Assessment of the Environmental Capacity of Enclosed Coastal Sea

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The assessment of environmental capacity is one of the tools for decision making in the selection of measures for sea quality protection in semi-enclosed and enclosed coastal seas. When assessing the environmental capacity, all of the processes affecting the assimilation or accumulation of anthropogenic matter in the marine ecosystem should be taken into account.

Introduction

Wastewater discharge into the coastal sea is carried out by means of coastal or long marine outfalls after previous treatment. The processes of initial dilution, diffusion, and dispersion are used to reduce the concentrations of waste matter. Beside the physico-chemical, biochemical and biological processes, which simultaneously take place in the sea, it is possible to preserve the quality state of the sea ecosystem for the desired purpose or use. For a particular planned use of the coastal sea, the degree of previous treatment of wastewater depends on: the wastewater characteristics, the discharge cite characteristics, and particularly, the hydrodynamic characteristics of the coastal sea.

Three types of characteristics of the discharge site and the receiving marine environment are discerned:

- the open sea in which strong currents and exchange of the sea water mass exist;
- a semi-enclosed type (estuary or river mouth and channels), with a satisfactory exchange of sea mass, either due to the difference in salinity or density, or due to the influence of tidal exchange.
- an enclosed sea system (lagoon or gulf), with a very limited sea mass exchange with the open sea.

When discharging wastewaters into a semi-enclosed or enclosed sea system, the total dilution takes place within a limited mass of sea water. Due to the limited effect of dilution and dispersion of wastewater, the physico-chemical, and biochemical and biological processes in a relatively minor mass of recipient water, there is danger of an increase in the concentrations of waste matter in sea water.

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Calculation of the Environmental Capacity

There are several ways to define Environmental Capacity. Generally, the term denotes the ability to accommodate a particular activity or rate of activity without an unacceptable impact. From the viewpoint of wastewater discharge into the coastal sea, the environmental capacity may be defined as the rate of introduction of a certain pollutant not exceeding the required quality standard for the critical target.

The calculation of the input of a contaminant and its effect on the critical target should be carried out taking into account the entire transfer with the various pathways in the system, as well as the transport of the system. For the calculation of the environmental capacity, mathematical models are applied, from very simple models to probabilistic models with a large number of variables. The determination of the boundaries of the ecosystem to be observed presents one of the important decisions. In cases of enclosed and semi-enclosed types, boundaries are determined by the topographic characteristics which, at the same time, frequently correspond to the hydrographic characteristics.

Target determination is one of the essential elements for the environmental capacity assessment. One of the ways of assessing the environmental capacity is the determination of a target(s) according to the risk arising by the waste matter input and the application of appropriate standards for their preservation.

Based on the calculation of the environmental capacity, the allowable input quantities of individual pollutants are established according to the desired goals. Methods which may be applied for waste reduction and discharge for industrial, as well as domestic, waste are: alternative treatment processes, reuse or elimination methods, on-land disposal alternatives, disposal into the open sea, appropriate low-waste technologies /1/. The determination of protective measures results in the definition of several variant solutions which meet the capacities of the environment, or the established goals.

Case studies in Yugoslavia

The total area of the coastal sea of Yugoslavia is almost 67 000 km^2. The aerial distance between the borders with Italy and Albania is 630 km, with the total coast length (including islands) of 6,116 km (1:10 ratio). A great number of bays and coves have been inhabited from the early periods of civilization, and in recent times they have become important for the development of tourism. As a result of increased urbanization of the coastal area and poor exchange of sea water in the enclosed and semi-enclosed sea systems (coves,

bays, estuaries), local disturbances of the marine environment have been noticed.

Intending to rehabilitate particular gulfs, in the early 1980's wastewater disposal studies were initiated for communities on the coasts of bays and estuaries. Studies were based on the methodological approach developed upon the capacity evaluation of different semi-enclosed systems /2/.

The Kaštela Bay is part of the coastal sea of Split.

The aim of the rehabilitation was the quality of the sea necessary for bathing and recreation. An oligotrophic to mezzotrophic degree of biological production, as well as the sanitary-hygienic conditions in the coastal sea, were selected as criteria. For trophic state standards, the limit values of phosphorus and nitrogen in the sea water were selected, and for the sanitary state, the limit values of the total coliforms and enteroviruses (calculated number) were used.

