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Research Article

MODELING OF NEAR-FIELD DILUTION OF HEATED DISCHARGES ON TEKIRDAĞ COASTS

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ABSTRACT

The main cause of heated water discharges is the use of seawater as a coolant by power plants and industrial manufacturers. Uncontrolled discharges into the ambient sea water having excess heat, have a negative effect on the ecosystems. In this study, the near field dilution of heated sea water discharges is modeled and the behaviors of pollutant clouds are analyzed using CORMIX (CORMIX2). The effects of different parameters such as total effluent discharge, diffuser length, port details, current on the near field dilution of heated discharges are investigated with different scenarios by numerical models CORMIX2, which is the submodule of CORMIX for submerged multiport diffusers. In spite of a hypothetical study, a real coastal region was selected to obtain and discuss realistic conditions. Since Tekirdağ coasts are surrounded by industrial manufacturers and also agricultural areas, they are under pressure of the coastal pollution. Therefore Tekirdağ coastal region is selected and CORMIX2 is applied to determine the effects of discharge parameters on near field dilution.

Keywords: *CORMIX, Heated discharge, Tekirdağ Coasts, Near-field dilution.*

1. INTRODUCTION

The energy demand increases with developing technology and many plants are built to satisfy the increasing demand. Thermal discharges come out in nuclear, thermal plants and different plants for cooling waters. The high temperature of the effluent effects negatively the marine environment. Legal regulations limit the effluent properties to minimize the negative impacts. Determination of dilutions can be made by mathematical models which include complex calculations of dilutions considering detailed oceanographic parameters.

Thermal discharge causes decrease of solubility of oxygen. Each living creature in the sea needs specific ambient temperature for metabolic activity. The diversity of the marine environment changes due to increasing temperature of sea water.

Diffusers are used to dilute the thermal effluent based on legal regulations. Using momentum effect, dilution is increased so that negative impact on the marine environment is decreased. The selection of the location and alignment of the diffuser is vital because the currents are effect significantly on the dilution. The main aim of a diffuser is providing to reduce the concentrations of the effluent under the limit values given in the regulations (Acar, 2014; Kanberli, 2003).

In this study, following effects of different parameters (total effluent discharge, diffuser length, port details and current) on the near field dilution of heated discharges in Tekirdağ coasts are investigated with different scenarios by numerical model CORMIX2.

2. STUDY FIELD

Tekirdağ coasts are located in the Marmara Sea of Turkey as shown in Figure 1. Agriculture, industrial facilities and increasing population with industrialization cause pressure on the environment. With deep soil structure and fertile lands, Tekirdağ is an important agricultural city. The main crops are wheat and sunflower. The Factory of Wine and Spirit of Tekel was established to increase grape production in 1931. The textile, leather and chemistry are the basic sectors of industry in Tekirdağ. In 2009, there are 1237 industrial establishment and there are 100000 workers in these establishments. Rapid and unplanned industrialization and rapid growth of population bring water pollution, air pollution, soil pollution. Their social ve economic impacts cause important environmental problems in Tekirdağ (Kısalar Gülen, 2011).

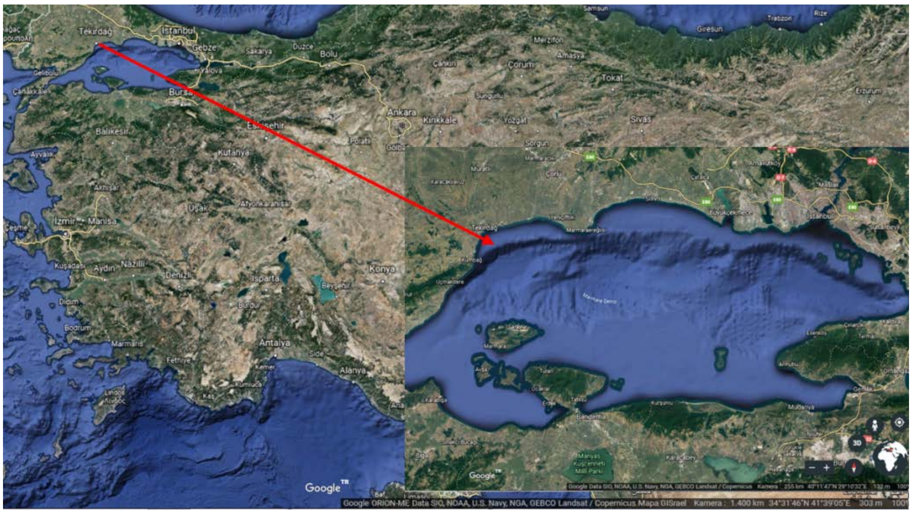

Fig. 1. Geographical Location of study area (Google Earth, 2019)

