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Spatio-temporal Variation and Health Risk Assessment of Selected Metals in Nile River Water, Beni-Suef Governorate- Egypt

Hamada M. Mahmoud[a,b], Asmaa S. Hamouda[a], Hossam F. Nassar[a]*, and Fatma Mabrook[a].

[a]Environmental Sciences and Industrial Development Department, Faculty of Postgraduate Studies for Advanced Sciences (PSAS), Beni-Suef University, Beni-Suef, Egypt.
[b]Zoology Department, Faculty of Science, Beni-Suef University, Beni Suef, Egypt.

ABSTRACT

Using the Eastern Desert as waste water dump is the main problem deteriorating surface water of the Torrent drainage channel (S_2 and S_3) and Nile River (S_1, S_4, and S_5) at the Eastern side of Beni-Suef Governorate. Spatio-temporal variations of selected physico-chemical parameters (pH, DO, EC, TDS, SO_4, NO_3, and NO_2) and metals (Cu, Pb, Zn, and Cr) assessed and analyzed. Health risk assessment was estimated by calculating the average daily dose (ADD), the hazard quotient (HQ) and the hazard index (HI) for (NO_3, NO_2, Cu, Pb, Zn, and Cr). The cancer risk (CR) for Pb and Cr via oral and dermal exposure routes based on USEPA methodologies was evaluated. The current data indicated that EC, TDS, SO_4 and NO_3 values in the five sampling sites were above the WHO limits during winter season, while during summer only S_2 and S_3 exceeded the WHO guideline values. Pb values in the five sampling sites were above the WHO limits during both winter and summer seasons. HQs of all parameters were less than 1 except for NO_3 in S_2 and S_3 which showed HQ> 1 through oral exposure. Collectively HIs for oral exposure values were higher than 1 in all the sampling sites except at S_1 during winter and summer seasons. HQs and HIs were less than 1 via dermal exposure. There is expected carcinogenic adverse health effects on human populations especially farmers and fishermen, where CRs were more than unity 1.0E-6 except for Cr via dermal exposure.

Keywords: Nile River, Water pollution, Water quality, Heavy metals and Risk assessment

Corresponding author

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INTRODUCTION

Nile River represents the principal source of fresh water for human activities in Egypt, so protecting its quality and availability has a crucial concern [1-2]. The Nile River in Egypt receives water supply from the High Dam that varies between 52.9 and 57.4 billion cubic meter/year [3-4]. There are many factors influence the water quality of the Nile, since there are 124 pointed sources of waste water discharge from agricultural and industrial drains along its whole course in addition to non-pointed sources [5-6]. Recently, many researchers detected deterioration of the Nile water in Egypt; Osman and kloas reported the water quality and metals along the whole course of the Nile River, where they found that water deterioration increased significantly from Aswan toward Rosetta and Damietta branches [7]. El Kashouty and Elsayed, and Elewa et al correlated the deterioration of the Nile River in Minia Governorate in relation to anthropogenic activities [8-5]. Badr et al reported some metals concentration in the Nile water along the greater Cairo which is affected by the excessive waste water discharge especially from the industrial regions [9]. Omar and Mahmoud reported metals and Polychlorinated biphenyls (PCBs) in the Nile River along the course of Cairo city which is densely populated area and their health risk on humans was evaluated [2].

Water quality assessment is a term used to indicate the suitability of fresh water to keep on various uses or processes [7]. Recently metals monitoring in the rivers' water has a significant concern in the whole world, because of the toxicity, persistence and bio accumulative dangerous nature of metals. Metals have been reported by several authors for their ability to induce carcinogenic and mutagenic effects [10-11-12-13]. Chronic exposure of living organisms and human beings to metals and other toxic substances may explain the remarkable increase of liver cirrhosis and renal failure in Egypt. Liver and kidney diseases represent the third and fourth causes of death in Egypt, with the percentage of 7.34% for liver and 5.19% for kidney [14].