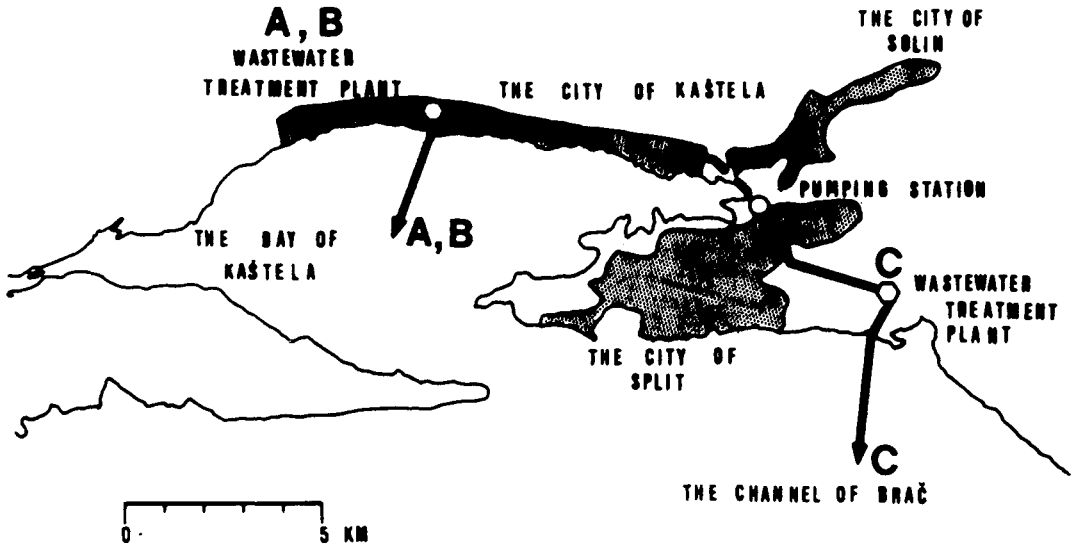

Fig. 1. Alternatives of wastewater disposal from Kaštela Bay

The input data are based on several years of sanitary and oceanographic research and socio-economic development plans of the region. The quantity of waste matter from point sources (housing, tourism, industry, precipitation water from communities) and non-point sources (precipitation water from agricultural, recreational, and forest surfaces, exchanged sea water) has been evaluated for the present state as well as the planned state. Evaluations were completed for a monthly waste matter inflow /3/.

After evaluating all the parameters of waste matter, the influence on the state of the sea quality is simulated.

Concerning the biological processes, the system is looked upon as a "black box", and the permitted concentration of nutrients during the winter months represents the "response" of the system. The calculation of the water mass in which dilution and dispersion takes place has been carried out with the assumption of wastewater being discharged in the centre of the bay (a long marine outfall) and with the application of a one-dimensional water quality model. After that, dilution in the monthly sea water quantity of the bay which is exchanged with the open sea ($7x10^8$ m^3/mo) has been chosen as the most favourable solution.

In the evaluation of the public-health state of the sea, the exponential model of microorganism mortality in the sea has been used (t_{90}=48 hours for enteroviruses and t_{90}=4 hours for total coliforms has been input).

The following variants of waste matter control have been considered for the proposed goals:

A - discharge into the bay with the biochemical level of treatment,
B - discharge into the bay with the physico-chemical level of treatment,
C - discharge into the open sea with mechanical treatment and a long marine outfall.

Based on the results of the evaluation of all investment costs, as well as operation and maintenance costs, the relative relationship of the total annual costs was established.

Table 1. Total annual costs of wastewater disposal in Kaštela Bay /%/

Period	Variants		
	A	B	C
1990	100.0	101.4	61.8
2000	112.1	116.7	66.6
2010	124.1	130.4	72.5

Concerning the operational safety, Variant C, with wastewater discharge out of the bay, eliminates the risk of periodic or continuous inadequate operation of the plant. This variant enables easier upgrading of effluent quality by incorporating additional treatment levels, for stricter standards of coastal sea quality or changes in wastewater characteristics. Finally, Variant C, with open sea discharge, was proposed for acceptance. The completion of Variant C is under way.

The Bay of Šibenik is a sunken river valley and represents the Krka River estuary. It is characterized by the mixture of river and sea water streaming into the surface layer towards

the open sea and at the bottom and/or medial layer towards the river and upstream (under the influence of the tide).

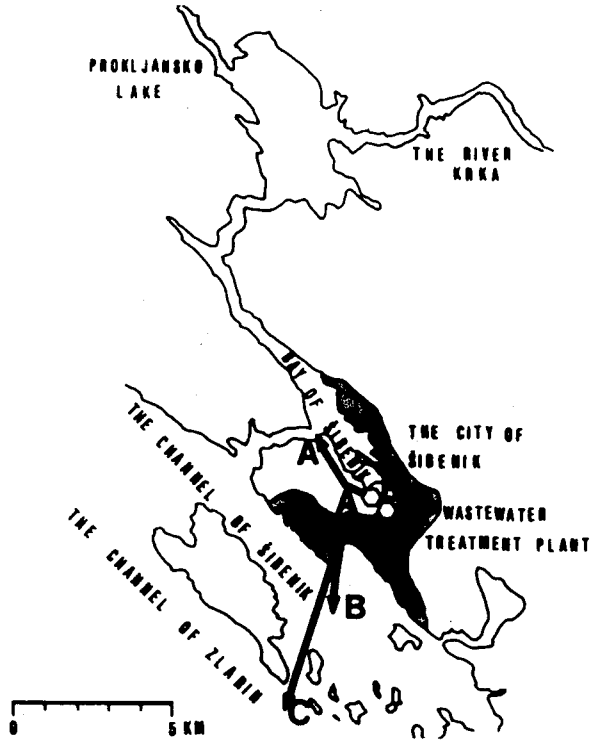

Fig. 2. Alternatives for the disposal of wastewaters from the city of Šibenik

As the result of this type of streaming, pollution with the waste material discharged into the Bay of Šibenik has been noted upstream of the Prokljansko Lake.