3. MATERIAL AND METHOD

The temperature of the effluent has negative impacts on the ecology of the marine environment. As the dilution ratio increases with the mixing process of the thermal water and marine water, effects of heated discharge on the environment decrease. There are three primary dilution steps: initial dilution (primary dilution, near-field dilution), dilution due to advection, diffusion and dispersion (secondary dilution, far-field dilution), and dilution due to bacterial decay (tertiary dilution). Near and far-field dilution can be seen in the Figure 2. The completion of these three steps can be a lengthy process. Therefore using a common model for different types of dilutions would be difficult. For each dilution, separate dilution models should be prepared and used together to predict the dilution accurately. Since the density of the heated effluent is smaller than the density of the ambient water, the effluent is positively buoyant.

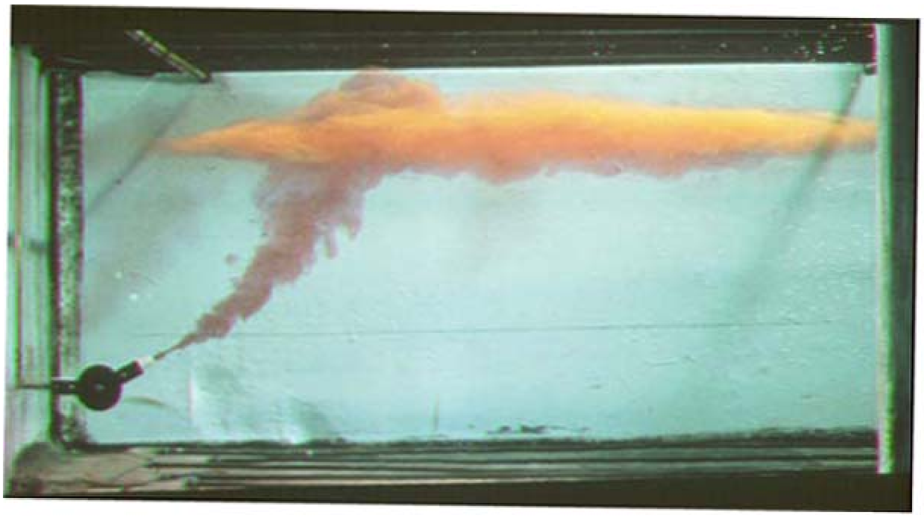

Fig. 2. Near and far-field dilution (CORMIX, 2019)

CORMIX is used for the calculations of near-field dilution. It can be applied to positively and negatively buoyant discharges. It is one of most important advantage of this model. CORMIX is used for the modeling of the near-field dilution of the pollutant in this study. CORMIX is a computer-aided-design system for outfall design and mixing zone analysis. CORMIX is a jet integral model and based on the conservation of the mass and momentum. CORMIX uses the length scale classification and the integral approach together so that the boundary interaction and the unstable conditions for the near field dilution can be considered. CORMIX has submodules for the submerged single port, the submerged multiports, and the surface discharges. In this study, CORMIX2 is used for the near field calculation and it is valid for submerged multiports (CORMIX, 2019; Doneker and Jirka, 2007; Inan, 2019; Morelissen et al., 2013; Yılmaz and Inan, 2018).

4.RESULTS AND DISCUSSION

In this study, the near-field dilution of a heated discharge in Tekirdağ Coasts is examined with CORMIX 2. The ambient conditions are taken from the measurements given in the literature. The worst case for a heated discharge is summer condition therefore the measurements corresponding to August are used. The temperature of the ambient water is 20.87 ^{0}C, the salinity is 28.45 ppt and the density of ambient water is ρ_{amb}=1019.55 kg/m^3 (Municipality of Tekirdağ, 2010). In this study, the characteristics of the effluents are determined based on the allowable values in Regulation of Water Pollution Control. The temperature difference can not exceed 10 ^{0}C and the maximum temperature of the effluent can be 35 ^{0}C. The increase of temperature in the near-field region of the thermal discharges cannot be greater than 1^0 C in summer and 2 ^{0}C in winter (RWPC, 2004). Therefore a diffuser has different operation values for different seasons. The properties of the hypothetical diffuser are given in Table 1.

