not very well defined practise for the minimum diameter for the diffuser ports in the area of 5 to 20 cm. For example the Spanish recommendation (*Ministerio de Obras Publicas y Transportes,* 1993) is a minimum diameter of 6 cm. In Denmark such a small diameter will not be perceived as technical permissible and to the authors knowledge a diameter less than 12 cm has not been used.

Examples can be given where the bathing water quality on the beach was spoilt because a direct discharge from an overflow after the diffuser with very small ports was blocked.

Priority of initial dilution in design of outfalls

The number of environmental problems seems endless, and from an economical and engineering point of view the only rational method to meet these problems is to rank them according to their importance.

Although it is not well documented it looks as many newer outfalls in Europe are designed too much to the safe side not at least because of strict initial dilution requirements.

In the design of diffusers for sea outfalls the initial dilution requirements has played a central role presumably because the design procedure is much more clear and unambiguous than the design in respect to the bathing water requirement. For example an excellent computer package, the CORMIX package (Jirka et al, 1996), is available for the diffuser design, whereas the procedure for finding distance from the coast for the diffuser, which basically is related to the water quality conditions, is much more complex and troublesome.

From the authors point of view the question on the bathing water quality should have the highest priority in the design of an outfall including reasonable safety factors. The question of initial dilution should only have a secondary priority in balance with a reliable engineering design.

Most actual problems with the bathing waters today in countries with a developed sewage treatment system can be related to storm overflows, therefore the future planning and design of outfalls should emphasise more on finding the most efficient solution when the capacity of the treatment plant is exceeded.

Conclusion

Initial dilution requirements are only of importance for very local environmental conditions close to the diffuser. The environmental value of strict initial dilution requirements seem rather limited in many cases especially because the European Directive on Municipal Discharges prescribes a treatment that reduces the environmental effects significantly. It seems reasonable to depart from the requirements in the cases where the risk of damage of the diffuser is obvious and give the proper engineering design a higher priority.

In the case of secondary or tertian treatment it should from the author's viewpoint be acceptable to design for an initial dilution of say 30 times if an adequate documentation for fulfilling the bathing water requirement has been carried out.

References

Fisher, H.B., List, E.J., Koh, R.C.Y., Imberger, J., Brooks, N.H. (1979). Mixing in inland and coastal waters. Academic Press, New York.

Jirka, G. H., Doneker, R. L., Hinton, S. W. (1996). User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters. U.S. Environmental Protection Agency, Tech. Rep., Environmental Research Lab, Athens, Georgia.

Larsen, T. (1992). Debate on Uncertainty in Estimating Bathing Water Quality, Water Science & Technology, Vol. 25, No. 9, pp 225-234.

Larsen, T. (1995). Diffuser design for marine outfalls in areas with strong currents, high waves and sediment transport. Water Science & Technology, Vol. 32, No. 2, pp 249-255.

Ministerio de Obras Publicas y Transportes (1993). Orden de 13 de julio de 1993 por la que se aprueba la instrucción para proyecto de cinducciones de vertidos desde tierra al mar. Madrid.

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