Assessment of drainage water quality due to covering of agricultural drains project in Egypt

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Egyptian Ministry of Water Resources and Irrigation started to cover open drains which cross villages and towns. This project is considered national project to reduce the pollution of these drains. Three covered drains are selected to carry out this study. They are EL-Serafy, Shobrakhit and Al-Amreya drains**.** They are located in the west Delta area. Water samples were collected monthly from the covered parts of these drains for a period of six months. Field measurements were done to measure pH, EC and DO. Water samples were analyzed in the laboratory to measure NO_3, NH_3, COD, TDS and PO_4. The results of this study showed that covering of drains has not been the best solution to prevent the problem of pollution. Drains water became more polluted in the covered region only. Moreover, there are not certain criteria for design of drain covering. For instance, in Al-Amreya drain, the dissolved oxygen DO decreased from 4.5 before the covering to 0.65 ppm in the covered drain but improved after the outlet. The other parameters such as NO_3, NH_3 and COD, increased from 33.7, 5.4, and 137 ppm at the inlet of the culvert to 54.9, 13.0, and 254 ppm at the outlet point, respectively. Ground water level close to the covering drain became higher than before applying the covering drains project. The pollution of drainage water increases after covering the drains due to increase of raw sewage drainage into the covering itself from the illegal connections. Emissions of CH_4 and H_2S, which are toxic gases, cause damage to the concrete culvert material.. Saturation of soils voids of drains after the covered parts by anaerobic wastewater causes failure to the drain side slopes due to the activity of anaerobic microorganism and availability of CO_2 and CH_4 which destroy the soil particles stability.

نظرا لمرور المصارف الزراعية المكشوفة داخل الكتل السكانية ونتيجة لإلقاء المخلفات سواء السائلة أو الصلبة داخل المصارف فقد أدى هذا إلى زيادة التلوث البيئي لهذه المصارف وللحفاظ على نوعية مياه المصارف من التدهور لجأت الدولة إلى تغطية هذه الأجزاء من المصارف الزراعية كمشروع قومي على مستوى الجمهورية. وذلك من خلال امرارها داخل مواسير خرسانية مسلحة مدفونة للمسافات الماره بالكتل السكانية ولكن اكتشف قيام السكان بتنفيذ العديد من وصلات الصرف الصحى من المنازل المتاخمه على مواسير الصرف المغطى كما لو كانت نظام للصرف الصحى، ويهدف هذا البحث إلى تقييم نوعية المياه وجودتها نتيجة تغطية هذه المصارف مقارنة بالمعايير المسموح بها. وتم ذلك من خلال أخذ عينات من مياه هذه المصارف قبل وبعد التغطية مباشرة وكذلك في بداية ونهاية المصارف المكشوفة، وذلك على فترات زمنية مختلفة وعمل تجارب معملية وحقلية وتحليل نتائج هذه التجارب لمعرفة تأثير تنفيذ مشروع تغطية المصارف داخل الكتلة السكنية على نوعية المياه.

Keywords: Covering drains, Pollution, Self purification, Anaerobic bacteria, COD

1. Introduction

With the increase of population in Egypt, the Egyptian government realized the necessity of accelerating its horizontal expansion plans into deserted and uninhabited regions of Egypt as a part of the horizontal expansion plan. Agricultural land will expand by an area of 3.4 million fedans by year 2017. Most of water comes from the Nile River, which carries a fixed annual water allocation of 55.5 milliards m^3 The per-capita share of water resources also has dropped during the last quarter of the centaury from 1713 m^3 in the year 1970 and it is expected to drop from a current amount of about 930 m^3/year to about 630 m^3 by the year 2025 (Aly [1]). Thus, the Ministry of Water Resources and Irrigation must work closely with agriculture, industry and municipalities in managing this complex water system to meet all of Egypt's water needs. The water needed must be balanced since the annual water resource is fixed. Therefore, new water resources are urgently needed. Reusing of existing drainage water is considerate one of these resources. Using water more than once is possible only if water quality standards are allowable for land reclamations and agriculture requirements.

The agriculture drainage network in Egypt has total lengths of over 19200 km of open drains (Amer and Ridder [2]). These open drains cross numerous villages and towns where they are subjected to excessive misuse residents along the course of the drains. People dispose their solid waste into the drains, thereby, adding pollution load to drain water and leading to large bottom deposits. Moreover, many houses and other building discharge their wastewater through illegal connections into these drains. Sewage evacuation tankers also discharge their loads into these drains in the absence of sewerage system and well functioning collection and management system for solid wastes in the villages. The Egyptian government started to cover some of the agriculture drains which cross numerous villages and towns to protect them from polloution and considered this project as a national project. Covering drains reduces dumping of domestic and industrial wastewater into open drains, and protects villages from the negative impacts of the already polluted drain crossing the residential areas. The local residents view covering of open drains as a simple solution. They start to make illegal connections between their houses and small industries and the covering. This helps to improve the environmental setting of the villages and negatively causes a more pollution to water in the covered drain.

