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ORIGINAL ARTICLE

Water Pollution Status Assessment of King Talal Dam, Jordan

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ABSTRACT

King Talal Dam (KTD) reservoir, Jordan's largest surface reservoir, is threatened by the activities of the catchment's area, both domestic and industrial, which emit untreated waste into the reservoir's tributaries, consequently, raising the pollution and contaminating the water chemically and biologically. Therefore, the objective of this study was to assess the water quality and the pollution load to the reservoir in terms of some cardinal water quality parameters. Water samples obtained from inside and release outlet site of the dam were chemically tested by analyzing the presence of heavy metals, phenolic compounds, trace elements using as a screening tool ICP-MS, GCMS, and other equipment for physico-chemical and other parameters. For the biological screening, eosine methylene blue (EMB) media was used to investigate the presence of the fecal coliform and *E. coli*. Results obtained from this study showed that the concentration of analyzed metals (Cu, Zn, Cd, Cr, Fe, Hg, Pb, Mo and Mn) and other parameters (pH, EC, TDS, BOD, turbidity) are within the recommended standard limits for these contents in irrigation water. Also, results obtained from this study indicates the pollution tendencies of the surface waters of KTD reservoir, attributable to high levels of organic compounds.. Results revealed significant toxicity of phenolic compounds was found in water samples, indicating the water quality of these samples is not potable. It is mainly due to the present of biological contamination. The maximum concentrations of phenol was (2.09 mg l^{-1}) and (1.82 mg l^{-1}) for outlet and inside water samples respectively. Among the selected phenolic compounds, the most frequently detected were cyclohexane and benzene, which was found to be present in all sampling sites. All the analyzed samples of fecal coliform showed contaminated status ranging between 1.1 ´ 10^3 to 2.1 ´ 10^6 CFU 100 ml^{-1} from water and sewage samples respectively. *E. coli* counts were more than 1.1 ´ 10^2 CFU in 100 ml^{-1} in all samples which indicates that our irrigation water have biological pollution which is very alarming. This study provides a very useful amount of information for detecting potential toxicity risks.

Key words: King Talal Dam, Biological Pollutants, Phenolic Compounds, GC/MS, Surface Water Quality, Heavy Metals

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Introduction

The King Talal Dam (KTD) is a largest surface reservoir in the hills of northern Jordan, which was originally constructed in 1977 to provide a storage capacity of 55 million m^3 (MCM). To meet the country's increased water demands, in 1984 work to raise the dam further was begun, , a project that was completed in 1988 with a gross storage capacity of 86 MCM. The main purpose of this reservoir is to supply agricultural irrigation water to the Jordan Valley. Meanwhile, the water from KTD reservoir is used to irrigate lands within the middle and southern zones of the Jordan Valley [1]. The Hashemite Kingdom of Jordan: Water Sector Review Update. Main Report. February 15, 2001. Rural Development, Water and Environment Group & Infrastructure Development Group, Middle East and North Africa Region. Report No. 21946-JO.] Zarqa River is the main artery flow over the KTD. The flow characteristics have been further modified by the discharge to the river of treated domestic and industrial wastewater that compose nearly all of the summer flow and substantially degrade the water quality. Water quality from the KTD is dramatically deterioration after the establishment of the largest wastewater treatment plants (WWTP) in 1985 at As-Samra which is about 42 km upstream the reservoir. The treated wastewater, discharged through the Zarqa River to KTD and spilled out downstream until it reaches to the Jordan Valley area, is mainly used for irrigation purposes. Therefore, any pollution in the river will lead to pollution in the dam, which in turn may affect the quality of agricultural produce in the Jordan Valley, which is partially irrigated from its waters [2].

