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Environmental and hydraulic design of thermal power plants outfalls "Case study: Banha Thermal Power Plant, Egypt"

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Abstract A physical model study was conducted for designing the intake/outfall combination to comply with the Egyptian environmental laws. Based on the dominant flow patterns, and temperature measurements, two alternatives were examined. The first alternative of outfall structure consists of surface open channel. The output of this design did not comply with the environmental laws and has negative impacts on the water quality and ecological life. It was proposed to widen the outfall with 24 nozzles (multi port diffuser) arranged in two rows and separate the outfall into many jets. This new alternative for the outfall hydraulic design succeeded to improve the mixing process and complies with the Egyptian environmental laws.

1. Introduction

The discharge of thermal effluent from thermal power plants into water bodies would result in harmful impacts on the ecological life. The higher forms of aquatic life require oxygen for survival. The high temperature decreases the concentration of oxygen in water. So, it is important to dilute the thermal concentration into water bodies and confine it into small areas to maintain the allowable limits of oxygen needed for the aquatic life. A case study of thermal power plant was selected and studied to deduce the optimal plant outlet which can help for improving the mixing process to comply with the environmental Egyptian laws and to increase the Saturated dissolved oxygen (DO) levels in the water bodies. For this purpose, Banha Thermal Power Plant was taken as a case study in this research. It will be located at El-Rayah El-Tawfiki and will abstract water from it through the intake for its once through cooling system. The effluent discharge will increase the water temperature above the ambient by 10 °C which will cause negative impacts to the environment. El-Rayah El-Tawfiki has an Average Water Quality Index, AWQI of about 70% which is characterized as fair for human activities.

The Egyptian Electricity Holding Company, EEHC is planning to construct a new thermal power plant at El-Rayah El-Tawfiki, which is Banha Power Plant. The plant power capacity is 750 MW. It will abstract its cooling water from El-Rayah El-Tawfiki through its intake for its once-through cooling system and will be discharged back to El-Rayah El-Tawfiki through the plant outfall. The effluent discharge is characterized by its increased water temperature above the ambient

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Nomenclature

AWQI	average water quality index	MOE	ministry of environment
DO	dissolved oxygen	pH	hydrogen-ion activity
BOD	Biochemical Oxygen Demand	n_q	discharge scale ratio
COD	Chemical Oxygen Demand	n_t	time scale ratio
Tp	Total-Phosphates	n_v	velocity scale ratio
NH_3	Ammonia	n_l	length ratio
NO_3	Nitrates	Fr	froude number
TDS	Total Dissolved Solids	Frd	densimetric froude number
TA	Total Alkalinity	V	velocity (m/s)
TC	Total Coliform	g	gravitational acceleration (m/s^2)
As	Arsenic	h	water depth (m)
Cd	Cadmium	ρ	density (kg/m^3)
Cr	Chromium	$\Delta\rho$	density difference (kg/m^3)
Cu	Copper	Δt	specified temperature excess
Fe	Iron	Δt_0	initial temperature excess
Zn	Zinc	q_r	river discharge
EEHC	Egyptian Electricity Holding Company	q_0	outlet discharge
HRI	Hydraulics Research Institute	x	centerline plume length
MWRI	ministry of water resources and irrigation	b	width of outlet

water by 10 °C. The Hydraulics Research Institute, HRI was assigned by the EEHC to carry out the hydraulic model study for the proposed once-through cooling system and the optimum design of the intake/outfall of the plant from the hydraulic point of view. El-Rayah El-Tawfiki is considered as one of the most ancient canals in Egypt, it was constructed in 1889. It runs over a length of 192 km and irrigates 970,000 feddans. It is feeded directly from the upstream of the Delta Barrages and estuaries at the Midetrenian Sea. It crosses Qalyoubia, Dakahlia and Damietta Governorates [1]. Its water is used for different purposes such as irrigation, drinking, industry and fishing. Fifteen water quality pollutants were selected as indicators, these are dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total-Phosphates (Tp), Ammonia (NH_3), Nitrates (NO_3), Total Dissolved Solids (TDSs), Total Alkalinity (TA), Total Coliform (TC), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), and Zinc (Zn). These indicators are used to calculate the Average Water Quality Index, AWQI for the collected samples [2]. It was found that, the AWQI at El-Rayah El-Tawfiki is about 70% which is characterized as fair. Fig. 1, shows AWQI for some irrigation canals and Rayahs in Egypt, [3–5]. Throughout the present paper, the physical model was conducted to design the intake/outfall combination to comply with the Egyptian environmental law with the classification of AWQI.

2. Bathymetric survey and field measurements

Regarding the bathymetric survey, it covered reaches of 4 km length at El-rayah El-Tawfeky upstream Gamgara regulator two kilometers upstream its intake and the two kilometers downstream the outfall out of Banha Power plant. As for the field measurements, they were carried out by HRI in August 2009 to collect the data required for the physical scale models. The data consisted of bathymetric survey and flow measurements.

Bathymetric data was acquired by a high precision echo sounder operating at 200 kHz. The echo sounder was operated and calibrated in both analogue and digital mode. The cross section was executed every 50 m with very high accuracy. The bathymetric data was used to obtain the contour map which is used to build the physical scale model with contour interval 0.5 m. all the details are shown in [6].

The flow measurements were carried out at three cross-sections covering the surveyed reach using calibrated current meters. The locations of the flow cross sections are shown in Fig. 2. The measured discharges and water levels at the measuring cross sections were used for the physical model calibration. A Van Veen grab sampler was used to collect the bed material samples. Analysis of samples was included grain size distribution and specific weight, Fig. 2, shows the schematic diagram of EL-Rayah EL-Tawfiki surveyed area.

3. Hydraulic physical model

The scaled physical model was constructed with fixed bed had an undistorted scale of 1:50 in the horizontal and the vertical direction represents four kilometers of EL-Rayah EL-Tawfiki in the vicinity of the Banha Thermal Power Plant intake/outfall. Model similarity, construction, calibration and measuring devices were reported in details in HRI [7].

For the important hydraulic and thermal phenomena in a hydraulic scale model, a number of requirements must be fulfilled when determining the model scales which are geometric kinematics and dynamic similarity as the follow:

3.1. Geometric similarity

Geometric similarity of a model is achieved if all geometric dimensions of length, width, and depth in prototype, exhibit a constant ratio to the corresponding dimensions in the model:

$$\text{Length ratio} = n_l, \quad \text{Area ratio} = (n_l)^2, \quad \text{Volume ratio} = (n_l)^3$$