WASTEWATER DISPOSAL IN THE RIJEKA REGION

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ABSTRACT

This paper emphasizes the need for detailed analysis of wastewaters and their impact on the environment in physical plans for urban/tourist coastal areas, as a significant contribution to environmentally sound development, especially the development of tourism in these areas. The paper describes an analysis of this kind, prepared as part of the Regional Physical Plan for the Rijeka Region to the Year 2000. (The Rijeka Region is a major part of the Yugoslav Upper Adriatic.) The existing situation regarding sewerage systems, sewage treatment methods and disposal methods of the communes of the Region is presented. The quantities of wastewaters generated by the residential and tourist populations and by industry are given (by sub-regions) as calculated in 1981 and as estimated for the year 2000. A survey was made of the impact of wastewater on receiving rivers and coastal waters, and the quality of the receiving waters is given, in grades as compared with those prescribed by the Yugoslav legal regulations. Based on urban development concepts, and on the estimated wastewater quantities, alternative forecasts are made of the future impact of wastewater on coastal waters. General guidelines are presented for the provision of adequate sewage disposal facilities in order to achieve the optimum situation.

KEYWORDS

Physical plan; wastewaters; quantities; impact; environment; coastal waters; sewage disposal.

INTRODUCTION

Wastewater originating from human settlements, industries, tourism and other activities of contemporary development, being discharged untreated into receiving waters such as rivers, lakes and seas, have become one of the growing acute causes of ecological imbalance in the natural environment.

Rapid population growth, urbanization, industrial development, and large influxes of tourists, even when followed by adequate construction of water supply systems, have certainly not been followed by adequate construction of sewerage systems, with the result that ever growing uncontrolled quantities of untreated wastewater are being discharged.

Such is the existing situation in the Rijeka Region, the most developed region of the Yugoslav Adriatic coast, which covers an area of 8,434 km² in the upper part of the coastal belt, including the hinterland and the nearby islands. The
Region's inland border is 443 km long, while the indented mainland and island coastline is of a total length of 1,551 km.

The Region comprises four distinct sub-regions: the fertile peninsula of Istria, the narrow stretch of littoral of the Kvarner Bay, the islands (KrK, Rab, Pag, Cres, Lošinj and many smaller ones), and the hinterland area of Gorski Kotar spreading inland behind the sharp mountain range that stretches along the coast. These sub-regions differ greatly in their geography, history, and natural environment, and thus have very different conditions for development.

The two major towns are the city of Rijeka (the largest port in the country), and Pula. Both towns are experiencing rapid industrial and urban growth. All along the mainland coast there are numerous towns and other settlements experiencing intensive development of tourism.

Thus, the mainland coast is under pressure due to industrial production and urbanization, while in the islands and the hinterland, stagnation of development and depopulation have been taking place. The urbanization in the coastal area has already brought conflict, as far as space is concerned, between industry, national and international transportation, infrastructure, tourism and housing, and has had impact on the environment and the quality of life.

Therefore, one of the major objectives of contemporary physical planning in the Region is to ensure that the transportation, infrastructure, and physical and other conditions exist for more balanced and better coordinated, environmentally sound development (economic, demographic, social and cultural). A long term Regional Physical Plan, to the year 2000, has recently been prepared, with the hope of achieving these objectives.

The Plan has a new approach to environmental issues. It considers that environmental protection and economic development are interdependent, and reinforces the ideas of sound environmental management of natural resources. These are no longer annexes to other planning issues, as they were in the past, but they represent the core of the Plan. The environment is considered as fundamental to the development of the Region, not only due to the maritime features of the coast, the fisheries, and similar resources, but also due to the attractions of the natural phenomena and beauty of the coast and sea, which are unique and should enable very prosperous development of tourism to take place if they are preserved and rationally managed. Among the most important of the natural phenomena are the purity and incomparable transparency of the Adriatic Sea along its Yugoslav coast, and therefore the problem of waste waters has been extensively covered in the Plan. Another new component in the Plan is an analysis of the natural features of the marine environment, with a written and graphic presentation of sea use related to land use.

EXISTING SEWAGE DISPOSAL FACILITIES IN THE REGION

Sewerage networks exist in most of the central towns and old urban settlements in the Region. They vary greatly in capacities, technical features and age. Generally, the existing situation is as follows:

- rapid development, urbanization, and the development of water supply systems in the coastal settlements have not been followed by adequate development of sewerage systems and sewage disposal facilities;
- sewage in coastal settlements is discharged into the sea, mostly without pretreatment and by way of very short outfalls;
- most of the sewerage networks receive municipal sewage, industrial wastes and rain water. They are generally very old, and were constructed for much smaller effluent quantities than they receive today, so that breakages are frequent during strong precipitation;
- wastewater treatment facilities, where they exist, including industrial waste pretreatment, do not function properly due to poor maintenance or due
to the fact that the design parameters defining the type of treatment and the capacity were not investigated sufficiently prior to construction.