Beni-Suef governorate is located at the Nile River; it depends on Nile water as the main source for drinking, fisheries, industry and agriculture. In the last 30 years, increased anthropogenic activities at the eastern side of the Nile River in Beni-Suef governorate have induced adverse effects on the nearby ecosystems including the Nile River. Such activities may include cement, chemical and food industry as well as desert land reclamation and building construction. The most serious problem that affects the surface water in the eastern side of Beni-Suef is using the desert as waste water dump, where waste water eventually reaches the Nile via drainage channels or through the ground diffusion. The sampling sites of the present study have been chosen based on preliminary observations and recordings of industrial, domestic, and agricultural waste water that reach the Torrent drainage channel which was designed nine years ago. Finally flood water and waste water flow through this drainage and end in the Nile River.

Risk assessment is a scientific process that quantifies the potential environmental hazards on human health. It is a tool that is used to identify and measure a hazard, determine the possible ways of exposure, and calculate a numerical value which represents the potential risk. It consists of four steps; hazard identification, dose-response assessment, exposure assessment, and risk characterization. Although several studies evaluated the concentration of metals in fresh water aquatic environment in Egypt, but throughout our literature review there are no studies referring to the Torrent drainage channel or for the eastern side of the Nile. Although there is a great current concern with the evaluation of the human health risk assessment, a few studies tackle the human health risk assessment for the Nile contaminants in Egypt. The principal reason for monitoring water quality has been the need to verify whether the observed water quality is suitable for intended uses. The aim of this study is discussing the effect of the torrent drainage channel on the Nile at that area by measuring some water quality parameters, and some metals in water for the estimation of the human health risk by calculating the hazard quotient (HQ), hazard index (HI) and cancer risk (CR) according to USEPA methodologies.

MATERIALS AND METHODOLOGY

The sampling sites description

As seen in graph no.1, the study area was subdivided into five sampling sites (S_1, S_2, S_3, S_4 and S_5) exposed to different pointed and non-pointed waste water discharge.

S_1: represents the upstream point in the Nile approximately 2.5 km before the Torrent drainage channel destination at the Nile River. It represents the reference site where water is drawn from it to the irrigation canals to feed all the cultivated lands in the eastern riverside. It is located at GPS coordinates of N 29°03`.726`` and E 31°31`.0224``.

S_2 and S_3: represent two points in the Torrent drainage channel that its entire length 2.2 km, the drainage is exposed to waste water from the new reclaimed desert lands, poultry and fish farms, leachates from the rubbish dump, the filter cleaning of the drinking water company of the new city of Beni-Suef, and some filtrated industrial and domestic waste water. They are located at GPS coordinates of N 29°023`.1876`` and E 31°426`.8464`` for S_2; and N 29°038`.1852`` and E 31°359`.7564`` for S_3.

S_4: represents the middle stream point at the Nile where the drainage water mixes with the Nile River water. It is exposed to different non-pointed sources of contamination through diffusion of industrial, agricultural and domestic waste water in addition to the near fish ponds in the Nile considered another source of pollution. It is located at GPS coordinates of N 29°055`.2744`` and E 31°327`.9828``.

S_5: is the downstream point at the Nile which lies after approximately 2.1 km from the Torrent drainage channel destination at the Nile and from this site the water is drawn to the irrigation canals for feeding all the new reclaimed desert lands. It is located at GPS coordinates of N 29°123`.2176`` and E 31°341`.6844``.

Graph No.1: The five sampling sites in Beni-Suef governorate, Egypt.

