Application of electrical resistivity prospecting in waste water management: A case study (Kharga Oasis, Egypt)

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Abstract  Electrical resistivity technique has been used to detect the subsurface stratigraphy and structures around Kharga Oasis, Egypt. 1D inversion approaches have been applied to interpret the electrical data obtained along 10 vertical electrical soundings (VES) using electrode spacing from 3 to 400 m.

A preliminary quantitative interpretation of the vertical electrical sounding curves was achieved firstly using two-layer standard curves and generalized Cagniard graphs. The manual models were used as initials to prepare the final model using the algorithm IPI2Win program. Model results were used to construct a geoelectrical section.

Three geoelectric units were identified: the superficial geoelectrical layer is composed mainly of sand and gravel with relatively high resistivity values (8−372 ohm m) and low thicknesses (0.523−4.92 m). The age of this layer is from late Pleistocene to Holocene (Quaternary deposits).

The second geoelectrical layer is composed of shale (Dakhla Shale). It is characterized by relatively very low electrical resistivity values (0.3−4.92 ohm m). The maximum depth to this layer ranges from 13.8 to 45.7 m.

The third layer represents the first Nubian Sandstone aquifer with moderate electrical resistivity values (23.9−233 ohm m) detected at the maximum depth of penetration, a great contrast for values according to the lithological content.

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Introduction

Kharga Oasis (Fig. 1) is one of the oases in the New Valley Governorate. Economically, it depends mainly on agricultural activities which yield large amounts of the agricultural drainage and wastewater. Such water is collected through drainage canals in the vacant and uncultivated lands, forming wastewater pond. The occurrence of most of those ponds poses a risk...
of collapse of the wall of the surrounding area and a risk of flooding the neighboring cultivated lands. So, that pond represents a serious threat to the population of that oasis.

Electrical resistivity investigation is a powerful tool for exploring the subsurface geology and collecting more information about the subsurface layers and structures (Mohamaden et al., 2009; El-Sayed, 2010). The target of the present study was to conduct an electrical resistivity investigation at the land areas surrounding ponds in order to determine the vertical and horizontal distributions of the subsurface layers. The results will throw light on the impact of the collected water for irrigation on the community and shallower ground water aquifers.

The leakage of water into the underground aquifer represents a serious threat to the population in this region, especially because they are totally dependent on groundwater. The presence of an impermeable layer such as shale and clays prevents the leakage of wastewater into the underground fresh water aquifer. Therefore, the shallow subsurface layers were studied to determine the shale distribution and the possibility of leakage through the different areas around the ponds and to determine the suitable areas for further activities using wastewater.

The area under investigation is located between latitude 25.367236 and 25.435271N and Longitude 30.525545 and 30.624352E (Fig. 2).

In this study, the geoelectrical resistivity method was used for shallow subsurface investigation to determine the distribution and thickness of the shale layer.

Many authors such as Koefoed (1965a, 1965b, 1965c), Gosh (1971), Zohdy (1975, 1989), Santos et al. (2006), El-Galladi et al. (2007), Sultan et al. (2004, 2009a, 2009b, 2009c, 2009d, 2009e), Sultan and Santos (2008a, 2008b, 2009), Mohamaden and Mahmoud (2001), Mohamaden (2005, 2008), Mesbah (2003), Mousa (2003), Ibrahim et al. (2004), Hosny et al. (2005), Nigm et al. (2008), Mohamaden and Abu Shagar (2008), Abbas and Sultan (2008) and Mohamaden et al. (2009). Hemeker (1984) studied the quantitative interpretation of the geoelectric resistivity measurements. The interpretation of the apparent electrical resistivity data was achieved using two methods, the first is based on the curve matching technique using the Generalized Cagniard Graph method constructed by Koefoed (1965), the output results are treated according to the inverse problem method using computer program (IPI2Win). Then results were represented as geoelectrical section.

The electrical resistivity survey consists of a transmitter, receiver, power supply, stainless steel electrodes, and shielded cables. In the present study, IRIS SYSCAL-PRO instrument was used which computes and displays apparent resistivity for many electrode configurations.

The geoelectrical configuration used in the study was Schlumberger collinear four symmetrical electrodes configuration, the current electrode separation being from 3 to 400 m.

The result of the geoelectrical survey was processed and quantitatively interpreted using available geological information.
and presented as geoelectrical sections along the various profiles. The obtained data are plotted using ready-made software in order to be processed and interpreted. After data processing and interpretation, layer parameters (true resistivities and thicknesses or depths) of the various current penetrated layers can be obtained (El-Sayed, 2010).

**Geoelectric study**

The area under investigation is covered by 10 vertical electrical soundings distributed along three profiles named profiles 1, 2 and 3 (Fig. 2). These profiles run from north to south. The geoelectrical resistivity sections obtained from the quantitative interpretation of vertical electrical soundings are discussed hereunder.

**Profile 1**

This profile covered by 5 vertical electrical soundings (1, 2, 4, 3 and 9) distributed from north to south respectively is as shown in Fig. 2. The Pseudo-section and geoelectrical section are shown by Figs. 3 and 4.