1.1. Drainage water

Amer [3] stated that the total discharge of drainage water in Egypt is about 27.00 BCM/year that reach mainly from 8.60 million feddans of irrigated lands, domestic and industrial sources. In Upper and Middle Egypt drainage water returns to the Nile system at about 4.0 BCM/year (Ragab [4]). Of about 1.50 BCM/year is spilled out into Qaroun Lake and Bahr Josef, and about 2.80 BCM/year are reused unofficially. In the Delta region, drainage water is about 18.70 BCM/year, of which about 5.30 BCM/year with low pollutants and an average salinity of about 1000 ppm are reused at the time being, and about 13.40 BCM/year are spilled out into the sea (Drainage Research Institute [5]). According to Salah [6] the methods for drain protection against pollution can be summarized as follows.

1. Diversion of the drain to a new location. This method cannot be applied in all cases due to the high cost and the difficulty of finding an alternative route. This method has been used on one location in Giza but its use is limited.
2. Protecting the drain through the residential area by using fencing. This method has been applied at the Labini drain in Giza and may be acceptable for very wide drains with high rates of flow. However, it has three disadvantages: It is still easy to through solid wastes from above or through the fencing, unless a very high fence is used, It is very difficult to gain access to maintain the banks of the drain mechanically, It has no impact on odors emanating from the drain or control of flies and mosquitoes.
3. Covering of the drains, using either pipes or a box section.

1.2. Describing of the covering

Covering of the agriculture drains consists of reinforcement concrete pipes of different diameters for discharging the drainage water within the residential area. The pipes are put on a horizontal plain concrete bed. The bottom level of the pipe is same as the design level of the drain bed. The covered pipes are constructed from precast concrete with a length of 2-3 m. They are connected to each other using concrete conductor. For maintenance purposes, manholes are constructed along the covered part at distance of about 50-100 m as shown in fig. 1. They are constructed from reinforced concrete with a square or circular cross section. They have a reinforced concrete covers and inner steel stairs. The upper level of these manholes is 25-50 cm higher than the road level.

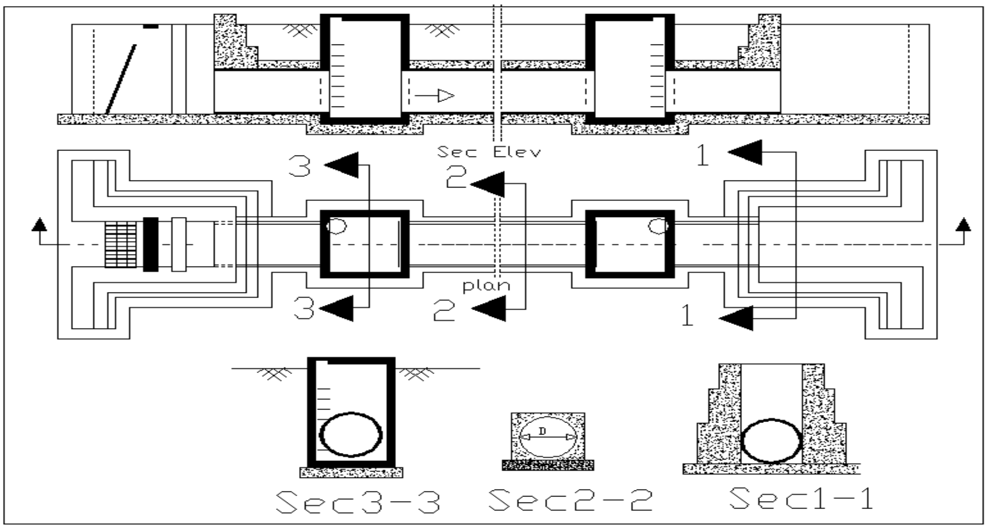

Fig. 1. Schematic sketch of the covered drains system.

1.3. Analysis of flow rate

The diameters of pipes that already used in different covering drains project in the rang of 1.0 to 2.0 m, and their expected flow rates in the rang of 0.02 to 2.14 m^3/s (EPADP [7]). It can be noticed that there is a very wide range of flow rates for the same pipe diameter. For instance, the velocity of flow through 1.0 m pipe diameter ranges from 0.027 to 1.91 m/sec. For 2.0 m pipe diameter, the velocity varied from 0.22 to 0.68 m /s. Accordingly, very low velocity is expected in some covered drains parts causes sedimentation problems in these pipes. It can conclude that there are no criteria for selecting of the pipe size although it should be dependent on the flow rate.