Water sampling and analysis

Surface water samples were collected from the five sites during winter season (December, January, and February) and summer season (June, July, and August) from 2014 to 2015.Water samples were collected at a depth of 30 cm below the water surface and stored at 4°C in 500 ml glass bottles which were pre-washed with acids and deionized water. In the laboratory, fifteen pooled water samples were prepared by mixing equal volume of three subsamples collected from three different localities along each sampling site for each month. The parameters such as pH, DO, EC, and TDS were noted on site by using portable meters, pH was measured by Twin B-22 Meter, DO was measured by YK-2 Meter, and EC and TDS were measured by CTS-406 Meter. The sampled water was examined for NO_3, NO_2, and SO_4 by UV spectrophotometer (HACH 2800). For metals detection, water samples were filtered by 0.45 μm Whatman filter paper, acidified (pH< 2) with 0.5 ml nitric acid (analytical grade Merck, Germany) and stored at 4°C for their metals analysis. Cu, Pb, Zn, and Cr concentrations in water samples were determined using flame atomic absorption spectrophotometer (Perkin-Elmer, Model 2380) using three replicates for each sample according to APHA [15].

Health risk assessment

Risk assessment is defined as the processes of estimating the probability of occurrence of any adverse health effects over a specified time period and is a function of the hazard and exposure. The level of exposure to different types of chemicals through ingestion and dermal contact with water was estimated by the equations (1) and (2) [**16-17**]:

$$ADD_{ing} = \frac{CxIRxEFxED}{BWxAT} \quad (1)$$

$$ADD_{derm} = \frac{CxSAxKpxETxEFxEDxCF}{BWxAT} \quad (2)$$

Where, ADD_{ing} is the average daily exposure dose (mg/kg-day) from drinking chemical contaminated water, and ADD_{derm} is the average daily exposure dose via dermal contact with chemical contaminated water. C is the concentration of chemical in water (mg/l), IR is the ingestion rate (2.2 L/day), EF is the exposure frequency (365 Days/year), ED is the exposure duration (70 year), BW is the average body weight (70 kg), AT is the average life time (25550 days), SA is the exposed skin area (18000 cm^2), ET is the exposure time (0.6 hr/day), CF is the unit conversion factor (0.001 L/cm^3), K_p is the dermal permeability coefficient (cm/hr) for Zn is 0.0006, Cu is 0.001, Pb is 0.004, Cr is 0.002, NO_3 is 0.001, and NO_2 is 0.001.

The risk assessment of non-carcinogenic adverse effects was estimated by calculating the hazard quotient (HQ) through intake or dermal contact with contaminated water. It is expressed by the ratio of ADD to the reference dose RfD of each chemical by the equation (3), when HQ≥ 1 there is a non-carcinogenic expected risk on humans through their life time [16].

$$HQ_{ing/derm} = \frac{ADD_{ing/derm}}{RfD_{ing/derm}} \quad (3)$$

Where, oral RfD (mg/kg-day) is available at the Integrated Risk Information System (IRIS) and in the Regional Screening level summery table of USEPA for NO_3 (1.6), NO_2 (0.1), Cu (0.04), Pb (0.0035), Zn (0.3), and Cr (0.003) [18-19]. Dermal RfD was derived from the equation $RfD_{derm} = RfD_{ing} \times ABS_{GI}$, where RfD_{derm} is the absorbed reference dose via dermal contact (mg/kg-day), RfD_{ing} is the reference dose via the ingestion pathway (mg/kg-day), and ABS_{GI} is the fraction of contaminant absorbed in gastrointestinal tract (dimension less) in the critical toxicity study [17-19].

For the multiple risk assessment of the chemicals in drinking water, the hazard index is calculated by equation (4), when HI≥ 1 the human population consumed the contaminated water may be experience adverse health effects.

$$HI = \sum_{i-0}^{n} HQ \quad (4)$$

Cancer risk (CR) was evaluated by using equation (5), when CR> 10^{-6} there is a carcinogenic risk [16-18-20]:

$$CR_{ing/derm} = \frac{ADD_{ing/derm}}{SF_{ing/derm}} \quad (5)$$

Where, CR_{ing} is the estimated cancer risk through the ingestion route, CR_{derm} is the estimated cancer risk via the dermal contact exposure, SF_{ing} is the cancer slope factor (mg/kg-day) through ingestion pathway, the SF_{ing} for Pb is (0.0085), Cr is (0.5), SF_{derm} is derived from the equation $SF_{derm} = SF_{ing}/ABS_{GI}$ [17-18-19].

