Significance of wetlands in water quality management – past and present situation of Kızılırmak Delta, Turkey

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Abstract Wetlands are of utmost importance in the sense of protecting the natural ecological balance of the environment. It is possible to improve the water quality of wetlands, which are located in coastal areas like river deltas and lakes without disturbing the ecological balance through rehabilitation and by controlling. However, many wetlands in the world have so far been dried and converted to agricultural areas due to insufficient knowledge of their ecological value. Such an understanding was also held as true in Turkey and most of its wetlands have been converted to agricultural land till recent years. An example of such an occurrence and modifications within years are observed in the delta of the Kızılırmak River, which is the longest river of Turkey ending in the Black Sea. The past and present situation of the Kızılırmak delta will be investigated in this paper together with the changes in water quality. An evaluation of the water quality of the river and of lakes within the delta is done based on available previous data and on the final findings of water quality measurements conducted within the framework of this study.

Keywords Black Sea; Kızılırmak Delta; water quality; wetlands

Introduction
Within recent years, the ecological significance of either natural or constructed wetlands is better understood, their utility in water quality control – by operating them as an engineering system in a controlled manner – has gained interest in developing countries where the share of national income spared for environmental protection is quite limited. Thus, effective use of this limited economic input depends highly on the cost of environmental protection technologies. The wetlands are the appropriate systems for prevention of water pollution caused by point sources of pollutants. As the operation and maintenance of such systems are quite simple and easy, it is an advantage for developing countries. On the other hand most of the pollution transported through creeks, rivers, lakes and seas are carried from land by surface run-off and erosion, and are defined as non-point sources of pollutants. Rivers transport a significant amount of these pollutants. Control of non-point sources of pollutants is a complex and difficult task compared to point sources of pollutants. Such problems have not even been recognised and/or taken into account in most of the developing countries. At this stage, the significance of natural wetlands situated at river deltas and/or near coastal waters and lakes is gaining interest. It is possible to use them for improving water quality without destroying the flora and fauna of the region and without spoiling the ecological balance. The only need is to rearrange and modify wetlands for effective utilisation.

However, most of the natural wetlands of the world have been dried and converted to forest or agricultural areas as their ecological importance was not well recognised and understood. In some, the ecological balance has been almost completely destroyed due to pollution by domestic or industrial wastewater discharges (Environmental Foundation of Turkey, 1995).

In this paper, the previous and existing situation of wetlands in the Kızılırmak river delta, which is the longest river of the country, was investigated, the changes in water...
quality were evaluated and the significance of wetlands in the delta in terms of water quality control was emphasised.

**Characteristics of Kızılırmak Delta**

The Kızılırmak Delta is situated along the Black Sea coast of Turkey. The Kızılırmak River, with a length of more than 1,150 km and with a drainage area of ± 75,000 km² is the largest river in Turkey flowing to the Black Sea after crossing the delta. The wetland is located within the borders of Bafra, Alacam and 19 Mayis counties where the Kızılırmak River joins the sea. The treated wastewater of Bafra town is discharged to Kızılırmak Delta. Bafra with a population of around 60,000 inhabitants forms the southern border of the delta (Figure 1).

Within the boundaries of the delta, there are a total of 25 lakes of various sizes of natural importance. These lakes are named as Bafra Balık Lakes, and cover an area of 2,700 ha in arid seasons and 9,250 ha in rainy seasons. The most important forest area of the delta is Galeric Forest with an area of approximately 1,500 ha. It also serves as a breeding and shelter area for many birds. Even though the delta is under the negative effect of illegal housing, extensive land hunting and pollution, it still continues to present a rich and healthy living environment to both flora and fauna. In the eastern part of the delta, there is a wetland of about 12,000 ha covering lakes, marshes, reed beds, sand dunes and aquatic pastures. The important lakes are Balık Lake (with Uzun Lake), Cernek Lake and Liman Lake. In the western part, there is another lake named Karabogaz.

The wetland ecosystem of the delta has great importance in terms of its biological diversity. The richness of flora and fauna has been proved by the scientific researches conducted. Fish production within recent years in Bafra Lakes due to pollution in the delta has decreased. As an example, gray mullet and zander production was almost none in 1990, while their production was around 85,000 and 160,000 kg/year in 1975, respectively. Carp production decreased from 580,000 to 20,000 kg/year within 1975–1990. The reed beds with vegetative cover in the sand dunes and variety of birds ensure that this region is

![Figure 1](https://iwaponline.com/wst/article-pdf/46/8/145/426015/145.pdf)
essential. The number of bird species determined up to now in the Kızılırmak Delta is 316. In the delta, approximately 140 bird species breed and almost 100,000 aquatic birds spend winter in the delta (Gonulol and Cakmak, 1992).