In the study of Šibenik wastewater disposal restoration, the same methodological approach for the evaluation of the wastewater recipient capacity has been applied /4/. Because of the assimilative capacity of the recipient, three variants of disposal had been investigated:

A - coastal discharge into the estuary with physico-chemical treatment,
B - marine outfall in the Channel of Šibenik with physico-chemical treatment,
C - long marine outfall into the open sea with primary treatment.

Owing to the specific conditions, the coastal outfall into the estuary in the surface layer can be utilized. The Channel of Šibenik is some 1500 m wide, up to 40.0 m deep, with an annual volume of exchanged sea water reaching 1.36×10^9 m^3. The channel has a limited capacity and the discharge into the channel cannot be considered as open sea discharge. Some of the main parameters for the variant selection are shown in Table 2.

Table 2. Relative disposal costs for variants

Description	Variants		
	A	B	C
Treatment efficiency, %	95	85	25
Diffuser depth, m	0	20.0	65.0
Distance from diffuser, m	0	1500	5250
Capital costs, %	100	94	58.1
O and M costs, %	100	124.1	20.5
Total costs, %	100	118.5	37.5

Preparations for the realization of the Variant C, which was proposed as the most favourable, are under way.

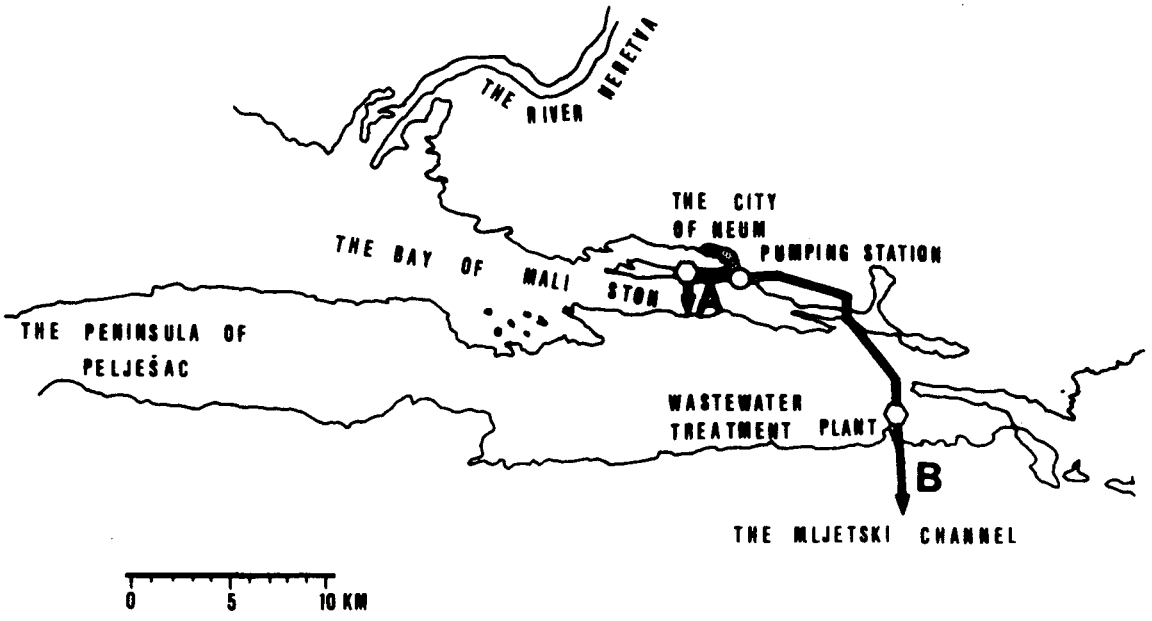

Fig. 3. Disposal of wastewater from the town of Neum

Particularly interesting is the case of Malostonski Bay, one of the most valuable parts in the east Adriatic for shellfish production. When planning the restoration of the tourist community of Neum, the discharge was planned to be into the bay, after previous biochemical treatment and using a marine outfall. By monitoring the environmental impact using the recipient capacity method, it was established that, from the sanitary viewpoint, the proposed treatment level is not sufficient for the sea quality necessary for shellfish production. The variant with wastewater discharge out of the bay was proposed /5/. After several years of additional investigations, the variant of the wastewater discharge into the open sea was constructed.

Conclusion

The application of the "Environmental Capacity" Method when considering the rehabilitation of the coastal sea is a significant help for decision-making about the location and manner of wastewater disposal. In principle, the Environmental Capacity Studies represent a specific approach to environmental management, and may generally be classified in the group of studies and documents known as Environmental Impact Assessment. One of the simpler versions of the environmental capacity assessment applications when deciding about the location and manner of wastewater discharge into semi-enclosed coastal seas has been presented in this work. The decisions made were on the safe side of environmental management while still being economically acceptable.

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