Statistical analysis

Data were statistically analyzed using one way analysis of variances (ANOVA) to determine the spatial variations. Tukey post hoc test was used for the multiple comparisons between the five sampling sites. Student t-test was used to determine the seasonal variations during winter and summer seasons. Pearson correlation analysis was used to evaluate the relationships between the water quality parameters for both winter and summer seasons. The data values were expressed as mean ± standard error of mean (SEM). $P < 0.05$ was the accepted significance level. All statistical tests were performed by using IBM SPSS statistical package version 22.

RESULTS AND DISCUSSION

The average values of selected physico-chemical parameters (pH, DO, EC, TDS, SO_4, NO_3 and NO_2) and metals (Cu, Pb, Zn and Cr) of surface water sampled from Torrent drainage channel (S_2 and S_3) and Nile River (S_1, S_4, and S_5) at the Eastern side of Beni-Suef Governorate for winter and summer seasons during the period from December 2014 to August 2015 are presented in table 1, the correlation analysis between physico-chemical parameters and metals are presented in table 2, HQ and HI for ingestion and dermal contact pathways are presented in tables 3 and 4, table 5 shows cancer risk through the two pathways for Pb and Cr, and finally graph no.**2** and graph no.3 show the HIs for ingestion and dermal pathways respectively.

Physico-chemical parameters and metals

Table 1 summarizes the concentrations of the selected surface water quality parameters and metals at the five sampling sites during winter and summer seasons. The average recorded pH values at the five sampling sites range from 7.36 to 7.96. The highest pH value (7.96 ± 0.056) is recorded in S_1 during winter season. The pH values in S_1 show a significant increase when compared with the other sampling sites at $P< 0.005$ and at $P< 0.01$ during winter and summer seasons respectively. These pH values exhibit slightly alkaline, but still within the WHO limits (6.5 – 8.5) [21], similarly Osman and kholas reported pH values that ranged from 7.8 to 8.4 along the whole course of the Nile in Egypt [7]. The pH values in the current sampling sites have no expected adverse health effects on the ecosystem health status or on the human health.

The average dissolved oxygen (DO) values range from 6.17 to 7.67 mg/l in the five sampling sites during the two seasons. The lowest DO value is detected at S_2 (6.17 ± 0.145 mg/l) during summer season, such value is significantly lower at $P< 0.05$ when compared with their relevant values in the other sites during the two seasons. Also a spatial significant decrease is shown in S_3 at $P< 0.01$ during summer season. Such recorded low values of DO in S_2 and S_3 could be an indication for the organic matter contamination due to waste water discharge from the surrounding poultry and fish farms. The low values of DO may induce serious physiological and behavioral alterations on wide range of living organisms especially fish and it may also alter their probability of surviving [22]. The average DO range in the current study is still within the limits (≥ 5 mg/l) [22]. DO values in the current study are less than DO range (5.2 – 11.1 mg/l) reported by Chiarenzelli and Skeels in the Raquette river at New York USA [23], and it is more than the range (0.5 – 3.5 mg/l) reported by Islam et al in Shitalakkhya River at Bangladesh [47].