Although in recent years the demand for new sewerage systems and the reconstruction of existing ones with obligatory purification equipment has been gaining ground, these undertakings are very slow because of the high investments required.

Conceptual plans, sewerage master plans, and projects of various types have been prepared in almost all of the 19 communes in the Region, including the urban and tourist settlements along the coast. Their implementation has started in some population centres and coastal settlements (Novigrad, Poreč, Pula, Labin-Rabac, Rijeka, Buzet, Crikvenica, Delnice, Rab and Pag), however, only four are well advanced in construction (i.e. in the final phase of completion) and have adequate wastewater treatment and discharge (Poreč, Labin, Rabac and Pula).

There are also quite a number of smaller urban and tourist settlements with individual systems of sewage treatment and discharge, e.g. the Bay of Lim with its developing aquaculture, the Spa of Istria, the new tourist settlement and campsite of Červar in Istria, the Padova campsite, the Suha Punta Hotels on the island of Rab, and others.

Regarding industrial wastes, all industries are required by the existing Water Law to build treatment facilities, depending on the type of production and technological processes involved, and the waste quantity and composition.

Most of the newly built or reconstructed industries have their own waste treatment plants (e.g. the oil refinery, the coke plant and the power plant near the city of Rijeka, the oil terminal at Krk, the tobacco factory at Rovinj, the sawmill at Pužine, the metalworks at Pula, the brewery and metalworks at Buzet, and others). However, many of these treatment processes do not have the expected treatment efficiency, mostly due to poor maintenance and in several cases due to ill-defined conception.

Old industrial plants, built before the Water Law was endorsed, still represent an open problem, because wastewater treatment is considered too costly to implement.


Wastewaters in the Rijeka Region are mostly organic in nature. Almost no cases of heavy metals spillages have been recorded. Pesticides and nutrients pose very few problems because of the limited agricultural activities in the Region. The historical record of typhoid and other waterborne epidemia does not give reason for alarm. The present pollutants, being organic in composition, can be treated without much difficulty.

However, the geology of the substrata of the Region is predominantly limestone, with all the characteristics typical of karst. Groundwater is rarely characterized by storage, but behaves as a series of underground streams. The majority of water for domestic and tourist supply purposes is abstracted from these underground streams. Karst crevices enable easy penetration of wastewaters into the groundwater. The underground streams, as well as most of the rivers in the area, flow into the Adriatic, so the coastal waters are the final recipient of almost all wastewaters, directly or indirectly.

Wastewaters, if generated in large quantities and concentrations, thus become a considerable threat to streams, water in karst crevices, sea water and other natural waters. They are potential pollutants with harmful health effects and negative effects on the delicate ecological equilibrium. Bearing in mind the development of tourism in the Region, it is very important to calculate the quantities of the wastewaters, to determine their impact on marine ecosystems, and to establish a proper level of wastewater treatment and adequate disposal.
In the course of drawing up the Regional Physical Plan, wastewater quantities were calculated on the basis of the following indicators: for residential populations - 200 l/d per inhabitant; for the hotels - 400 l/d per tourist (for 5 months); for the campsites - 120 l/d per tourist (for 3 months); for private tourist accommodation - 250 l/d per tourist (for 3 months); and for industries - 1 l/s for 8 hours per day and 300 days per year.

According to the 1981 population census, there were 537,456 inhabitants in the Region. The capacity of the accommodation was about 433,200 tourist beds (there is a large influx of people during the 2 - 4 month tourist season in the coastal urban/tourist areas, increasing the resident population in some places by a factor of four or more). The results of calculations for 1981 showed a quantity of 51,376,245 m³ of municipal wastewater and 16,413,540 m³ of industrial wastewater, giving a total of 67,789,785 m³. Of this quantity, 48% was discharged directly into the coastal sea. Fifty per cent of the total quantity generated in the Region is from the area of the largest demographic, tourist and industrial concentration: the city of Rijeka and the littoral along Kvarner Bay.

Table 1 shows wastewater quantities as calculated in 1981 by sub-regions and also by origin (i.e., residential population, tourist population, industry). The total daily inflow of wastewater into the sea is 230,000 m³.

