EFFECT OF COVERING IRRIGATION CHANNELS ON TOTAL DISSOLVED SOLIDS AND TOTAL SUSPENDED SOLIDS

SHERINE ELBARADEI, MAI ALSADEQ, and SARAH ABDEL KADER

Civil and Infrastructure Engineering Program, Nile University, Giza, Egypt

The increase in the evaporation rate is one of the crucial effects of climate change. Water losses due to evaporation are considered as an important challenge that faces the agriculture sector considering the recent water crisis in Egypt. So, covering irrigation canals with the aim to decrease evaporation could be a good solution for this problem, especially if the coverage is expected to be used for power production by covering these canals with solar panels. However, the main concern is the effect of the covering on the quality of water. So, this research study investigates the effect of irrigation canals’ covering on rates of evaporation and some water quality variables specifically total dissolved solids (TDS) and total suspended solids (TSS). The results of the study showed that covering irrigation canals will have a significant effect on water quality parameters. It is found that the studied water quality parameters; TSS and TDS both are decreasing from 56.39 to 56.35 mg/l and from 160.15 to 160.00 mg/l, respectively by increasing the percentage coverage of the canal from 0% to 100%.

Keywords: TDS, TSS, Irrigation canals, Covering of canals, Mathematical modeling, Water quality.

1 INTRODUCTION

Agriculture is an important sector that plays a major role in the Egyptian economy and food security. However, this sector is facing several challenges that affect this role and productivity; the availability of clean water is one of these challenges. According to the World Water Development report which was issued by the United Nations in 2018, Egypt is currently lower than the poverty threshold of water estimated by the U.N., which lead to facing water scarcity and considerably heading towards certain water scarcity (WWAP 2018).

One of the crucial effects of the increase in the weather temperature is the increase in the evaporation rate. So, many research studies investigated some attempts to reduce the water losses due to evaporation. These attempts include increasing reservoirs depth, installing windbreaks and covering water surfaces (Craig 2005, El Baradei and Alsadeq 2018b). An important study was conducted to investigate the effect of irrigation canals’ covering on rates of evaporation, taking the canal of Sheikh Zayed as a case study which located in Toshka at Upper Egypt governorate, indicated that covering 100% of the canal can provide the amount of water needed to irrigate 6.5% of the planned area that will be cultivated in the New Valley project located in Toshka (El Baradei and Alsadeq 2018a, El Baradei and Alsadeq 2020). However, the main concern was the effect of this solution on the quality of water. So, this research work will investigate the impact of irrigation canals’ covering on evaporation rates and some water quality variables specifically total dissolved solids (TDS) and total suspended solids (TSS).
2 SITE DESCRIPTION

Sheikh Zayed canal is an irrigation canal which is planned to be responsible for irrigation of the New Valley project. The inlet of the Canal is on Lake Nasser upstream the Aswan High Dam in Upper Egypt governorate. The Canal’s location, branches, pumping station, and Toshka depressions (lakes) are shown in Figure 1. The government is planning to increase the cultivation area with about 2,310,000,000 m$^2$ (550,000 feddans) in the New Valley project (El Baradei and Alsadeq 2018b). The Canal system contains a main channel and other sub-branches. The total length is approximately 300 km. Mubarak Pumping Station is responsible for transferring water from Lake Nasser throughout the Canal (Wahby 2002). The average water velocity in the main channel is 1.2 m/sec and the volume flow rate of water in the pumping station is 300 m$^3$/sec. This research study is focusing on Sheikh Zayed Canal’s main channel. The main canal’s dimensions are total length is 50 km, water depth is 6 m, top width is 54 m, bottom width is 30 m, and horizontal to vertical side slopes ratio are 2:1.

![Figure 1. Location of the studied Sheikh Zayed Canal, its main and subbranches, and Mubarak pumping station placed on Lake Nasser.]

3 MATHEMATICAL MODELING

This research study is studying the effect of covering irrigation canals on rates of evaporation and some water quality variables. The water quality variables studied are Total Dissolved solids (TDS) and Total suspended solids (TSS). As the main objective of the larger project is covering Sheikh Zayed Canal with solar panels in order to lessen the evaporation water volume and to produce electricity. It is important to minimize the influence of covering on the Canal’s water quality. The study was obtained by covering the canal with assumed number of panels and then the percentage covering for each trial.