An extensively large wetland has been formed along the eastern coast of the delta consisting of numerous parallel sandy beach ridges with depressions in between. Some of the depressions can be characterised as lagoon systems. The delta can be divided into three regions; the higher parts of the delta are almost completely devoted to agricultural activities, lower parts are in use as pastures and wetlands, there exist dunes and beach ridges between the lower part of the delta and the Black Sea.

Prior to construction of Altinkaya and Derbent Dams for irrigation, hydroelectric generation and flood control purposes, the Kızılırmak was flowing in an uncontrolled manner and was feeding the delta based on its flowrate. The channels such as Hacılar, Badut and Bakırpinar were forming a bridge between the lakes and the delta. Pollution carried by Kızılırmak together with the domestic discharges of Bafra town led to severe pollution of water. On the other hand, it is assumed that part of the pollution is removed in the wetlands. The lakes present a significant seasonal variation in water depth. All lakes are quite shallow and they are almost at sea level (Dijksen and Kasparek, 1985). The flat nature of the delta’s topography ensures that relatively small changes in water level cause substantial changes in the areal extent of the lagoons and lakes.

According to Hollis and Thompson (1992), the possible sources of water feeding the wetland are: groundwater originating from the Kızılırmak river, inputs of surface and local groundwater from the channels, surface run-off from the delta plain, groundwater flow derived from the dunes, direct precipitation on the lakes and marshes, locally, seawater may seep up in the wetland (Stuyfzand, 1993). According to a classification the surface water in the channels is fresh brackish whereas most of the lakes have brackish to salt-brackish water types. Temporal wet pastures form a transition zone between the agricultural area and the permanent wetland. The lower parts of this grassland are often flooded in late winter and early spring (Husting and Van Dijk, 1994) and therefore belong to the wetland region. The vegetation of the pastures consists mainly of grasses, herbs and bushes. The wetland area is situated in the lower parts of the delta near the Black Sea, bounded by the pastures in the west and dunes in the east. The area consists of numerous lakes surrounded by treeless marshes which both are considered to be important ecosystems and add significantly to the high biodiversity of the delta. The density of vegetation is highly variable. Near pastures and on heavily grazed beach ridges, it has an open character whereas the permanent marshes especially in less grazed areas have a very dense vegetation structure.

The present situation of Kızılırmak Delta
Following the completion and operation of Altinkaya Dam, constructed in 1988 for energy generation, and Derbent Dam, constructed in 1990 for irrigation, overflow, energy generation, positive changes started to occur in the delta both in terms of ecology and environment.

From the outlet of Derbent Dam till the point where the river joins the Black Sea, the delta has been used for agricultural purposes. The State Water Works Association tendered “Bafra Plain Irrigation System, 1st stage” in 1991 to develop agricultural facilities in the delta. Drainage channels are constructed in the northern part of the delta causing the wetlands to dry. It was obvious that a variety of birds, fishes, flora and fauna residing and reproducing in the area would be decreased. Therefore, the construction work stopped for a period, but it has started again. The irrigation systems have not been completed yet (Special Interviews, 2001).

Illegal land hunting, rapid urbanisation with insufficient infrastructure and illegal
housing, use of pesticides and commercial fertilisers in agricultural lands led to eutrophication in the lakes as the pollutants reached to the lakes via drainage channels. Finally, death of fishes forced many organisations to take protective measures against pollution. The Preservation of Wild Life Association tried to register the area in the list of Internationally Important Wetlands and stated the region as the Ramsar area, as reported in the Official Newspaper dated 15.04.1998 and ref. no 23314. However, the protected area does not involve all the delta, is a part of the region covering the Black Sea coast and a certain land area. Nowadays, Kızılırmak River is flowing in its rearranged bed and has no contact with the delta apart from the region where it joins the Black Sea. Badut creek, which ends in the Cernek Lake, served as a receiving water body for domestic wastewater of Bafra Town with a population of 60,000 till recent years. A significant amount of the wastewater has been discharged directly to Kızılırmak. The sewage channel and wastewater treatment plant has been completed in year 2000 within the framework of activities to protect the delta. The plant consists of advanced nitrogen and phosphorus removal units and the effluent is discharged to Kızılırmak. Therefore, further pollution of Badut Creek and Cernek Lake is almost completely stopped. A total population of 12,500 resides in the delta among which the important counties are Yorukler with a population of 3,000, Doganca with 3,500 and Yakakent with 5,000. These residential areas are outside the Ramsar area and they have tried to solve their treatment facilities through the use of septic tanks. In this area, there exists a textile factory and various small-medium scale factories with daily wastewater flow rates of less than 50 m³ and they all have their own treatment plants.