1.4. Plan of covering agricultural drains in Egypt

Egyptian Public Authority for Drainage Projects (EPADP [7]) started to expand the covering agricultural drain project in a wide scale in the upper and Lower Egypt. The total covered length is 90,422m. The total cost of the project is 104,329,673 L.E., which served an area of about 1,751,364 fed. The average cost of one meter of the covering drains project is about 1015 L.E. /m.

1.5. Natural treatment process

According to Metcalf and Eddy [8], three zones layers exist in polluted water bodies as shown in fig. 2. They are (1) a surface zone layer where aerobic bacteria and algae exist in a symbiotic relationship, (2) an anaerobic bottom zone in which accumulated organic solids are decomposed by anaerobic bacteria, and (3) an intermediate zone layer that is partly aerobic and partly anaerobic, in which the decomposition of organic wastes is carried out by facultative bacteria. Anaerobic breakdown of the solids in the sludge layer results in the production of dissolved organics and gases such as CO2, H2S and CH4, which are either oxidized by the aerobic bacteria or vented to the atmosphere. In practice, oxygen is maintained in the upper layer of facultative lagoons by the presence of algae and by surface reaeration. In some cases, surface aerators have been used, because of increasing the anaerobic activity and water becomes septic. The advantage of using surface aerators is that a higher organic load can be applied.

2. Description of drains under study

To assessment the impact of covering agricultural drains on the water quality, three drains are selected to carry out this study. They are: AL-Sairafi drain, and Shobrakit drain,. In AL-Behaira Governorate and AL-Amreya drain in Alexandria Governorate.

2.1. AL-Sairafi drain

AL-Sairafi drain is located near Abou-Hommos city in El-Behaira governorate. It starts near Balakter village. Its length is 4.800 km and serves an area of about 2000 fedans. The bed width of the drain is 2.00 m and the side slope is 3:2. Its design flow rate is 0.76 m^3 /sec excluding domestic wastewater. The drainage water duty is about 33 m^3/fed./day. Fig. 3 shows the layout of the drain and its cross sections. The covered part of the drain, which has been investigated, has a length of 250 m. It extends from kilometer 2.350 to 2.600. It contains one pipe of 1.00 m diameter. The water depth in the pipe is 0.90 m. At the inlet of the covered pipe, there is a screen consists of steel bars with a cross section of 4 mm ×30 mm and about 200 mm apart.

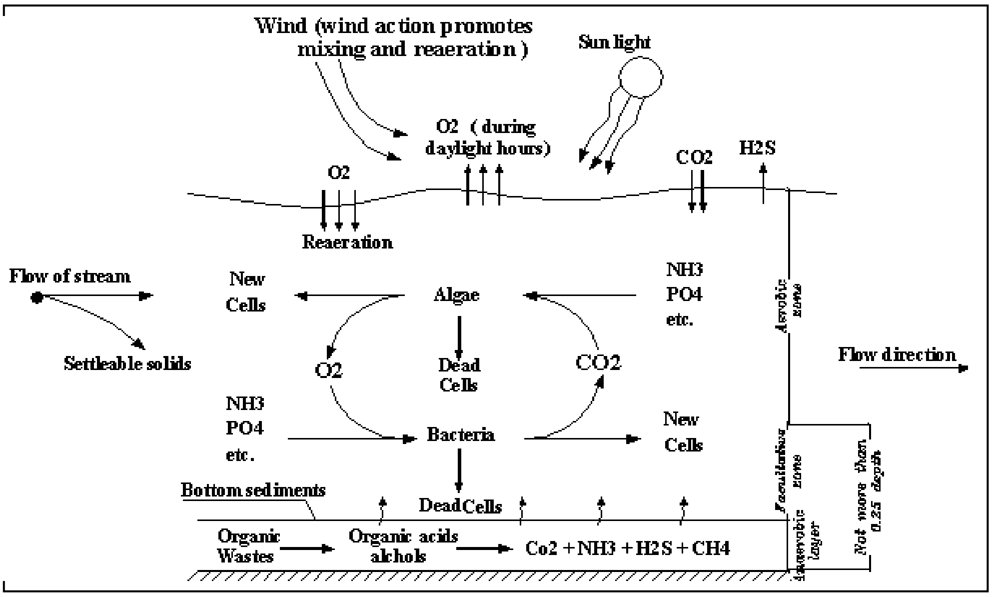

Fig. 2. The self purification streams and surface water.