The average values of electric conductivity (EC) and total dissolved solids (TDS) in the current study range from 351 to 45500 µs/cm and from 227 to 29757 mg/l respectively. S_2 clarifies the highest values for EC (45500 ± 2400 µs/cm) and for TDS (29757 ± 1559 mg/l) during winter season. EC and TDS show a spatial significant increase in S_2 and S_3 at $P< 0.0001$ for the two study seasons. During winter season, EC and TDS values are above the WHO limits (1500 µs/cm) for EC and (600 mg/l) for TDS in all the sampling sites except for EC in S_1 [21-24]. During summer season, only S_2 and S_3 exceed the WHO limits for EC and TDS. At the current sampling sites the average detected EC values are higher than that recorded by Osman and Kloas of (250 – 570 µs/cm) in the Nile River from Aswan to Damietta and Rosetta branches in Egypt [7]. The average TDS values are higher than those reported by Yang et al of (69.7 – 1189.2 mg/l) at the upper reaches of Huai River basin in China [25]. The high values of EC and TDS in the current sampling sites could be due to the agricultural waste water from the desert land reclamation project at the eastern side of the Nile. Increasing the salinity of fresh water at the current sampling sites may affect the different biotic communities by excluding fresh water species that can't tolerate the increased salinity during winter season and consequently altering the biodiversity. Scannel and Duffy reported that exposure of some fresh water fish species to TDS above 2500 mg/l during their fertilization stage caused the death of 50% percent of their offspring [26].

The average sulfate (SO_4) concentration values in both seasons range from 20 to 8233 mg/l in the current study. The highest value is recorded in S_3 (8233 ± 1398 mg/l), it shows a seasonal significant increase at P< 0.05 in winter season when compared with its relevant value during summer season. During winter season, the detected SO_4 values are higher than WHO limits (250 mg/L) in all the sampling sites except S_1, while during summer season only S_2 and S_3 are higher than the limits [21]. The average SO_4 concentrations in the current study are found to be higher than those recorded by Li et al of (2.6 – 680.6 mg/l) in surface water samples from an agricultural area in China [27], and those reported by Donoker et al of (15 – 193 mg/l) along the Jimi River and its tributaries at Obuasi in Ghana [28]. The high recorded SO_4 levels could be attributed to fertilizers, fungicides and insecticides application, dyes, glass and paper industries, and the aluminum sulfate that is used as a sedimentation agent in the drinking water plants. Human population at the study area may expose to cathartic effects, including dehydration, due to the consumption of drinking water contains sulfate with concentration above 600 mg/L [29].

The average nitrate (NO_3) and nitrite (NO_2) values in the current sampling sites range from 2.5 to 118 mg/l and from 0.03 to 1.87 mg/l respectively. S_2 manifests the highest values for NO_3 (118 ± 2.6 mg/l) and for NO_2 (1.87 ± 0.14 mg/l) during summer season. NO_3 shows a spatial significant increase in S_2 and S_3 at P< 0.0001 for both winter and summer seasons. NO_2 in S_2 shows a spatial significant increase at P< 0.0001 when compared with the other sampling sites, and it shows a seasonal significant increase at P< 0.05 during summer season. All the recorded NO_3 values with the exception of those S_1 exceed the WHO limits (11 mg/L) during winter season. During summer season only water sampled from S_2 and S_3 exceed the limits [21]. NO_2 values in the five sampling sites during winter and summer seasons are within WHO limits (0.9 mg/L) except for S_2 during summer season [21]. The average NO_3 concentration values in the current sampling sites during winter and summer seasons are higher than their relevant values (0.288 – 0.858 mg/l) reported by El-Otify and Iskaros in the Nile river at Upper Egypt [30]; (0.034 – 0.058 mg/l) reported by Ibrahim et al in the Nile River and El-Rahawy drain at El-Kanater El-Khyiria in Egypt [31]; and higher than (1.3 – 13.2 mg/l) recorded by Al-Badaii and Othman in the Semenyih River at Peninsular Malaysia [32]. The average NO_2 range in the present study is found to be higher than NO_2 range (ND – 0.001) reported by Chaves et al at the Boqueirão de Parelhas Dam in Brazil [33]. The high concentration of NO_3 and NO_2 in the present sampling sites may be attributed to the excessive application of fertilizers, manure and bio solids in the surrounding agricultural lands, or from the domestic waste water continuous discharge. Exposure of humans, especially infants at 0 – 3 months may cause a disease called methemoglobinemia, which may end with coma and death [34]. It may also induce different types of cancer for both children and adults [35].

