



Long-Term Exposure to the Water of Wadi El-Rayan Lakes Induced Testicular Damage and Endocrine Disruption in *Mugil cephalus*

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Abstract

This study aimed to investigate the testicular function of *Mugil cephalus* that inhabit Wadi El-Rayan lakes. Testes of fish inhabiting the upper lake (site 2) and the lower lake (site 3) of Wadi El-Rayan showed significant decreases in gonadosomatic index, high accumulation levels of six metals, and eight organochlorine pesticide residues. Compared to reference fish, high percentages of histological alterations as testicular degeneration, germ cell reduction, testicular inflammation, vacuolization, and loss of tubular arrangement were observed in sites 2 and 3. Moreover, endocrine disruption signs were recorded based on the percentage of ovotestis appearance and the ovotestis severity index values. The maximum defective testicular antioxidant mechanisms were recorded in site 3 as indicated by sharp decreases in catalase, superoxide dismutase, glutathione reduced levels, and high thiobarbituric acid reactive substances. Finally, long-term exposure to Wadi El-Rayan water may impair the reproductive health of fish via testicular oxidative damage and endocrine disruption.

Keywords Metal pollution · Pesticides residues · Endocrine disruption · Testicular oxidative damage · Testes histopathology · Wadi El-Rayan lakes

Lakes are closed water bodies that are more influenced by human activities (Haredi et al. 2020). Lake Qaroun (the largest lake in El-Fayoum province, Egypt) is a sink for a variety of anthropogenic contaminants through unregulated agricultural, domestic, and industrial waste disposal (Abdel-Khalek 2018). Due to the growing land reclamation and agricultural activities in El-Fayoum province, another basin was originated to receive the excess discharges that exceed the capacity of Lake Qaroun. This was done by transporting excess discharges into two man-made lakes (at two different altitudes) in the depression of Wadi El-Rayan. The upper lake collects wastewater effluents from the Wadi drain, then the surplus water streams via the shallow connection channel to the lower lake of Wadi El-Rayan (Abdel-Khalek et al. 2020a). The growing chemical discharges and extensive water evaporation rates have led to several ecological changes and an elevation in pollutant concentrations

of anthropogenic origin in both lakes. Metals and organochlorine pesticides (OCPs) are known to be one of the most widespread contaminants in Wadi El-Rayan lakes (Zaghloul et al. 2011; El-Sherif et al. 2016; Abdel-Khalek et al. 2020a). Many of those persistent pollutants are well known as endocrine-disrupting chemicals (EDCs) and their adverse impact on the reproductive capacity of fish has been documented in various toxicological studies (Sun et al. 2016; Martyniuk et al. 2020). To our knowledge, no research has shown the possible reproductive dysfunction and endocrine interference in fish inhabiting Wadi El-Rayan lakes. The evaluation of the adverse impacts of EDCs on fish is very complicated since the endocrine system controls many biochemical, physiological, and genetic procedures at various stages. This complexity can be clarified by investigating reproductive and developmental disorders, which contributes to the practical explanation for adverse outcomes. Exposure to EDCs has several biological consequences, such as excessive egg yolk production, morphological deformations in gonads, and the occurrence of ‘intersex’ condition (Iavicoli et al. 2009). Many fish species that are chronically exposed to domestic and agricultural wastes have a frequent occurrence of intersex signs and other gonadal disorders (Martyniuk et al. 2020). Ovotestis appearance (the presence of oocytes inside

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