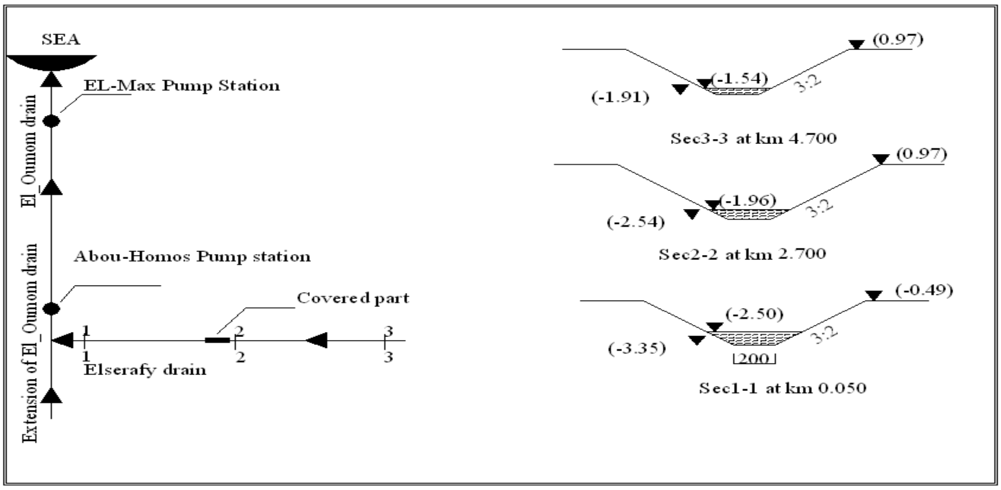

Fig. 3. The layout of the AL-Sairafi drain and its crosss sections.

2.2. Shobrakit drain

Shobrakit drain is located near Shobrakit city in Al-Behaira governorate. It starts near Abou-Mangog village. Its length is 22.560 km and serves an area of about 18000 fedans. The bed width of the drain is 3.00 m and the side slope is 3:2. Its design flow rate is 2.95 m^3/sec, excluding domestic wastewater. The drainage water duty is about 14 m^3/fed/day. Fig. 4 shows layout of the drain and its cross sections. The covered part of the drain, which has been investigated, has a length of 600 m. It extends from km 25.000 to 25.600. The covering consists of one pipe 1.50 m diameter. The water depth in the pipe is 1.40 m. At the inlet of the pipe there is a screen consists of steel bars with cross section of 4 mm ×30 mm and about 200 mm apart

2.3. AL-Amreya drain

AL-Amreya drain is located near AL-Amreya city in Alexandria governorate. It starts near EL-Naseria village. Its length is 16.100 km and serves an area of 2500 fedans. The bed width of the drain is 2.00 m and the side slope is 3:2. The design flow rate is 0.60 m^3/sec excluding domestic wastewater. The drainage water duty is about 20 m^3/fed/day. Fig. 5 shows a layout of the drain and its cross sections. The covered part of the drain, which has been investigated, has a length of 2200 m. It extends from km 4.550 to 6.750. The covering part consists of one pipe. There are two different diameters are used. A pipe of 1.00 m diameter is used at begining of drain from km 5.750 to km 6.750 and a diameter of 1.50 m is used from km 4.550 to km 5.750, respectively. No screen is found at the inlet of the pipe covering. The bed level of the drain at the inlet side is relatively high due to the accumulation of solid waste and sludge. Twelve manholes have been constructed along the first covered part, with a spacing of 100 m. These manholes are used for maintenance and removing sediments purposes only. The first manhole is located at km 4.550. The inner diameter of these manholes is 2.50 m; nine manholes have been constructed along the second part of the covering. The first manhole is located at km 5.750. The inner diameter of these manholes is 2.00 m.

3. Methodology of field work

In order to evaluate the impact of covering drains on water quality, water samples were collected just before and after the covered part. Four stations are investigated along each drain. Station No. (1) is located at a long distance before the covering. Station No. (2) and No. (3) are located at the inlet and outlet of the covering part of the drain respectively. Station No. (4) Is located at the end of the drain. Fig. 6 shows the location of these stations.