3.1 Evaporation Model

According to the obtained study by Elbaradei and Alsadeq (2018a), among a comparison obtained between three evaporation calculation models: De Bruin Keijman, Penman-Monteith, and Priestley-Taylor it was found that the most reliable model is the Penman-Monteith (Elbaradei and Alsadeq 2018a). The Penman-Monteith formula is written as shown in Eq. (1) (Monteith 1965):
where $E$ is the rate of evaporation of water (mm/day), $\lambda$ is the vaporization latent heat (MJ/kg), $\Delta w$ is the saturation water vapor curve’s slope (kPa/°C), $R_n$ is the net solar radiation (MJ/m²/day), $G$ is the heat storage change in the studied water body (MJ/m²/day), $e_a$ is the vapor pressure (kPa), $e_w$ is the saturated vapor pressure (kPa), $f(u)$ is the wind function (MJ/m²/day/kPa), and $\gamma$ is the psychometric constant (kPa/°C).

The calculations are done using a developed mathematical model using a spread sheet to calculate the rates of evaporation using the equation of Penman-Monteith from the Canal. The required meteorological data for calculations are air temperature, relative humidity, wind speed etc. were obtained at Aswan weather station by the American Meteorological Organization while the solar radiation records are gathered from NASA website (NASA 2017, WUO 2017).

### 3.2 Water Quality Model

The studied water quality variables are TDS and TSS. They are simulated using a developed Excel spreadsheet. The flow rate is assumed constant along the canal. The assumption is based on the real data of Mubarak pumping station which directly pumping water to Sheikh Zayed canal with a constant flow rate of 300 m³/s all over the year. The Canal it is partitioned into equal lengths of control volumes. Every length of control volume is 100 m. The mass balance equation is applied at each control volume, see Figure 2.

![Figure 2. Control volume representing the mass balance equation for calculating the concentrations of studied water quality variable.](image)

The general mass balance equation is written as shown in Eq. (2):

$$C_{i+1} = C_i + \frac{\Delta C}{Q_i} \cdot dx$$

where $C_i$ is the initial constituent concentration at the control volume’s start, $C_{i+1}$ is the final constituent concentration at the control volume’s end, $\Delta C$ is the change in the constituent concentration, and $dx$ is the length of the control volume. Moreover, the hydrodynamics of the Canal is calculated using the Manning’s equation. It is written as shown in Eq. (3):

$$Q = \frac{1}{n} \cdot A \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

where $Q$ is the volume flow rate of water, $n$ is the Manning coefficient (it is taken for concrete lined canals), $A$ is the channel’s cross-sectional area, $R$ is the channel’s hydraulic radius, and $S$ is the channel’s longitudinal slope.

#### 3.2.1 Total dissolved solids

Total Dissolved Solids (TDS) reflects the salinity of water. It is an important water quality variable as it affects the aquatic life in water bodies such as flora and fauna which live in a certain salinity range. In this research study, the concentration of TDS is calculated assuming that the
main influencer of TDS concentration is the water volume. The water volume is mainly affected by evaporation volume of water and no account for chemical reactions. The initial TDS concentration is 160 mg/l which observed by the Ministry of Water Resources and Irrigation (MWRI) (Toufeek and Korium 2009).

3.2.2 Total suspended solids

Total Suspended Solids (TSS) are the amount of solids in water that trapped by a filter. The sediment coming from the Ethiopian highlands through the flood period is the major source of TSS in Lake Nasser (Ahmed et al. 2003). In this study, the TSS concentration is simulated during the flood period in August. The initial TSS concentration is 56 mg/l.

The inorganic settling is calculated by (Chapra 2003) shown by Eq. (4):

\[ \text{InorgSettl} = \frac{v_i}{H} m_i \]  

where \( v_i \) is the settling velocity of inorganic suspended solids, \( m_i \) is the suspended sediments mass, and \( H \) is the depth of water.

3.3 Model Validation

The developed evaporation calculation and water quality models are validated on Sheikh Zayed Canal with actual observations. All validations are done at the case of uncovered canal. The validation of the evaporation model is done with actual observations authorized by the MWRI at Toshka. The results of validation result approved the model with a slight error of 2% (El Baradei and Alsadeq 2018b).