For the time being, KTD water is mixed with treated wastewater which comes from the As-Samra WWTP at a rate of 70 MCM Y^{-1} [3]. The treated effluent from the WWTP is mixed with fresh water resource from the Zarqa River Basin in a ratio of approximately 1:1 [4] before it discharged to Wadi Zarka Basin system and flows into the reservoir [2]. Subsequently, the amount of sewage flowing into the As-Samra wastewater treatment plant has been increasing rapidly and has overloaded almost three times the plant's designed capacity [5], mainly due to the high population growth in the metropolitan Amman-Zarqa area. Also, the KTD reservoir is threatened by factories industrial areas, which emit untreated waste into the reservoir’s tributaries, raising salinity and levels of chemical and metal [6]. Moreover, groundwater salinisation and agricultural residues also influence surface waters, so that, the reservoir was reported to be highly euthrophic [6, 7]. It is necessary to determine the water quality for agriculture since it plays an important role in soil for growing crops [8]. While there is little evidence [9] of real deterioration of soil quality from irrigation using KTD water, there tends to be a psychological aversion to consuming this produce. Concern over microbiological contamination has lead to restrictions on the use of the treated wastewater. Typically, green vegetables are not irrigated with this water, while fruit trees are. Also, groundwater in the area of the plant has witnessed serious deterioration [10].

Water quality concerns dominated the earliest developmental phases. Population increases, however, exert more pressure on limited high quality surface sources and contaminated water sources with human and industrial wastes, which led to deteriorating water quality. The activities in catchment's area of the KTD have the main contribution and effect in the water quality by polluting and contaminating the water chemically and biologically. Recently, new plant was initiated by the government to upgrade As-samra WWTP to improve the quality of its effluent discharges and to reduce its impact on the Zarqa River. This study focuses on the present water quality of the KTD and defines the existing problem encountered with the water quality in respect of the agricultural irrigation purpose. A full deep study and further investigations will be beneficial to determine the problem statement by identifying the type of contaminants which can lead the government to the source of the contamination and the type of treatment required. Some data on KTD water quality are available [11], but little or any information have been provided on the bioavailable heavy mental and organic fractions of the reservoir. Phenol and phenolic compounds are a group of organic pollutants that often appear in wastewaters from many heavy chemical, petrochemical, and oil refining industries. Because of their toxicity and poor biodegradability [12], phenolic compounds are important water pollutant which are subject to legislation, even at low concentration. A European Community directive specifies a legal tolerance level of 0.1 $\mu g\ l^{-1}$ for each phenolic compounds and 0.5 $\mu g\ l^{-1}$ for the sum of all compounds in water intended for human consumption [13, 14][2] EEC Drinking Water Guideline 80/779/EECNOL 229/11–29, 1980.. Hence, the present research was carried out on KTD to determine the physico-chemical characteristics, heavy metals, biological, and phenolic compounds in surface water, this planned research will be helpful to assess the impact of the pollution of the catchment’s area effluent in KTD on the surrounding water bodies.

Materials and Methods

Sample collection and preparation

Surface water samples (raw water) of KTD were collected about 10 cm below the water surface using glass bottles. Water samples in this study were collected in July 2007 from different places (Inside and outlet) of the KTD (Fig. 1). Standard procedures were followed for the collection of water samples for physico-chemical analysis. Polyethylene bottles were used to store surface water samples based on the methods described in APHA [15]. For biological analysis and placed in an icebox and transported to the laboratory for immediate analysis. The samples were stored at 1 – 4 °C temperature prior to analysis in the laboratory. Water samples collected were filtered through 0.45 µm membrane filter paper (Millipore®) using glass filtration unit and acidified with concentrated HNO_3 acids in order to preserve the metals and also to avoid precipitation [16].

Water quality analysis

The water pH, temperature, electrical conductivity (EC) and total dissolved solid (TDS) were determined at the time of sampling in the field using a portable WTW Cond. 315i HANNA, HI991301 Model Oaklab. Total Solid (TS), Total Suspended Solid (TSS), were determined according to APHA methods [16]. Chemical oxygen demand (COD), Dissolved Oxygen (DO) and Biological oxygen demand (BOD) were also determined following the procedure of Hamer [17].