The average Cu concentrations range from 0.014 to 0.142 mg/l in the current sampling sites during both seasons. The highest Cu value (0.142 ± 0.093 mg/l) is recorded in S_4 during winter season. Cu shows no spatial or seasonal significant differences (P ≥ 0.05). All the Cu values in the current study are within the WHO permissible limits (2 mg/l) [21]. The average detected Cu values are higher than Cu range (0.02 – 0.026 mg/l) reported by Omar and Mahmoud in the Nile River at Cairo city in Egypt [2]; and it is within Cu range (0.0001 – 0.123 mg/l) reported by Damodharan and Reddy in the Uppanar River at Poland [36]. The high detected Cu concentrations in the sampling sites may be attributed to Cu addition as a nutrient in fertilizers and animal feeds to support plant and animal growth, or through the extensive application of fungicides, algaecides, insecticides and wood preservative [37].

The average Pb values range from 0.014 to 0.081 mg/l in the current study. S_2 shows the highest values for Pb (0.081 ± 0.053 mg/l) during winter season. Pb shows no spatial or seasonal significant differences (P ≥ 0.05). Pb exceeds the WHO limits (0.01 mg/l) in the five sampling sites during winter and summer seasons [21]. The average Pb concentrations in the current study are lower than those of (2 – 9 mg/l) reported by Authman et al in water samples collected from Sabal drainage canal at El-Menoufyia province in Egypt [38]; and it is within the range of (0.037 – 0.14 mg/l) reported by Bakheit in White Nile at Sudan [39]. The high concentrations of Pb in the current sampling sites may be resulted from the rubbish dump incineration or from the fuels combustion at the near highway, where Pb is slightly soluble in water and it transports mainly through the atmosphere; also the excessive application of different types of fertilizers may be another source of Pb contamination. Human population in the area of study are probably exposed to a cumulative tissue poison which gets stored in different parts of the body especially in bones, liver, kidney and brain. Pb exposure in children leads to neurophysiological development, intelligence decrease, behavior disorders, growth retardation and death [40].

In the present study, the average detected Zn values range from 0.035 to 1.113 mg/l. S_4 shows the highest values for Zn (1.113 ± 0.923 mg/l) during winter season. Zn shows no spatial or seasonal significant differences ($P \geq 0.05$). Zn detected throughout the study period is within the WHO permissible limits (3 mg/l) [21]. The average Zn values in the current study are higher than those of (0.096 – 0.46 mg/l) reported by Ibrahim and Omar in the Nile River at Assuit governorate in Egypt [41]. The high concentrations of Zn in the current sampling sites may be attributed to zinc carbamates that are used as pesticides and sewage disposal [42]. Toxicity due excessive intake of zinc has been reported to cause electrolyte imbalance, nausea, anemia, and lethargy for humans [43].

The average Cr values range from 0.009 to 0.05 mg/l in the current study. S_2 manifests the highest values for Cr (0.05 ± 0.035 mg/l) during summer season. Cr shows no spatial or seasonal significant differences ($P \geq 0.05$). Its level in the sampling sites during winter and summer seasons is within the WHO permissible limits (0.05 mg/l). The average Cr range in the present study is lower than its range (0.09 – 0.23 mg/l) reported by Tabinda et al in Sutlej River at India [44]. The detected Cr concentrations in the current study may be attributed to the use of fertilizers and manure of the livestock in all the surrounding agricultural lands [45]. In animal studies, Cr is found to accumulate mainly in liver, kidneys, spleen, and bone marrow [46].

The effect of the Torrent drainage channel (S_2 and S_3) on the Nile River (S_4 and S_5) is clearly noticed during winter season, where EC, TDS, NO_3, and SO_4 values in S_4 and S_5 are higher than WHO limits and higher than S_1 or the upstream site. This effect during winter season is a result of the seasonal decrease in the Nile flow and stream; during summer season, S_4 and S_5 show higher values than S_1, but still within the limits of WHO, because of the dilution effect of the annual flood in the Nile.