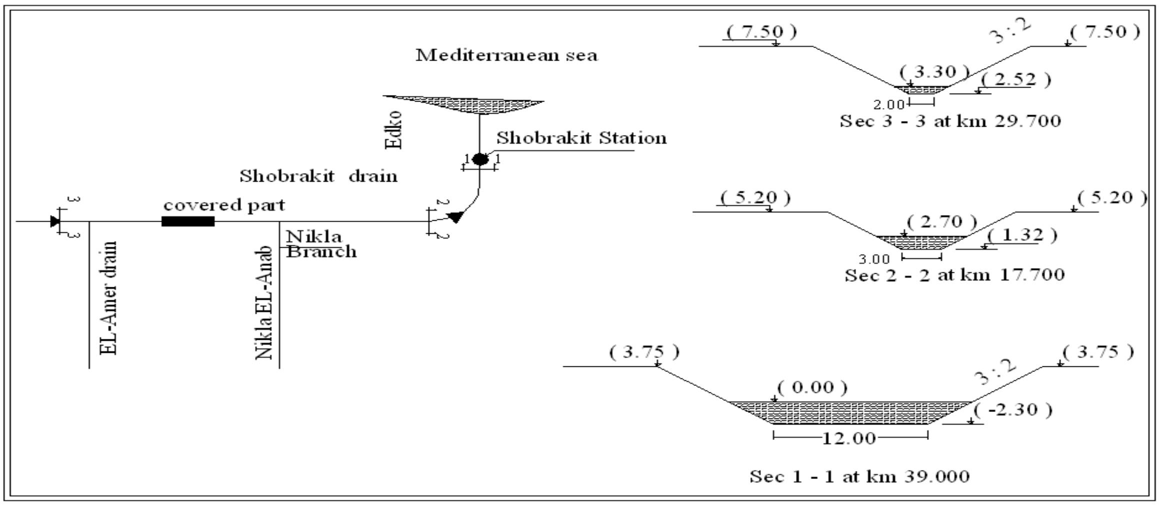

Fig. 4. Layout of the Shobrakit drain and its cross sections.

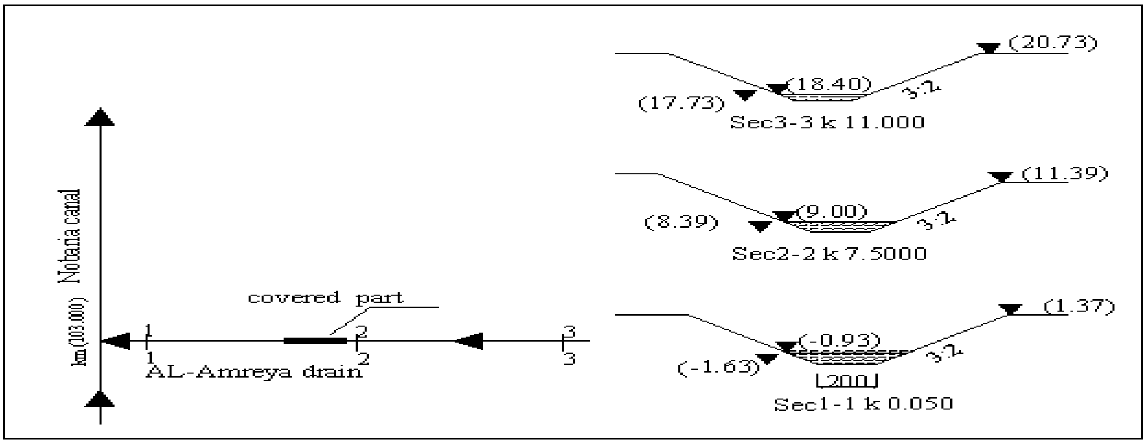

Fig. 5. The layout of AL-Amreya drain and its cross sections.

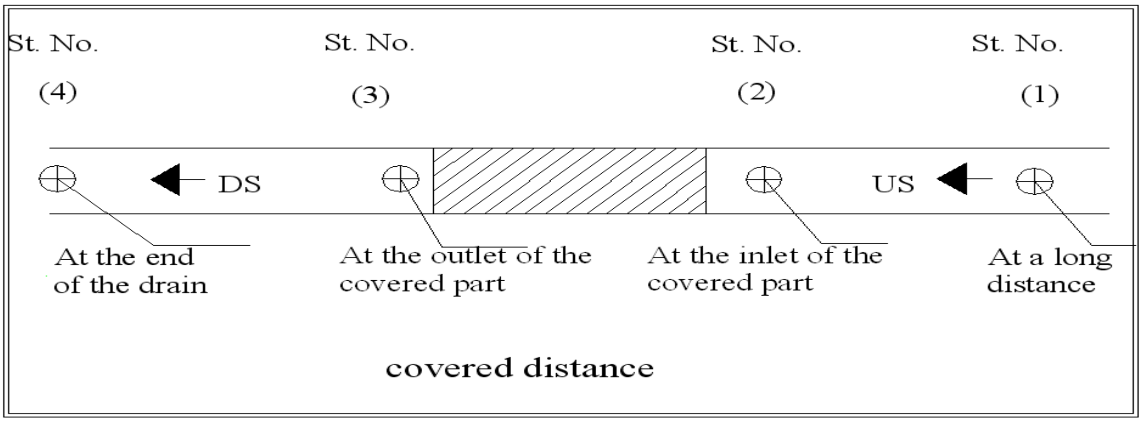

Fig. 6. The arrangement of sampling locations along of the drains.