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Residential population m³/y</th>
<th>Tourist population m³/y</th>
<th>Industry m³/y</th>
<th>Total m³/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Istria</td>
<td>9,855,657</td>
<td>6,303,896</td>
<td>2,541,024</td>
<td>18,790,577</td>
</tr>
<tr>
<td>Mid Istria</td>
<td>3,804,103</td>
<td>410,625</td>
<td>1,689,120</td>
<td>5,903,848</td>
</tr>
<tr>
<td>Littoral</td>
<td>19,053,365</td>
<td>3,344,234</td>
<td>11,634,106</td>
<td>34,031,705</td>
</tr>
<tr>
<td>Islands</td>
<td>1,914,936</td>
<td>1,941,399</td>
<td>190,000</td>
<td>4,046,415</td>
</tr>
<tr>
<td>Gorski Kotar</td>
<td>4,571,333</td>
<td>86,697</td>
<td>359,210</td>
<td>5,017,240</td>
</tr>
<tr>
<td>TOTAL</td>
<td>39,119,394</td>
<td>12,176,851</td>
<td>16,413,540</td>
<td>67,789,785</td>
</tr>
</tbody>
</table>

The estimated quantities of wastewaters for the year 2000 were calculated in the same way, based on the projections of population, tourist beds, and industrial growth in the Regional Plan, see Table 2. Wastewater quantities will certainly be larger than these predicted values, due to the expected general improvement of standards of living, and the pollutant content will be greater, due to the expected future increase of toxic substances in wastewater. However, these factors were ignored in the analysis because of the constraints on the planned projections expected in the spheres of water supply and coastal space.

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Residential population m³/y</th>
<th>Tourist population m³/y</th>
<th>Industry m³/y</th>
<th>Total m³/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Istria</td>
<td>12,118,000</td>
<td>11,400,000</td>
<td>2,884,872</td>
<td>26,402,872</td>
</tr>
<tr>
<td>Mid Istria</td>
<td>4,124,500</td>
<td>985,000</td>
<td>2,067,552</td>
<td>7,177,052</td>
</tr>
<tr>
<td>Littoral</td>
<td>24,820,000</td>
<td>7,275,000</td>
<td>14,600,320</td>
<td>46,695,320</td>
</tr>
<tr>
<td>Islands</td>
<td>2,117,000</td>
<td>4,270,000</td>
<td>223,776</td>
<td>6,610,776</td>
</tr>
<tr>
<td>Gorski Kotar</td>
<td>4,635,500</td>
<td>405,550</td>
<td>417,998</td>
<td>5,500,648</td>
</tr>
<tr>
<td>TOTAL</td>
<td>47,815,000</td>
<td>24,335,550</td>
<td>20,393,618</td>
<td>92,586,668</td>
</tr>
</tbody>
</table>

According to population projections, there will be 655,000 inhabitants in the Region by the year 2000, and 666,700 tourist beds are planned (hotels, private accommodation and campsites). Municipal wastewater is estimated as up to 47,815,000 m³ yearly, and wastewater from tourists as up to 24,335,550 m³.
yearly. It is estimated that the existing and new industries, transportation activities and terminals planned in the industrial zones in the Region (of which the most important are those in Kvarner Bay, the Rača Valley and close to Pula) will generate altogether about 20,393,618 m³ of industrial wastes yearly.

The total wastewater quantity of 92,586,668 m³ estimated for the year 2000 shows an increase of about 27% in relation to 1981.

IMPACT OF WASTEWATER ON RECEIVING WATERS

Sewage is the main pollutant of the coastal waters of the Adriatic Sea in the Rijeka Region. Therefore, an analysis of receiving waters should offer a sound indication of the impact of wastewater, since the impact of solid wastes (from the coast and from ships) is very small, and is almost negligible in comparison to wastewater.

The analysis of research and monitoring activities carried out before and during the drawing up of the Regional Physical Plan, resulted in a systematized graphic presentation of the existing water quality in the rivers and the coastal Adriatic waters of the Region. Grades were established according to the existing standards for receiving waters in the Yugoslav legal regulations, with limits not to be exceeded.

Some of the existing standards for coastal receiving waters of the Yugoslav Adriatic Sea are shown in Table 3.