Table 1:Average values (± SE) of selected physico-chemical parameters and metals of surface water samples collected from different study sites (S_1 to S_5) during winter and summer seasons of the study period from December 2014 to August 2015 (Values in mg/L except EC in µs/cm)

Site / Element	S_1	S_2	S_3	S_4	S_5	WHO limits*
pH						
W	7.96 ± 0.056	7.59 ± 0.001	7.64 ± 0.031	7.72 ± 0.49	7.73 ± 0.03	6.5-8.5
S	7.36 ± 0.055	7.74 ± 0.015	7.79 ± 0.08	7.61 ± 0.115	7.71 ± 0.175	
DO						
W	7.67 ± 0.318	6.47 ± 0.12	6.57 ± 0.291	6.83 ± 0.203	7.43 ± 0.24	NA
S	7.63 ± 0.26	6.17 ± 0.145	6.33 ± 0.186	6.71 ± 0.176	7.6 ± 0.208	
EC						
W	1489 ± 832	45500 ± 2400	42633 ± 1444	9023 ± 5635	9210 ± 5499	1500
S	351 ± 9.5	41600 ± 2320	32600 ± 4100	475 ± 17	609 ± 29	
TDS						
W	977 ± 541	29757 ± 1559	27712 ± 938	5866 ± 3663	5969 ± 3575	600
S	227 ± 6.2	27040 ± 1560	21190 ± 2665	308.8 ± 12	395.9 ± 19	
SO_4						
W	115.3 ± 57.4	4950 ± 1650	8233 ± 1398	1245 ± 785	714 ± 543	250
S	20 ± 2.2	2400 ± 100	2025 ± 275	27 ± 1.2	35 ± 3	
NO_3						
W	6.2 ± 2.7	98.9 ± 10.9	117 ± 1.53	29.7 ± 18.9	25.3 ± 16.5	11
S	2.5 ± 0.3	118 ± 2.6	109.5 ± 2.5	4.2 ± 0.6	4.5 ± 0.5	
NO_2						
W	0.48 ± 0.43	0.78 ± 0.15	0.75 ± 0.1	0.399 ± 0.29	0.45 ± 0.31	0.9
S	0.03 ± 0.003	1.87 ± 0.14	0.83 ± 0.12	0.03 ± 0.001	0.03 ± 0.002	
Cu						
W	0.014 ± 0.001	0.05 ± 0.036	0.025 ± 0.002	0.142 ± 0.093	0.039 ± 0.004	2
S	0.123± 0.091	0.073 ± 0.054	0.061 ± 0.006	0.068 ± 0.025	0.076 ± 0.051	
Pb						
W	0.014 ± 0.011	0.081 ± 0.053	0.028 ± 0.011	0.041 ± 0.035	0.039 ± 0.025	0.01
S	0.042 ± 0.01	0.031 ± 0.004	0.053 ± 0.01	0.075 ± 0.003	0.066 ± 0.019	
Zn						

W	0.051 ± 0.045	0.283 ± 0.138	0.182 ± 0.144	1.113 ±0.923	0.038 ± 0.001	3
S	0.035 ± 0.001	0.038 ± 0.009	0.054 ± 0.015	0.055 ± 0.009	0.058 ± 0.011	
Cr						
W	0.009 ± 0.006	0.031 ± 0.022	0.016 ± 0.005	0.031 ± 0.023	0.015 ± 0.009	0.05
S	0.016 ± 0.007	0.05 ± 0.035	0.011 ± 0.003	0.043 ± 0.009	0.035 ± 0.02	

* , WHO permissible limits [**21-24**]; NA, not available.
W, winter season; S, summer season.
DO, dissolved oxygen; EC, electric conductivity; TDS, total dissolved solids; SO_4, sulfate; NO_3, nitrate as nitrogen; NO_2, nitrite; Cu, Copper; Pb, Lead; Zn, Zinc; Cr, Chromium.
All values are represented with mean values ± standard error.