3.1. Field and experimental measurements

Experimental measurements were carried out from January to June 2005. Four samples were collected monthly from the selected drains and examined in the Lab. Eight parameters were tested for each sample. Three parameters were measured in the field, and the other five parameters were measured in the laboratory. The field measurements included the electric conductivity (EC), dissolved Oxygen (DO) and pH. Meanwhile five parameters NO_3, NH_3, COD, TDS and PO_4 were examined in the laboratory. The samples were analyzed by qualified chemists in the central laboratories for the West Delta Drainage Region in Damanhour city (MWRI). All the parameters were determined in accordance with the American standard methods for the examination of water and wastewater (Lenore et al. [9]).

3.2. Water table level measurements

In order to measure the effect of the covering drain project on the water table beside the drains, five boreholes were drilled at a distance of 300 m in the right side of Shobrakit drain opposite to the covered part. Three of boreholes have depths of 1.00 m, while the other two boreholes have depths of 2.00 m. They are located at km 25.200, 25.300, 25.400, 24.900 and 25.700, respectively. Fig. 7 shows a layout of the locations of boreholes. For Al-Amreya and Sairafi drains, they were difficult to drill boreholes due to the existing of residences and markets.

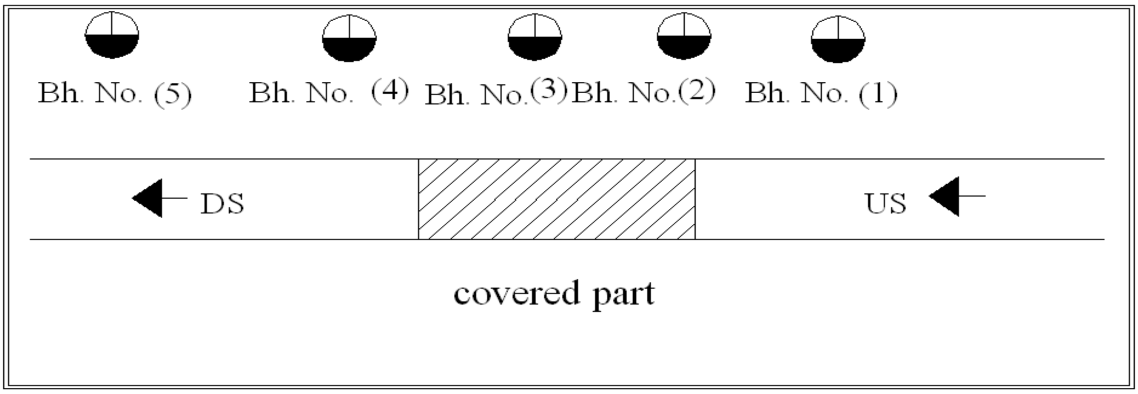

Fig. 7. Layout of the boreholes.

Table 1
Average results for AL-Sairafi drain during Jan. to June 2005

Parameters	Sites of samples(km)				Law 48/1982
	4.000	2.600	2.350	0.000	
pH	7.50	7.53	7.58	7.55	7-8.5
DO (mg/l)	5.3	4.4	2.0	3.0	5
COD (mg/l)	40.5	40	84	52	15
PO_4 (mg/l)	0.14	0.16	0.31	0.21	1
NO_3 (mg/l)	22.3	21.8	34.0	28.5	45
NH_3 (mg/l)	4.2	4.7	6.8	4.9	0.5
TDS (mg/l)	730	1109	1196	875	500

4. Results and analysis

All samples were collected and analyzed for the three drains during the same time of the investigation period from January to June 2005. The parameters were compared to the allowable limits of the law 48/ 1982 [10].

4.1. Al-Sairafi drain

Results of the biological activity for Al-Sairafi drain are shown in table 1. These results give a clear indication about the effect of covering on the water quality are investigated Variations of concentrations of pH, EC, TDS, DO, NO_3, NH_3, COD and PO_4 before and after the covered parts. They are also compared with the water samples at the beginning and at the end of the drains.
Dissolved Oxygen (DO), should not be lower than 5 mg/l. However, measured DO decreased to be less than 2 mg/l which indicates that there is a great source of pollution. Anaerobic condition also occurs when water is polluted to kill most aquatic life.
According to Metcalf and Eddy[8]Anaerobic breakdown of the solids in the bottom layer results in the production of dissolved organics and gases such as CO_2, H_2S and CH_4 , which are either oxidized by the aerobic bacteria or vented to the atmosphere as shown in the following two equations.
Organic wastes + anaerobic (acitogenis) → organic acids alcohols + anaerobic (methenogenis) → $CO_2 + NH_3 + H_2S + CH_4$