Table 1. The properties of the diffuser of the sea outfall in Tekirdağ

Discharge	Q=4 m^3/s	Current velocity	u= 0.1 m/s	Port diameter	D=0.25 m
Temperature difference	dt=10 ^{0}C	Density of the effluent	ρ_{eff}=999 kg/m^3	Port number	8
Water depth	D=30 m	Diffuser Length	Ld=100 m	Wind velocity	Uw=2 m/s

The effect of the diffuser length, current velocity, discharge, port diameter and port number on the near-field dilution are studied. In Figure 3, the change of the near-field dilution depending on the diffuser length is shown. The range of the near-field dilution is in between 87 and 265. As the diffuser length increases, the near- field dilution increases linearly. Based on the Turkish Regulations, the minimum near-field dilution must be at least 40 (RWPC, 2004). The results satisfy this regulation.

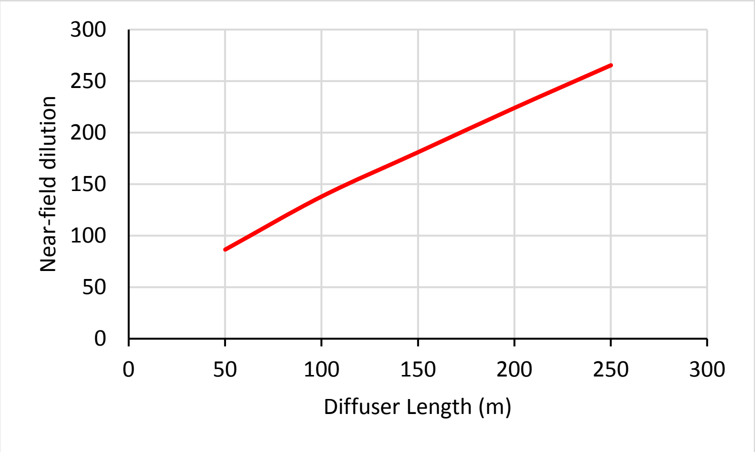

Fig. 3. Diffuser length vs. near-field dilution

The relationship between current velocity and near-field dilution is studied and shown in Figure 3. The current velocities vary from 0.05 m/s to 0.35 m/s. The current velocity of 0.05 m/s indicates the still water condition. Near-field dilution increases with increasing current velocity and near-field dilution is greater than 40 for all every current velocities, as shown in Figure 4.

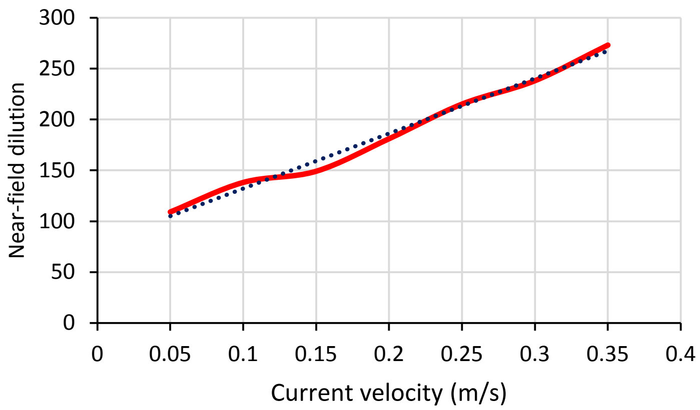

Fig. 4. Current velocity vs. near-field dilution

The effect of heated discharge on the near-field dilution is shown in Figure 5. As the discharge increases, the asymptotic behaviour of the curve begins. The results, that are shown in Figure 4, fullfil the condition that the near-field dilution should have a value not smaller than 40. As the discharge of heated water increases, the horizontal distance of the near-field dilution increases. It changes approximately from 50 m to 250 m.

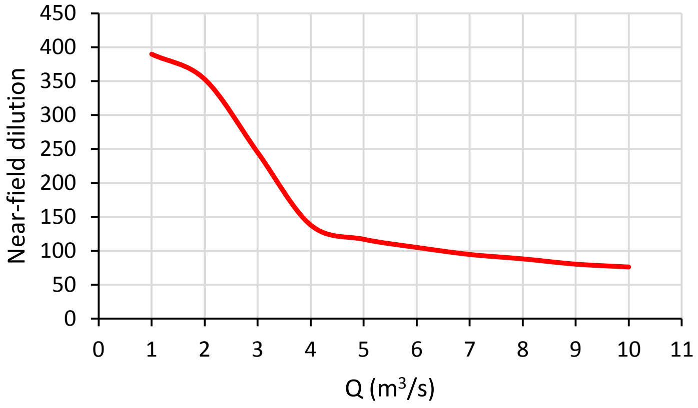

Fig. 5. Discharge vs. near-field dilution

The effect of the port diameter on the near-field dilution is figured out in Figure 6. Port diameter changes port velocity and also the Froude Number. The diameter from 0.1 m to 0.25 m, the near-field dilution is nearly 140 and the horizontal distance of the near-field dilution is 110 m. When the port diameter is greater than 0.25 m, near-field dilution is about 190 but the horizontal distance of the near-field dilution extends and reaches to 150m.