**TABLE 3 Six of the Existing Standards for Coastal Receiving Waters, the Limits of Which are Not to be Exceeded**

<table>
<thead>
<tr>
<th></th>
<th>Class 1**</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids, mg/l</td>
<td>10</td>
<td>30</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>MPN total coliforms/1000 ml</td>
<td>100</td>
<td>5000</td>
<td>200,000</td>
<td>-</td>
</tr>
<tr>
<td>pH*</td>
<td>6.1±0.2</td>
<td>8.1±0.3</td>
<td>8.1±0.3</td>
<td>8.1±0.4</td>
</tr>
<tr>
<td>Visible solid waste</td>
<td>without</td>
<td>without</td>
<td>without</td>
<td>without</td>
</tr>
<tr>
<td>Increase of temperature</td>
<td>0°C</td>
<td>2°C</td>
<td>3°C</td>
<td>12°C</td>
</tr>
<tr>
<td>Oils, petroleum, petroleum</td>
<td>0.05</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>derivatives, mg/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* pH which can be tolerated if the salinity is diminished due to the natural inflow of freshwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**Class 1 = waters containing shellfish nurseries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 2 = waters for swimming and recreational purposes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 3 = waters for fishing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 4 = waters in closed harbours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The analysis of the sea water shows most of the waters along the coast of Istria and the western coast of the island of Krk to be of class 2, while class 3 waters appear along the north-western coast of the Rijeka Bay, and at smaller areas in the vicinity of the towns, such as Rovinj, Umag, Poreč and others. Class 4 waters appear only inside the large harbours of Rijeka and Pula. Coastal waters of class 1 standard are present along the south-eastern coast of Istria, and along the coast of all the islands except for small areas in the vicinity of towns, where waters of class 2 appear. The existing shellfish nurseries are in waters of class 1 standard (the Bay of Lim in Istria), however, not all the sea areas where new nurseries are planned are of an adequate standard.

The river waters of the Region have also been classified, to enable comparison with the existing standards for freshwaters in Yugoslavia. These standards are, of course, different from those for coastal sea waters, however, there are also four classes, as follows:

Class 1 - Potable water (naturally or after disinfection) and salmonid nurseries.
Class 2 - Water for swimming and recreation, and cyprinid nurseries (also potable after conditioning).
Class 3 - Water for agriculture and industries which do not need pure water.
Class 4 - Others.

Waters of almost all the rivers of the Region that flow into the Adriatic were analysed: the Mirna, the Raša, the Boljunčica, the Pazinčica, the Rječina, and the Dubračina.

The waters of the upper courses of all the rivers were of class 1. They changed to classes 2 and 3 upon receiving wastewaters in their lower reaches: the Mirna after receiving industrial and municipal wastewaters at Buzet; the Raša after receiving industrial and coal mining waste at Potpinč; the Boljunčica after receiving agricultural waste at Čepić; the Pazinčica after receiving municipal and industrial wastewaters from the city of Pazin; the Dubračina after receiving sawmill waste at Fužine; the Rječina after receiving papermill waste and sewage from the city of Rijeka. Most of these rivers become class 4 in their estuaries.

There is no evidence that these localized contaminated waters have any influence regarding polluting the main water mass along the coast.

ALTERNATIVE FORECASTS OF FUTURE IMPACT OF WASTEWATER ON COASTAL RECEIVING WATERS

Based on wastewater quantities calculated for 1981 and those estimated for the year 2000, alternative forecasts of the future impact of wastewater on coastal receiving waters of the Adriatic Sea in the Region have been prepared, within the scope of the Sea Use Study, which is an integral part of the Regional Physical Plan.

One alternative is pessimistic, because the results of continuing present trends in wastewater treatment and disposal have been projected to the year 2000. If all the quantities estimated for the year 2000 were to be discharged into the coastal waters without provision of proper sewage facilities and without pretreatment, the coastal waters would be of class 3 all along the western coast of Istria, while waters of class 4 would be permanent in all the harbours, e.g. Rijeka, Bakar, Pula and Rovinj. The rest of the mainland coast, as well as the Eastern parts of the islands of Krk and Cres would have coastal waters of class 2. Waters of class 1 would remain only along the main part of the island coast, except for class 2 waters close to the central settlements or even class 3 waters in some places (Krk, Lošinj, Pag).

The other alternative considers environmentally sound future development of the Region, which follows all the guidelines of the Plan, with environmentally sound management of resources, sound land and sea use, and with implementation of all the proposed measures of environmental protection, the most important of which is provision of satisfactory sewage disposal facilities.

Very optimistic results are achieved: the coastal waters of the Upper Adriatic Sea would be of class 1 almost all along the mainland and the island coast, except for some parts of the western coast of Istria and the Bay of Rijeka, where class 2 waters would appear. There is only one area where waters of class 3 would persist - in the Bay of Bakar.