$H_2S+2O_2 \rightarrow H_2SO_4$

Emissions of CH_4 and H_2S which are toxic gases, cause damage problem to the concrete culvert material, and difficulty of its maintenance. Moreover, saturation the voids of soils along the side slope of the drain at the outlet of the culvert by waste water under anaerobic conditions causing failure of the soil stability (Krishna and Adams [11]). It can be noticed that COD values in the different samples exceeded than the allowable limit. These data show that the COD is always higher than 15mg/L. This indicates that these drains contain wastewater. Many houses and other buildings discharge their waste water through illegal connection into these drains and people dispose solid waste into the drain which causes increasing the pollution of drains. Ammonia (NH_3) exceeded than the allowable limit. This indicates that pollution increased in the drain water through the covered distance.

4.2. Shobrakit drain

Results of the biological activity for Shobrakit drain are showed in table 2. These results give a clear indication about the effect of covering on the biological environment through the field investigation and water analysis. Variation of concentration of pH, EC, TDS, DO, NO_3, NH_3, COD and PO_4 before and after the covered parts is investigated. They are also compared with the water samples at the beginning and art the end of the drains.

Decreasing of DO to be less than 1 ppm, indicates that water is polluted during the covering part. It can notice that COD values in the different samples exceeded allowable limit. These data show that the COD is always higher than 15. Type of pollution varies from location to another depending on the human activities. The other parameters such as NO_3 and NH_3 exceeded the allowable limit, this indicates the increasing of pollution in the drain water after covering.

4.3. Al-Amreya drain

Results of the biological activity for Al-Amreya drain are showed in table 3. These results give a clear indication about the effect of covering on the biological environment through the field investigation and water analysis. Variation of concentration of TDS, DO, NO_3, NH_3. COD and PO_4 directly before and after the covered parts are investigated. They are also compared with the water samples at the beginning and the end of the drains.

The other parameters such as NO_3, NH_3 and COD exceeded the allowable limits. This indicates that more pollution was occurred in the drain water after the covering.

Table 2
Average results for Shobrakit drain during Jan. to June 2005

Parameters	Sites of samples (km)				Law 48/1982
	29.300	25.600 (Outlet)	25.00 (Inlet)	17.700	
pH	7.68	7.67	7.46	7.59	7-8.5
DO (mg/l)	5.25	4.3	0.8	4.6	5
COD (mg/l)	32.7	131	357	31	15
PO_4 (mg/l)	0.28	0.42	0.48	0.37	1
NO_3 (mg/l)	53.8	50.1	81.1	46.44	45
NH_3 (mg/l)	7.4	8.4	10.3	5.6	0.5
TDS (pp/m)	905	942	940	743	500

Table 3
Average results for AL-Amreya drain during Jan. to Jun. 2005

Parameters	Sites of samples (km)				Law 48/1982
	8.600	6.750	4.600	0.000	
DO (mg/l)	6.4	4.5	0.65	1.2	5
PH	7.89	7.59	7.48	7.41	7-8.5
PO_4 (mg/l)	0.06	0.06	0.60	0.70	1
NO_3 (mg/l)	30	33.7	54.9	47.1	45
NH_3 (mg/l)	4.6	5.4	13.0	30.0	0.5
COD (mg/l)	35.7	137	254.0	95.5	15
TDS (mg/l)	2869	3233	2472	2395	500

4.4. Effect of covering length

The covering lengths for AL-Sariafi, Shobrakit, Al-Amreya drains are 250, 600, 2200 m respectively. In order to investigate the effect of covering length on the water pollution, two parameters are investigated along the three drains, DO and NH_3. Fig. 8 shows the variation of average DO concentration for the three investigated drains, before and after the covering. It can be noticed that the lowest value of DO occurred in Al-Amreya drain and followed by Shobrakit and AL-Sariafi drains, respectively. Meanwhile, the maximum variation of DO before and after the covering also occurred in Al-Amreya drain. Fig. 9 shows the variation of average concentration of NH_3 along the covering parts of the three drains. The highest value of NH_3 is observed in AL-Amreya drain and followed by Shobrakit and AL-Sairafi drains. This is also attributed to the covering length. This is because that Al-Amreya drain has the longest covering length, which prevents the natural aeration chance compared with short covering length.

5. Water table level

The agriculture drainage network in Egypt executed to dump excessive water more than plant needs, which reaches to the drains by gravity through soil voids. However, the analysis of the measured ground water levels shows that the covered drains stopped this function as listed in table 4. It can be noticed that ground water levels increased at the covering part (boreholes No.2, 3 ,4) compared to water levels before and after the covering (boreholes No.1,5).