ICP-MS analysis

For determining heavy metal concentrations, 50 ml of each water samples were acidified with approximately 0.5 ml of concentrated HNO_3 (Merck, suprapur) and passed through acid washed folded filters (MN 280 1/4, Macherey-Nagel). The filtrate was stored in acid washed polypropylene tubes (62.548.004 PP, Sarstedt) until it was measured. Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) Optima 2000 DV, spectrometer Autosampler model (PerkinElmer) was used to determine and accurately the trace metal concentrations in water samples. The validation of the procedure for metal determination was conducted by spiking samples with multielement standard solution containing 0.5 mg l^{-1} of all metals analysed. Spiked samples were analysed under the same experimental conditions used for procedural blanks and samples. Acceptable (>90%) recoveries from the spiking experiment validate the experimental procedure.

Gas Chromatograph - Mass Spectrophotometer

Capillary GC/MS analysis was carried out on an Agilent (Palo Alto, CA, USA) Model 6890N gas chromatograph, equipped with a split/splitless injection port, interfaced to an Agilent 5975C inert mass-selective detector (MSD). For each sample, 10 ml of water was placed in a 20-ml test tube (with screw cap) or a reaction vial and dissolved in 10 ml of hexane. A 100 µl of 2N potassium hydroxide in methanol (11.2 g in 100 ml) was added. Samples were vortex for 30 seconds. After then centrifuged at 4000 g for 3 min and the clear supernatant was transferred to a 2-ml autosampler vial [18].

A DB-5MS fused silica capillary column (J&W Scientific, Folsom, CA, USA) was used; the dimensions of the column were 30 m × 0.25 mm i.d., 0.25 µm film thickness. Ultra high purity helium (He) with an in-line Alltech oxygen trap was used as carrier gas. The carrier gas-line pressure was set at a flow of 1.0 ml min^{-1} and column head pressure at 26.04 psi. The temperature of the injector was maintained at 320 ○C and the injected sample volume was 1.0 µl in the splitless mode with 1:50 split ratio. The interface temperature was held at 280 ○C. The column temperature program was: oven equilibration time 1 min; initial temperature 120 ○C for 3 min, then raised to 292 ○C at a rate of 5 ○C/min and then to 320○ at a rate of 30 ○C/min with a final isotherm of 2 min. The mass spectrometer was calibrated with perfluorotributylamine at an electron impact ionization energy of 70 eV. The identification of individual peaks in the total ion chromatogram was done by the Agilent data system having a NBS mass spectra library of about 40 000 compounds.

Microbiological parameters

Bacteriological analysis of water samples collected from five different sites of KTD was conducted after sampling. The presence of Coliforms and *E. coli* specifically was tested using Colitag™ kit. A transparent bottle containing 100 ml of water sample mixed with Colitag reagents was incubated at 37°C overnight. After incubation, the bottles were examined for yellow color formation which indicated coliforms presence. Positive bottles were then checked for the presence of *E.coli* by looking for fluorescence under UV light. Standard Plate count method was used for further water analysis. Liquefied tubes containing Tryptone glucose agar were inoculated with 1 ml of water sample, mixed and poured into a Petri dish. The Petri dishes were then incubated at 37°C for 24 hours. The amount of bacteria in water is expressed as the number of Colony Forming Units per 100 milliliters (CFU 100 ml^{-1}). Total coliforms and *E. coli* were analyzed using Eosine Methylene Blue (EMB) agar plates and Lactose broth with Durham tube [19].

Fig. 1: Locations of the sampling sites on KTD by Google earth

Results and Discussion

Physico-chemical analysis

A summary of the physico-chemical parameters obtained in KTD for two different sites are presented on Table 1. pH was found to be all alkaline in nature in the range between 7.76 to 8.24 in summer. WHO has recommended maximum permissible limit of pH from 6.5 to 9.2 [20]. On the whole the KTD has pH values within the desirable and suitable range. The high pH values during summer may be due to high photosynthesis of micro and macro vegetation resulting in high production of free CO2, shifting the equilibrium towards alkaline side [21].