By the operation of Derbent and Altinkaya Dams in the Kızılırmak River, major sediment transportation to the river mouth has been prevented. It used to take place by the south-eastern sea current towards the eastern coastline of the delta. Due to this decrease of sediment supply, the coastline is retreating (Hollis and Thompson, 1992).

**Past and present water quality of the delta**

Presently, the water quality of Kızılırmak River at the delta section is at an acceptable level. The results of the latest experiments on organic matter, nitrogen and phosphorus of water samples taken from four stations on March 2001 present similarities and concentrations vary within a narrow range i.e. COD 5.8–7.0 mg/l, nitrate 1.08–3.67 mg/l, TKN 3.35–4.25 mg/l, total phosphorus 0.78–0.95 mg/l as given in Table 1. BOD₅ concentrations at three stations near the upstream are measured as 1 mg/l, whereas it is 6.8 mg/l at the downstream station where the river ends in the sea. This unusual finding may be due to the high organic matter content of the sea compared to Kızılırmak River.

There exist dams at the upstream of the river now, however before their construction, the overflow river water at high flow rate periods used to feed the wetlands of the delta. Unfortunately, no chronological water quality data is present belonging to these old days when the wetlands reflected a more natural and a more stable ecological balance. However, water quality parameters measured by various local authorities from 1992 onwards

<table>
<thead>
<tr>
<th>Parameters (mg/l)</th>
<th>Station 1*</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃-N</td>
<td>3.67</td>
<td>1.19</td>
<td>1.08</td>
<td>1.08</td>
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<tr>
<td>COD</td>
<td>6.41</td>
<td>6.74</td>
<td>5.79</td>
<td>6.96</td>
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<td>BOD₅</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6.8</td>
</tr>
<tr>
<td>TKN</td>
<td>4.2</td>
<td>4.25</td>
<td>3.35</td>
<td>3.45</td>
</tr>
<tr>
<td>Total PO₄</td>
<td>0.776</td>
<td>0.945</td>
<td>0.887</td>
<td>0.84</td>
</tr>
<tr>
<td>Chloride</td>
<td>27.3</td>
<td>27.3</td>
<td>27.3</td>
<td>35.46</td>
</tr>
</tbody>
</table>

*: The station numbers refer to the map in Figure 1
(Provincial Environmental Situation Report, 1994 and 1999), are summarised in Figure 2
(a, b, c, d). These data belong to lakes and water channels, which are fed by either surface
runoff, or by Kızılırmak River.

Water quality measurements taken from the downstream of the point where the domestic
wastewater of Bafra town is discharged to Kızılırmak River from January 1998 to
September 2000 shows that dissolved oxygen concentrations varied around 10 mg/l. At the
same station, COD concentrations varied between 30–35 mg/l, NO₃-N between 2–4.5 mg/l,
suspended solids of 30–80 mg/l were detected between years 1992–1998. Following the
construction and operation of Bafra Wastewater Treatment Plant, COD values started to
decrease from 1998 onwards by the effect of seasonal factors and varied between 5–30
mg/l, and the final measurement of September 2000 is stated as 12 mg/l. Similarly, the
decreasing trend is also observed in nitrate and nitrite concentrations between years
1993–1998. NO₃ concentration varied between 1–3 mg/l in years 1998–2000. At this specific
station, the long-term measurements clearly indicate the improvement of water quality
within years especially due to the operation of the Bafra Wastewater Treatment Plant.

The water quality of one of the important wetlands of the delta named as Cernek Lake
was at a highly critical position between years 1995–1996 in terms of dissolved oxygen,
COD, BOD₅ and NO₃ parameters. Unfortunately, no new data on water quality of this lake
exists.

However, an improvement in water quality of Badut Channel feeding this lake has been
observed from 1997 onwards. The BOD₅ value of 3 mg/l in September 1997 was measured at
the channel, which indicates an indirect positive effect on lake water quality.

In another wetland of the delta named as Balık Lake, the dissolved oxygen concentration
decreased up to 6 mg/l from time to time and according to the recent data of September
1997, COD varied between 40–90 mg/l and BOD₅ increased up to 64 mg/l, showing signs
of high pollution. At the outlet of Derbent Dam on the upstream of the delta a higher water
quality is observed. The recent measurements of September 1999 belonging to samples
taken from the three stations in the Dam Lake indicate that dissolved oxygen varied
between 8.5–10 mg/l and COD 10 mg/l.

**Discussion**

Wetlands are important water bodies in terms of ecological balance. Turkey pays attention
to the well being of wetlands within the concept of Ramsar Agreement especially in the
recent years. Wetlands are important breeding areas of many flora and fauna types, and act
as active and natural treatment systems, which in turn give rise to the improvement of water
quality. Kızılırmak Delta has been effectively reduced in size from its original condition by
the construction of Altinkaya and Derbent Dams, modifications done on especially the
region between the Black Sea and the outlet of the Derbent Dam by constructing sets. The
area within the delta with its officially registered boundaries in 1998 has been devoted to
agricultural activities. Thus the recent situation of the delta has restricted its benefits in the
improvement of water quality.