GENERAL GUIDELINES FOR THE PROVISION OF ADEQUATE SEWAGE DISPOSAL FACILITIES

Provision of satisfactory disposal facilities is identified by the above analysis as being an essential infrastructural condition not only to maintain and improve existing living standards, but also to support the urban and economic development projected by the Regional Physical Plan to the year 2000.

Unlike water supply, sewage disposal cannot be accomplished by means of extensive regional systems. Specific methods for treatment and disposal should
be selected for each particular case, in accordance with the local situation. Therefore, no general pattern can be applied everywhere, although due to a number of common aspects and problems, overall strategic guidelines ought to be followed, and these should also assist in solving individual problems.

It is of the utmost urgency that the existing conceptual plans, sewerage master plans and projects be revised, co-ordinated among neighbouring communes, and finalized, so that the first stage of their implementation can start, to ameliorate the most acute pollution. Smaller centres and settlements, where no plans have been prepared so far, should initiate feasibility studies and ensure their timely follow-up. In principal settlements in each commune, adequate limited systems should be planned and constructed to include suburbs and tourist recreational zones within fairly easy reach of such systems. Adequate pretreatment of all wastewaters discharged into the Adriatic coastal waters will have to be applied in future.

In urban/tourist areas along the coast, oceanographic surveys are fundamental for the provision of satisfactory facilities to ensure optimum advantage is taken of the sea's own natural ability for self purification, and to determine whether to install the first stage of conventional treatment processes (inland), or a combination of preliminary and primary treatment with longer outfalls. Such surveys have already been undertaken in some places along the western coast of Istria, in Pula and Rabac.

Studying the receiving waters to determine, for example, seasonal variations in wind, tide, current, temperature, etc., would provide the necessary information to establish the optimum methods for sewage disposal, to finalize the precise configurations of the sewerage systems, and to determine the degree of pretreatment to be given to sewage, the length of the outfalls, the precise positions of the discharge points and the amount of artificial diffusion that should be provided so that the discharged wastewaters reach beyond a 'point of no return'. Investigations into the geology of the sea bed along likely routes of new longer outfall pipelines would provide information to determine the most suitable means of outfall construction.

Implementation should be planned and carried out in stages so that immediate improvement of the existing sewage disposal methods can be achieved while remaining within the constraints of available finance. Each subsequent stage is implemented if or when so dictated by the careful examination of the results achieved by the previous stage. Sophisticated treatment processes would be installed where other simpler methods of treatment are proved to be unsatisfactory. In this way, the environment would be continually improved and the problems of cost lessened.

This means that the plans and projects for sewerage systems in the coastal areas should provide for preliminary and primary (mechanical) wastewater treatment in the first stage, but also for the possibility of subsequent inclusion of equipment for secondary (biological) treatment in further stages.

In harbours and cities generating large quantities of wastewaters of higher concentrations (such as Rijeka and Pula) and wherever the sewage is expected to contain large amounts of chemical or non-organic materials, conventional treatment processes will have to be used and the necessary equipment for biological treatment provided.

Inland sewerage systems with outlets into rivers and streams should also have the necessary equipment for secondary or even tertiary wastewater treatment.

Comparative investigations of alternative solutions for sewage disposal should be undertaken. Detailed financial appraisal of the construction and operating costs of all satisfactory alternatives should be prepared to enable the selection of the least cost option that will comply in every way with the town plan. In the coastal residential area it is of importance to determine the relationship, regarding costs, between conventional pretreatment processes versus length of outfalls.
The treatment methods of industrial wastewaters should depend upon the type of production and technological processes involved, and also upon the quantities and composition of the wastewaters. When discharged, they should have no negative impact upon the receiving waters (either streams or sea water). Industrial wastes should not be discharged into municipal sewers. Exceptionally, where there are no alternative solutions, industrial wastewater must undergo complete treatment if its composition differs from that of domestic wastewater.

It is necessary to obtain complete data on all significant sources of pollution and pollutants (industrial and others) and to set conditions for the discharge of wastewaters into rivers, streams and the sea. Efforts towards the acquisition of such data have already been initiated in the Rijeka Region by the Water Authorities.

In addition to careful control of water at the outlets upon construction of each stage of a sewage treatment system, it is obligatory to carry out continuous monitoring of wastewater composition and concentrations.

Oceanographic research and monitoring are expected to continue and to develop further, so as to ensure permanent control of the coastal waters and of the main water mass of the Adriatic Sea in the Rijeka Region.

REFERENCES