The TSS is validated versus the Qual2k model. Qual2K is a water quality modelling program for water channels which created by Chapra and Canale (2002). The Qual2K was calibrated and validated various times before in addition to its original developers who obtained it a reliable computer model (Fang et al. 2008, Hadgu et al. 2014). So, Qual2K could be considered as a reliable reference for calibration the developed model. Moreover, the TDS is validated versus site measurements observed by the MWRI on Lake Nasser at Toshka station. The validation results of the water quality variables studied in this research paper are summarized in Table 1. Finally, the mathematical model is well calibrated and is reliable for further calculations.

<table>
<thead>
<tr>
<th>Water quality variable</th>
<th>Model outputs</th>
<th>Observed value</th>
<th>Percentage Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS (mg/l)</td>
<td>56.17</td>
<td>56.05</td>
<td>0.21</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>140.08</td>
<td>140.00</td>
<td>0.001</td>
</tr>
</tbody>
</table>

4 RESULTS

4.1 Evaporation Results

The results of evaporation volume for each % covering of the Canal are plotted in Figure 3. The findings logically show that the maximum volume of evaporation occurs at the case totally uncovered Canal, and the minimum volume of evaporation occurs at the case of totally covered Canal. The volume of evaporation at totally uncovered canal is 8.64 Mm³/year. The volume of
evaporation is decreasing by increasing the coverage percentage till reaching nearly zero volume of evaporation at fully covered canal.

Figure 3. Evaporation volume vs. coverage percentage of Sheikh Zayed main canal.

4.2 Water Quality Results

The results of the covering consequence on TDS concentration indicate the same trend as volume of evaporation which is decreased by the coverage percentage increase of the Canal. This happened because the TDS is directly influenced by the water volume. The TDS concentration decreased from 160.15 to 160.00 mg/l corresponding to percentage covering of 0% to 100% of Sheikh Zayed Canal, Figure 4(a).

Figure 4. (a)TDS concentration at the Canal’s end for each % coverage of the Sheikh Zayed Canal’s total length, (b)TSS concentration at the Canal’s end for each % coverage of the Canal’s total length.

The TSS results show that it is decreasing by increasing the coverage percentage of the Canal. The main influencer of TSS concentration is algae throughout the inorganic settling. The impact of covering the canal on algae concentration was studied before by Elbaradei and Alsadeq (2020) where it was concluded that algae is mainly affected by the amount of solar radiation reaching water as it is directly affecting the photosynthesis. Therefore, by covering the canal the solar radiation is decreased and algae concentration is decreased as well and TSS because of the canal coverage. The concentration of TSS ranges between 56.39 and 56.35 mg/l at the Canal end for coverage percentage 0% to 100%, Figure 4(b).

5 CONCLUSIONS

To conclude, covering irrigation canals affects the water quality variables. Certain water quality parameters are influenced more than other parameters. So, it was important to examine the impact of covering Sheikh Zayed Canal by solar panels for power production purposes on water quality parameters. The water quality variables studied by this research are TDS and TSS. It is found that both are decreasing with increasing the coverage percentage of the canal. Although
their main influencer is not the same. For the TDS, the main influencer is the water volume which is directly proportional to the evaporation volume. So, by increasing the percentage covering from 0% to 100%, the evaporation volume decreased from 8.6 Mm³/year to 0 m³/year as a result the TDS concentration decreased from 160.15 to 160.00 mg/l. The change in TDS concentration is considerably small in Sheikh Zayed Canal as there are no pollution sources all over the Canal. In other cases where there is a pollution source specially an industrial waste, the effect of covering will have significant impact on TDS but following the same trend as this study. For the TSS, the main influencer is the algae concentration which is directly influenced by solar radiation change which is created because of the covering. The TSS decreased from 56.39 to 56.35 mg/l at the Canal end for coverage percentage 0% to 100%. The change in TSS is also minor in Sheikh Zayed Canal and in other canals it may differ by the abundance of one or more sources of pollution; as well as, by the canal size.

Acknowledgments

This research is part of a larger funded research titled “Irrigation canals covered with solar cells”. The research is funded by Misr El Kheir Agency. Misr El Kheir Foundation (MEK) is an Egyptian non-profit development institution established in 2007 with the objective of developing the Egyptian individual in a comprehensive manner.

References


Craig, I. F., Loss of Storage Water Due to Evaporation – A Literature Review, Reports - University of Southern Queensland 75, 2005.