The value of total dissolved solid (TDS) ranges from 1.98-2.36 mg l^{-1} all the values of total dissolved solid is in the prescribed limit of WHO [22] it is due to high dissolved salts of Ca, Mg and Fe. Determination of TDS is associated with the general acceptance of water by population as its presence in excessive quantities reduces the palatability and imparts bad taste to water [23].

Turbidity was found in the range of 8.11 to 32.8 NTU of outlet to inside sample respectively. Turbidity level exceeding 10 NTU in the dam water, affects the aesthetic quality of water, significantly. Water may not be safe from hygienic point of view as under such conditions it becomes very difficult to maintain the minimum desirable limit of chlorine in the water.

Electrical conductivity (EC) of water is also an important parameter for water quality. The values of EC were 1240 µS cm^{-1} for both samples sites (Table 1). Higher conductivity of water could indicates high amount of ions that exceed the recommended limit by WHO [22].

A range of 4.1-6.2 ppm of Biochemical Oxygen Demand (BOD) was obtained at inside and outlet samples respectively (Table 1). BOD indicates the presence of microbial activities and dead organic matter on which microbes can feed. BOD is directly linked with decomposition of dead organic matter present in the dam and hence the higher values of BOD can be directly related with pollution status of the dam. An inverse relationship was found between the dissolved oxygen concentration and biological oxygen demand values [24].

Chemical Oxygen Demand (COD) indicates the pollution level of a water body as it is related to the organic matter present in the dam [22]. COD concentrations in the range of 19-39 ppm were obtained in the outlet and inside samples respectively (Table 1). From the observed value of Bio-Chemical Oxygen Demand, it may safely be concluded that the bacteriological load in KTD is high due to Eutrophication and dumping of waste materials. From the observation it is also seen that the Chemical Oxygen Demand (COD) was slightly higher. This is also a bad indication.

Microbial analysis

The presence of fecal coliform is an index of biological pollution in water samples. The analytical data values of fecal coliform bacteria and *E. coli* are presented in Table-2. The bacteriological contamination of total coliform at the four water samples obtained from different sites of KTD excessively exceeded the permissible limit. Fecal coliform showed a wide amplitude of variation at all the study points and it ranged from 1.1 ′ 10^{3} CUF 100 ml^{-1} to 2.3 ′ 10^{4} CUF 100 ml^{-1}. In raw sewage concentration of total

Table 1: Physico Chemical Parameters of KTD during summer at two selected sites of inside and outlet of the dam

Sampling point at the dam	pH*	EC(µs cm^{-1})	TDS (mg l^{-1})	VDS (mg l^{-1})	Turbidity (NTU)	BOD$_5$	COD (mg l^{-1})
Inside	7.76	1420	2.36	1.1	32.8	4.1%	39
Outlet	8.24	1420	1.98	0.42	8.11	6.2%	19

Table 2: Analytical data of cations and heavy metals. The determination of trace elements in KTD waters by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS).

Sampling point at the dam	Heavy metals (mg l^{-1})					
	Cu	Zn	Cr	Mn	Fe	Co
Ref. Values:	0.01	0.01	0.01	0.05	0.05	0.01
Inside	0.00031	Nil	Nil	0.0006	0.0006	0.009
Outlet	0.00014	Nil	Nil	0.2995	0.0236	0.004
	Heavy metals (mg l^{-1})					
	Mo	Sn	Pb	Ni	Hg	Phenol
Ref. Values:	0.01	0.01	0.01	0.05	0.01	
Inside	0.0058	0.0122	0.0003	0.0032	0.0034	**1.829**
Outlet	0.0038	0.119	Nil	0.0034	0.0018	**2.092**
		Cations (mg l^{-1})				
		Mg$^+$	Na$^+$	Ca$^+$		
Ref. Values:		30	60	30		
Inside		49.19	263.3	116.1		
Outlet		58.61	241.9	152.7		