**Pseudo-section**

The contour lines of the apparent electrical resistivity reflect that the apparent electrical resistivity values increased toward the central part of the profile with high gradient near VES 3, which reflect a fault existence.

**Geoelectrical section**

The geoelectrical section of that profile is formed from three main geoelectrical layers (Fig. 4).

The ground surface south to VES 1 at the northern side of this profile is covered by alluvial deposits with low thicknesses ranging from 0.523 to 1.71 m and electrical resistivity ranging from 7.9 to 20 ohm m.

The second geoelectrical unit is the dominant for this profile consisting of shale. This unit is characterized by low electrical resistivity values ranging from 0.3 to 0.9 ohm m extending to the maximum depth of penetration with exception at vertical electrical sounding No. 9.

The third geoelectrical unit exists at VES 9 consisting of Nubian Sandstone (first main aquifer for the groundwater) at depth for about 45.7 m.

Structurally, this profile may be affected by a fault located north of VES 9 with downthrown side toward to the northern direction. So, as the thickness of the clay (shale) layer has its
maximum thickness at the northern part along this profile (Fig. 4). It can be concluded that reclamation can be conducted at this part without affecting the groundwater aquifer.

Profile 2

This profile is aligned by 3 vertical electrical soundings namely; 5, 6 and 8. It runs from the north to the south direction. The pseudo-section and geoelectrical section deduced that (Figs. 5 and 6).

Pseudo-section
Structurally, this profile may be affected by a fault located north of VES 9 with downthrown side toward to the northern direction. So, as the thickness of the clay (shale) layer has its maximum thickness at the northern part along this profile (Fig. 4) it can be concluded that reclamation can be conducted at this part without affecting the groundwater aquifer.

Geoelectrical section
The superficial layer is composed of sand (Quaternary deposits) with low thicknesses ranges from 1.11 to 2.54 m and electrical resistivity from 184 to 255 ohm m.

The second geoelectrical layer is composed of shale characterized by very low electrical resistivity (1.5–4.92 ohm m.) and depth range from 13.8 to 62.3 m with an exception around VES 6 where the maximum depth of penetration reached.

At the maximum depth of penetration around VES 5 and 8 we can detect the Nubian Sandstone with moderate electrical resistivity values (127–233 ohm m.). It is the first aquifer for the area under investigation.

This profile is affected by two geoelectrical faults south of vertical electrical sounding No. VES 5 with down thrown side toward the south. The other fault is located north of vertical electrical sounding No. 8 with down thrown side toward the north direction. These two faults formed a suggested graben formation.

According to the results, the central area of this profile is a promising area for reclamation.

Profile 3

This profile is covered by 3 vertical electrical soundings named 5, 7 and 10. The pseudo-section and geoelectrical section deduced that (Figs. 7 and 8).

Pseudo-section
The pseudo section for apparent electrical resistivity concluded that the area south of VES 5 is characterized by high electrical resistivity values with condensed contour lines which reflected that this zone is affected with a fault.

Geoelectrical section
The superficial geoelectrical layer is characterized by electrical resistivity values from 218 to 372 ohm m and low thicknesses
Figure 6  Geoelectrical section for profile 2.

Figure 7  Pseudo-section for profile 3.

Figure 8  Geoelectrical section for profile 3 (Kharga Oasis).
(1.21–4.92 m). This layer covered the ground surface all over this profile. It consists of sand.

The second geoelectrical layer is composed of shale with low electrical resistivity values (1.29–4.92 ohm m.). It extends in depth from 13.8 to 37.7 m with an exception around VES 7.

At the maximum depth of penetration, we can detect the third layer consisting of Nubian Sandstone around VES 5 and 10 with electrical resistivity values from 38 to 127 ohm m.

The area around this profile is affected by two faults with down thrown side toward the central part forming a graben structure.

The most promising area for decimation is at the central part of this profile.

Results and conclusions

The areas under investigation were located between latitude 25.367236 and 25.435271 N and Longitude between 30.525545 and 30.624352 E.

Geoelectrically, the superficial geoelectrical layer is mainly composed of sand and gravel with relatively high resistivity values (8–372 ohm m) and low thicknesses (0.523–4.92 m). The age of this layer is from late Pleistocene to Holocene (Quaternary deposits).

The second geoelectrical layer is from shale (Dakhla Shale). It is characterized by relatively very low electrical resistivity values (0.3–4.92 ohm m). The maximum depth of this layer ranges from 13.8 to 45.7 m.

The Nubian Sandstone (upper aquifer) third layer with moderate electrical resistivity values (23.9–233 ohm m) could be detected at the maximum depth of penetration.

Structurally, the area under investigation is affected by two geological and geoelectrical faults at the central part the area with down thrown side toward the central part to form a graben structure.

The most promising area for decimation is at the central part of this profile according to the maximum thickness of the Dakhla Shale Formation.

Conflict of interest

There is no conflict of interest to declare.

References