Even though it is impossible to make a systematic evaluation of water quality of the
delta, the final water quality measurements of 2001 report that the water quality between
the outlet of the dam and the Black Sea is of higher quality compared to the values detected
at the point where the river joins the Black Sea. This condition shows that the Black Sea is
comparatively more polluted than the river and that the river behaves as a diluting water
resource. Based on the quality measurements of the important wetlands existing in the
delta, it can be stated that the lakes are more polluted compared to the present situation of
Kızılırmak, except for the Cernek Lake, whose water quality improved after the construc-
tion of Bafra Wastewater Treatment Plant.
Similar to the European Community receiving water standards, in the Turkish Water Pollution Control Regulation (TWPCR, 1988) inland waters are divided into four groups with the following recommended beneficial uses:

- **Class I**: High quality water (drinking water supply after disinfection, recreational uses, trout breeding and farm requirements)

**Figure 2** Water quality parameters measured in different stations along the Kızılırmak Delta (a) Dissolved oxygen, (b) COD, (c) BOD₅, (d) NO₃
• Class II: Sparsely polluted water (drinking water supply after traditional treatment, recreational uses, fish breeding other than trout, irrigational uses after the current irrigation water criteria are satisfied, all other uses apart from the ones listed in Class I)
• Class III: Polluted water (industrial water supply except for those areas requiring high quality like food and textile industries, after suitable treatment)
• Class IV: Highly polluted water (Surface waters of lower quality than the above listed classes).

The conventional approach to national water quality classification states the related parameters of Table 1 and Figure 2 as given in Table 2.

Evaluation of the four water quality parameters measured at different stations along the Kızılırmak River given in Figure 2 according to the national quality criteria referred to in Table 2 points out that there is a significant increase in water quality terms of the four parameters after January 1998 and even the positive trend is highly sensed in the recent measurements stated in Table 1.

Dissolved oxygen, COD, BOD₅ and NO₃-N measurements apparently represent Class I characteristics for Kızılırmak. However, the recent measurements of TKN show a classification trend between Class II and III whereas total phosphorus can be characterised as Class IV. The chloride parameter on the other hand slightly tends towards Class II. Such an improvement in water quality must be monitored frequently by the local authorities and especially the efficiency of Bafra Wastewater Treatment Plant must be controlled.

Any troubles that might be faced in the operation of the wastewater treatment plant will directly affect the water quality.

Conclusions
Conversion of wetlands to agricultural land has restricted the integrated improvement of water quality and of the natural ecosystem. It is of high importance to protect the existing wetlands determined by the Ramsar Agreement to prohibit their deterioration by human activities. It is vitally significant to control especially diffuse sources of pollutants that threaten the lakes in the delta. A general evaluation may be done considering all the available data on the delta, that pollution in lakes and channels carried by the Kızılırmak River at the upstream are negligible compared to pollution arising from residential areas and from agricultural activities. This condition is basically due to constructing sets and barriers between river and wetlands, installing channels leading to dryness of wetlands, which in turn cause the effectiveness of diffuse sources of pollutants.

In order to protect the ecological value and water quality of the region, point sources of pollutants must be controlled and wetlands around the river, channel and lakes must be rehabilitated and restored against diffuse sources of pollutants.

Various authorities, which must have joined in a unique association, have directed

![Table 2](https://iwaponline.com/wst/article-pdf/46/8/145/426015/145.pdf)

<table>
<thead>
<tr>
<th>Parameters (mg/l)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
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<tbody>
<tr>
<td>Dissolved Oxygen (mgO₂/l)</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>25</td>
<td>50</td>
<td>70</td>
<td>&gt;70</td>
</tr>
<tr>
<td>BOD₅ (mg/l)</td>
<td>4</td>
<td>8</td>
<td>20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Nitrate-N (mgNO₃-N/l)</td>
<td>5</td>
<td>10</td>
<td>20</td>
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<tr>
<td>Total Kjeldahl Nitrogen (mg/l)</td>
<td>0.5</td>
<td>1.5</td>
<td>5</td>
<td>&gt;5</td>
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<tr>
<td>Total PO₄ (mgPO₄³⁻-P/l)</td>
<td>0.02</td>
<td>0.16</td>
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<td>&gt;0.65</td>
</tr>
<tr>
<td>Chloride (mgCl⁻/l)</td>
<td>25</td>
<td>200</td>
<td>400</td>
<td>&gt;400</td>
</tr>
</tbody>
</table>
studies conducted at the region so far and such attempts are on the way to update the measure-
ments in a systematic manner, and to monitor the water quality.

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