coliform and fecal coliform was 1.7 ′ 10^7 and 2.1 ′ 10^6 CUF 100 ml^{-1} respectively. All the analyzed samples show contaminated status and *E. coli* counts were more than 1.1 ′ 10^2 CUF 100 ml^{-1} sample. The presence of fecal coliform bacteria indicates that the water is contaminated with fecal human or animal waste, while the total coliform counts indicate that the water is contaminated with both fecal waste and other bacteria from the soil. The large number of bacteria present in wastewater not only pose a health hazards to the person who uses it for irrigation but also there is risk of contaminating food products[ ]. WHO standards for the use of wastewater in agricultural production for export generally require a level of treatment that ensures that the fecal coliform content of the wastewater is less than 10^3 CFU 100 ml^{-1} [25]. The results obtained from this study in was exceeded the irrigation reuse standard limited of 1000 most probable number MPN of fecal coliform per 100 ml and the treated wastewater standard limit for total coliform [26], it indicates that our irrigation channels have biological pollution which is very alarming.

Heavy metals analysis

Among the inorganic contaminants of the KTD water, heavy metals are getting importance for their non-degradable nature and often accumulate through tropic level causing a deleterious biological effect [27]. Though some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in plants and microorganisms, while many other metals like Cd, Cr and Pb have no known physiological activity, but they are proved detrimental beyond a certain limit [28, 29] which is very much narrow for some elements like Cd (0.01 mg l^{-1}), Pb (0.10 mg l^{-1}) and Cu (0.050 mg l^{-1}). The deadlier diseases like edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented [30, 31]. Therefore, monitoring these metals is important for safety assessment of the environment and human health in particular. The trace elements analysis was carried out through UPM laboratories using ICP-MS. The average analytical results of trace elements of the KTD water samples are presented in Table 3. The results indicate that all of the heavy metals, compared with the optimum concentrations of ideal concentrations [32], were within the accepted limits for irrigation.

Chemical analysis

Organic compounds analyzed by GCMS in the KTD water samples studies are shown in Table 4. A typical computerized reconstructed ion chromatogram of phenolic compounds for which the water samples were analyzed is shown in Figure 2.

The high chemical variability shown by the row water samples in study were observed. More than 100 compounds were detected in the organic

Table 3: Analytical data of faecal Coliform (*E. coli*)

Sample	Total Plate count (CFU100 ml^{-1})	Faecal Coliform bacteria (CFU100 ml^{-1})	*Escherichia coli* levels (CFU 100 ml^{-1})	pH
Raw Sewage	1.7×10^7	2.1×10^6	1.4×10^3	7.4
Sample 1	1.6×10^3	2.3×10^4	1.6×10^2	7.1
Sample 2	1.4×10^3	1.8×10^4	1.4×10^2	7.4
Sample 3	1.1×10^3	1.3×10^4	1.3×10^2	7.6
Sample 4	1.6×10^2	1.1×10^3	1.1×10^2	7.3

Table 4: Organic compounds identified by GCMS in the KTD water samples and their percentage of apparition