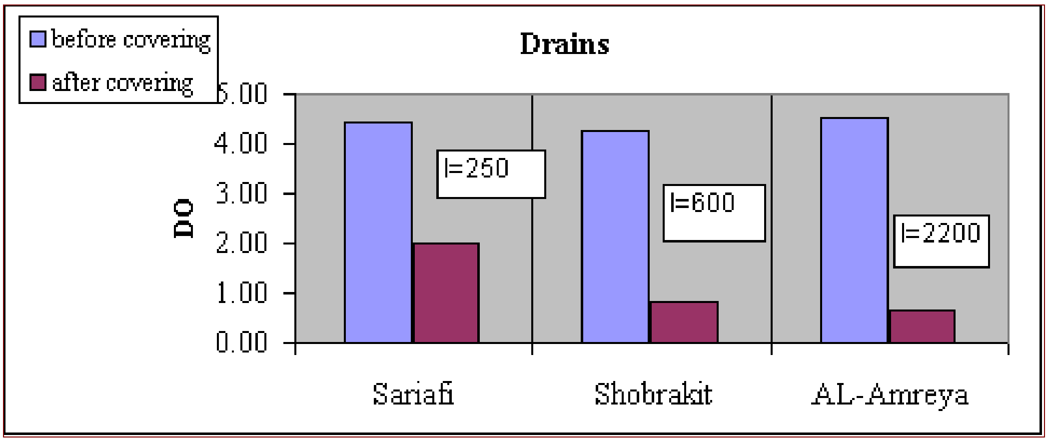

Fig. 8. The concentration of DO throughout of three drains.

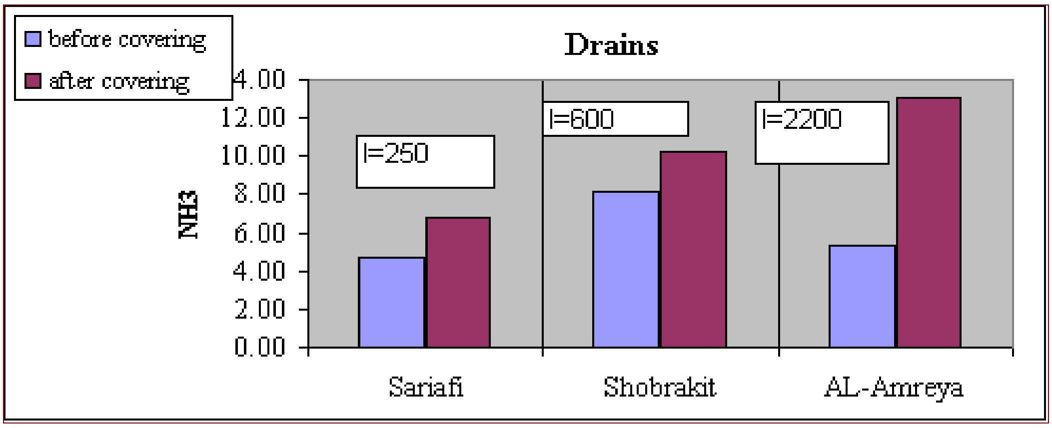

Fig. 9. The concentrations of NH_3 through out the three drains.

Table 4
The measured ground water depths along Shobrakit drain

Borehole No	Location (km)	Water depth from the ground surface (m)
1	25.700	1.40
2	25.500	0.70
3	25.300	0.70
4	25.100	0.75
5	24.900	1.50

6. Conclusions

Based on this study, the following conclusions can be introduced:

1. Quality of water is generally deteriorated along the studied covered parts of drains.
2. Converting the condition of wastes through the covered distance from aerobic to anaerobic has been creating a serious problem due to emissions of H_2S and H_2SO_4, which cause damage of concrete culvert.
3. Saturation of soils voids of drains after the covered parts by anaerobic wastewater causes failure to the drain side slopes due to the activity of anaerobic microorganism and availability of CO_2 and CH_4 which destroy the soil particles stability.
4. Emission of toxic gases and absence of oxygen inside the covered distances causes difficulty of maintenance. CH_4 is flammable gas if it is subjected to the fire.
5. Covering drain by reinforced concrete pipes prevents ground water to flow into drains, causing an increase of the ground water level beside the culvert.
6. Along the covered part, the dissolved oxygen DO decreased to a very low value below the minimum allowable limit. Values of chemical oxygen demand COD and NH_3 increased above the upper allowable limits.
7. AL-Amreya drain is suffering from serious pollution compared to Al-Sairafi and Shobrakit drains. The water quality deteriorates as the increase of the covering part length.

It is suggested to use GRP pipes instead of reinforced concrete pipes, or lining these pipes by bituminous material to resist the effect of H_2S and H_2SO_4 and to increase its life service. Monitoring programs for detecting water quality of covered drains are required to observe the pollution levels.

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