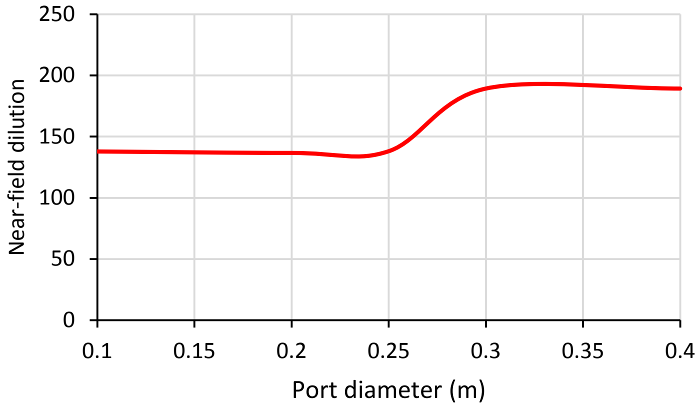

Fig. 6. Port diameter vs. near-field dilution

The relationship between port number and near-field dilution is illustrated in Figure 7. The diffuser length is taken as 100 m. Up to the 8 port number, near-field dilution is about 140 and the horizontal distance of the near-field dilution is 115 m. If the port number is greater than 8, than merging of the plumes begin to occur and the behavior of the plume changes. Near-field dilutions are 200 and 220 for the port numbers 10 and 20, respectively. Similarly, the horizontal distance of the near-field dilution increases from 175 m to 225 m. Merging coordinates (x, z) are (69 m, 12 m) and (30 m ,6 m) for the port number 10 and 20, respectively. x is horizontal distance and z is vertical distance from the sea bottom.

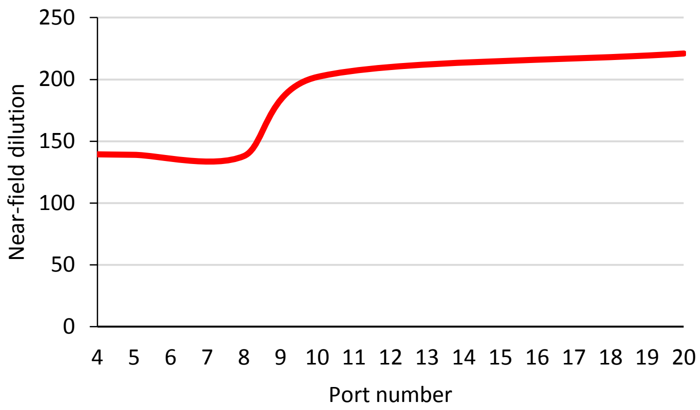

Fig. 7. Port number vs. near-field dilution

5. CONCLUSION

In this study, the sensitivity analysis of port configurations for near-field dilution of heated discharges is examined by CORMIX 2. Thermal discharges are positively buoyant, therefore horizontal jets are used because of momentum fluxes. As current increases, near-field dilution increases. The discharge effect on the near-field dilution depends on the density of the effluent. When the discharge increases, near-field dilution decreases in positive buoyancy; otherwise it increases. As the discharge increases, the horizontal distance of the near-field dilution increases. The discharge changes the Froude Number, it changes also flow type of the effluent. If the port diameter rises, near-field dilution decreases. Port diameter effects on the port velocity and Froude number, directly. As Froude number increases, dilution increases. Froude Number should be greater than 10, but Froude Number greater than 20 is recommended in the design generally. In this study, the changes of the Froude Number are studied, too. For a constant diffuser length, as the port numbers increases, the port spaces decreases and it can cause merging and line sourced plume. Single sourced plumes are preferred in the point of view of the near-field dilution. If the diffuser length is extended, the near-field dilution increases. Since the temperature and salinity of the ambient water change seasonally, the operation values of the effluent discharges should be different in winter and summer considering legal regulations.

ACKNOWLEDGMENT

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