Library/ID	CAS #	R.T min	% of total
4-Decene, 3-methyl-, (E)-	062338-47-0	3.318	0.78%
3-Heptene, 2-methyl-,(E)-	000692-96-6	3.318	0.78%
3-Ethyl-4-methyl-2- pentene	019780-68-8	3.349	1.82%
2-Methyl-2-heptene	000627-97-4	3.349	1.82%
1-Hexene,3,3,5-trimethyl-	013427-43-5	3.349	1.82%
Dodecane,4,6-dimethyl-	061141-72-8	4.104	0.77%
Undecane,4,6-dimethyl-	017312-82-2	4.104	0.77%
Dodecane, 2,7,10-trimethyl-	074645-98-0	4.168	1.29%
Undecane	001120-21-4	4.217	1.03%
Benzene, 1,2,3-trimethyl-	000526-73-8	4.724	1.18%
Cyclopentane, (2-methylbutyl)-	053366-38-4	4.921	3.25%
Cyclohexane, 1,1,2-trimethyl-	007094-26-0	4.921	3.25%
1-Hexene, 3,3-dimethyl-	003404-77-1	4.986	4.62%
2,3-Dimethyl-3-heptene,Z)-	059643-73-1	5.048	3.47%
Nitric acid, nonyl ester	020633-13-0	5.048	3.47%
Hexacosane	000630-01-3	5.554	0.70%
Dodecane, 1-iodo-	004292-19-7	5.622	1.51%
Sulfurous acid, 2-ethylhexyl hexyl	1000309-20-2	5.622	1.51%
Undecane, 3,6-dimethyl	017301-28-9	5.683	1.99%
Nonane, 4,5-dimethyl	017302-23-7	5.683	1.99%
Benzene, 1,3-bis(1,1-dimethylethyl	001014-60-4	5.748	6.14%
Benzene, 1,4-bis(1,1-dimethylethyl	001012-72-2	5.748	6.14%
Heptadecane	000629-78-7	5.814	1.17%
Tridecane, 1-iodo-	035599-77-0	5.814	1.17%
2-Bromo dodecane	013187-99-0	5.814	1.17%
1-Hexene, 3,5,5-trimethyl-	004316-65-8	5.999	0.75%
2-Nonanol, 5-ethyl-	000103-08-2	5.999	0.75%
Cyclooctane, butyl-	016538-93-5	5.999	0.75%
Cyclohexane,1-ethyl-2,3-d-imethyl-	007058-05-1	6.278	1.24%
Cyclohexane,1,1,3,5-tetramethyl-,	050876-31-8	6.278	1.24%
1-Hexadecanol, 2-methyl-	002490-48-4	6.393	2.31%
Cyclohexane, 1,1,3,5-tetramethyl-,cis-	050876-32-9	6.393	2.31%
1-Butene, 3,3-dimethyl-	000558-37-2	6.536	1.22%
2-Pentene, 2-methyl-	000625-27-4	6.536	1.22%
Pentadecane, 8-heptyl-	071005-15-7	6.81	0.46%
Eicosane	000112-9S-8	6.81	0.46%
Tetratriacontane	014167-S9-0	6.864	0.45%
Decane, 2-methyl-	006975-98-0	6.966	0.56%
10-Methylnonadecane	056862-62-5	6.99	0.90%
Octacosane	000630-02-4	7.129	1.05%
Pentacosane	000629-99-2	7.129	1.05%
Methoxyacetic acid,2-tetradecy)ester	1000282-04-8	7.419	0.61%
Cyclohexane, 1-ethyl-2-propyl-	062238-33-9	7.459	1.37%
Hexene, 2,2,5,5-tetramethyl	000692-47-7	7.459	1.37%
Undecane, 5-methyl-	001632-70-8	7.611	1.33%
Cyclooctane, ethyl-	013152-02-8	7.644	3.22%
Nitric acid, nonyl ester	020633-13-0	7.683	1.95%
3-Hexene, 2,2,5,5-tetramethyl-, (Z	000692-47-7	7.683	1.95%
Cyclohexane, 1-ethyl-2,3-dimethyl-	007058-05-1	7.706	1.14%
Cyclohexane, 1,2,4-trimethyl2-	002234-75-5	7.774	1.67%
Undecene, 4,5-dimethyl-, [R*,S*- (Z)1_	055170-93-9	7.774	1.67%
Disulfide, di-tert-dodecyl	027458-90-8	8.35	1.74%
Cyclohexane, 1,3,5trimethyl-	001795-26-2	8.564	0.79%
L -Hexadecanethiol	025360-09-2	8.611	1.10%
Oxalic acid, allyl hexadecyl ester	1000309-24-4	8.674	2.09%
Cyclooctane, ethyl-	013152-02-8	8.674	2.09%
2-Heptene, 4-methyl-, (E)-	066225-17-0	8.674	2.09%
Tetrapentacontane, 1,54-dibromo	1000156-09-4	8.728	1.98%
Tetratetracontane	007098-22-8	8.812	1.08%
Cyclohexane, 2-ethyl-1,3-dimethyl-	007045-67-2	8.847	0.85%
Pyrene	000129-00-0	8.938	1.15%
Sulfurous acid, butyl undecyl este	1000309-17-8	9.002	0.73%

Table 4: Continue

Heneicosane	000629-94-7	9.002	0.73%
Pentacosane	000629-99-2	9.319	0.90%
Tetrapentacontane, 1,54-dibromo	1000156-09-4	9.319	0.90%
Heptacosane	000593-49-7	9.319	0.90%

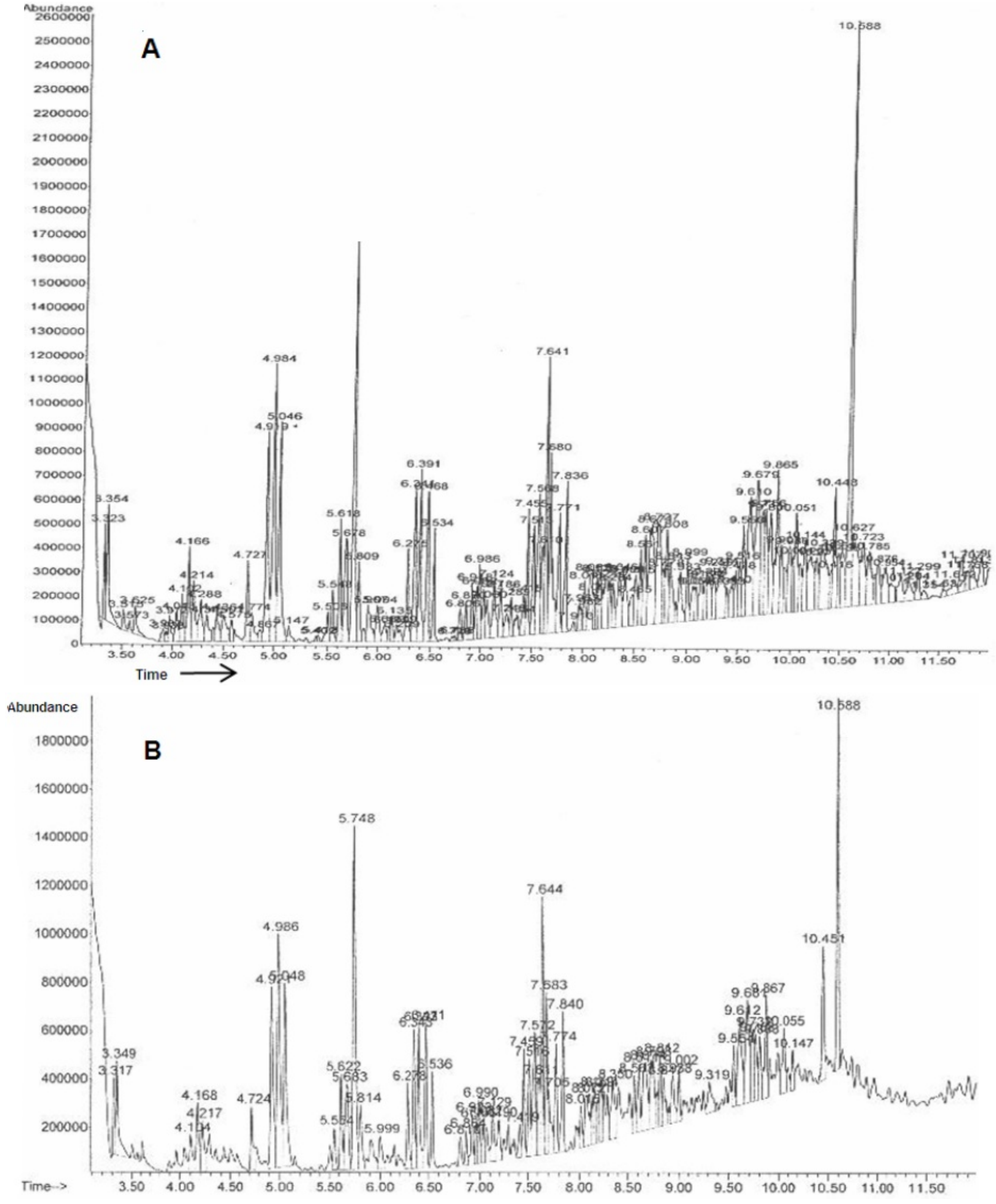

Fig. 2: Chromatogram of total phenolic compounds from KTD water of outlet A, and inside the reservoir B, using GCMS. Phenolic compounds are presented in Table 4

fraction. The most frequently detected compounds at two sampling sites from KTD were bisphenol A (BPA), octylphenol (OP), 1,2-benzenedicarboxylic acid, bis(2-ethylhexyl) ester (DEHP) and 1,2-benzenedicarboxylic acid, bis(methylpropyl) ester (DBP).

A methylated phenolic compound 2,6-bis(1,1-dimethylethyl)4-methyl phenol was detected very frequently at all sampling sites. The frequency of phthalate ester (Benzene dicarboxyclic acid diethyl) was highest among the detected esters

Samples from the KTD were run, alternately, for the total extractable organics in scan mode in order to monitor organic pollution other than phenols. Many extractable organics were found in the KTD during this survey. From the results it is assumed that the reservoir is organically polluted with cyclohexanes. Since the Zarqa river passes through agricultural areas of northern Jordan where cyclic pesticides, insecticides and herbicides are regularly used in order to protect crop from pests, it is most likely that these compounds have entered the river as water runoff and present as a photo-geothermal degradation by products of these pesticides.

Recently, Al-Zu'bi [9] reported various levels of heavy metals concentration in the soil of irrigated area from KTD and the treated wastewater discharged through the Zarqa River to KTD until it reaches to the Jordan Valley area, is acceptable for irrigation purposes. However, the fate of other pollutants like phenols, chlorophenols and organochlorine compounds had not been evaluated. The major sources of widespread phenols, chlorophenols and bromophenols in the water have probably been the industrial effluents, petrochemical, agricultural runoff, chlorination of wastewater prior to the discharge in the waterways and transformation products from natural and synthetic chemicals [33]. Health risks resulting from phenols and chlorophenols in the water have not been established, however, they are known to cause taste and odor problems in drinking water even at trace level [34].

For the GC, it is clear that there are a big number of chemicals involved in the pollution; expected chemicals are more than 100 pollutants such as hexane, toluene, benzene and their derivatives. Supported by the result of Phenol which is very high according to WHO standards to meet the discharge requirements for sewage and industrial effluents (0.001 mg l^{-1} -WHO) and for recommended raw water quality criteria and frequency of monitoring is 0.002 mg l^{-1}-WHO). However the results of ICP show that the presence of heavy metals is not contributing a lot in the pollution. Supporting by the COD results which are lower than expected. From the screening, we can say that the pollution is not caused by hydrocarbon sources, but it is because of the presence of certain chemicals such as phenolic compounds that may be discharged from the pharmaceutical industry or another industries involved and located in the catchment's area of the Dam.

The KTD does not comply with the WHO effluent regulations for these parameters and is a significant point source of pollution into the Zarqa river and the Dam. The KTD needs further upgrading to improve its treatment performance to ensure sustainable use of the water for the downstream users. It is not an easy job to select the type of treatment before identifying the real problem by testing the water. Adsorption treatment by activated carbon is highly recommended or carbon nano tube can be used to solve the problem of heavy metals. Bioremediation which is the use of biological agents to reclaim soils and waters polluted by substances hazardous to human health and/or the environment; it is an extension of biological treatment processes that have been used traditionally to treat wastes in which micro-organisms typically are used to biodegrade environmental pollutants. The target of treatment can be achieved by assessment of biological process with micro-filtration (MF) using hollow fiber membrane as pretreatment for Reverse osmosis RO/ Nano filtration NF Processes, assessment of membrane technologies (NF &RO) as advanced treatment processes, demonstrating the reuse of reclaimed water for landscape irrigation and evaluating treatment costs and economics of water reuse. It is still early to make a decision on what type of treatment can be used to solve the problem. In fact a sampling protocol and strategy must be considered in addition to frequently site monitoring. This is not a single hand project, expertise; professional hands must be involved as well as a site visit will be highly recommended.

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