Correlation analysis

The correlation analyses between different parameters for each season are presented in table 2. During winter season, there is positive correlation between EC and TDS with SO_4 (r = 0.835, P< 0.01) and NO_3 (r = 0.931, P< 0.01), while EC and TDS show a negative correlation with pH (r = -0.677, P< 0.05). Positive correlation is observed between NO_3/SO_4 (r = 0.882, P< 0.05), Cu/Zn (r = 0.912, P< 0.01), Pb/Cr (r = 0.927, P< 0.01), and DO/pH (r= 0.769, P< 0.01); significant negative correlations is noted between DO/EC (r= - 0.677, P< 0.05) and DO/TDS (r= -0.677, P< 0.05). During summer season, EC and TDS pose positive correlation with SO_4 (r = 0.999, P< 0.01), NO_3 (r = 0.991, P< 0.01) and NO_2 (r = 0.952, P< 0.01). Positive correlations are observed between SO_4/NO_3 (r = 0.994, P< 0.01), SO_4/ NO_2 (r = 0.935, P< 0.01), NO_3/NO_2 (r = 0.912, P< 0.01) and pH/Zn (r = 0.643,P< 0.05); a significant negative correlations are observed between DO/EC (r = - 0.807, P< 0.01), DO/TDS (r =-0.807, P< 0.01), DO/SO_4 (r = - 0.804, P< 0.01), DO/NO_3 (r = -0.785, P< 0.01), and DO/NO_2 (r= -0.783, P< 0.01). Pearson correlation analysis clarifies the positive correlation during the two seasons between EC, TDS, SO_4, and NO_3 that means they may originate from the same pollution sources all over the year. Metals may originate from different non-pointed sources, whereas the Cu/Zn and Pb/Cr show positive correlation during winter season. In the current sampling sites, pH show negative correlation with EC and TDS during winter season. pH showed positive correlation with Zn during summer season, because metals such as Zn are more soluble in alkaline water [24]. DO and pH show a positive correlation during winter season, while EC, TDS, SO_4, and NO_3 show a negative correlation with DO during both winter and summer seasons that means increasing contamination level in water cause depletion in oxygen content.

Table 2:Pearson correlation analysis of water quality parameters winter season is below the diagonal and summer season above the diagonal

	pH	DO	EC	TDS	SO_4	NO_3	NO_2	Cu	Pb	Zn	Cr
pH	1	-0.628	0.544	0.544	0.555	0.549	0.455	-0.250	0.226	0.643*	0.328
DO	0.769**	1	-0.807**	-0.807**	-0.804**	-0.785**	-0.783**	0.415	0.192	-0.064	-0.175
EC	-0.677*	-0.774**	1	1.000**	0.999**	0.991**	0.952**	-0.198	-0.553	-0.151	0.026
TDS	-0.677*	-0.774**	1.000**	1	0.999**	0.991**	0.952**	-0.198	-0.553	-0.151	0.026
SO_4	-0.467	-0.524	0.835**	0.835**	1	0.994**	0.935**	-0.194	-0.540	-0.124	0.031
NO_3	-0.547	-0.739*	0.931**	0.931**	0.882**	1	0.912**	-0.197	-0.501	-0.141	0.000
NO_2	-0.085	0.039	-0.091	-0.091	-0.312	-0.384	1	-0.168	-0.611	-0.268	0.163
Cu	-0.320	-0.207	-0.246	-0.246	-0.186	-0.239	-0.106	1	-0.061	0.055	0.391
Pb	-0.272	-0.339	0.432	0.432	0.276	0.297	0.179	-0.010	1	0.551	0.217
Zn	-0.282	-0.255	-0.188	-0.188	-0.152	-0.151	-0.177	0.912**	-0.307	1	0.367
Cr	-0.136	-0.265	0.337	0.337	0.277	0.305	0.034	0.023	0.927**	-0.265	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Health risk assessment

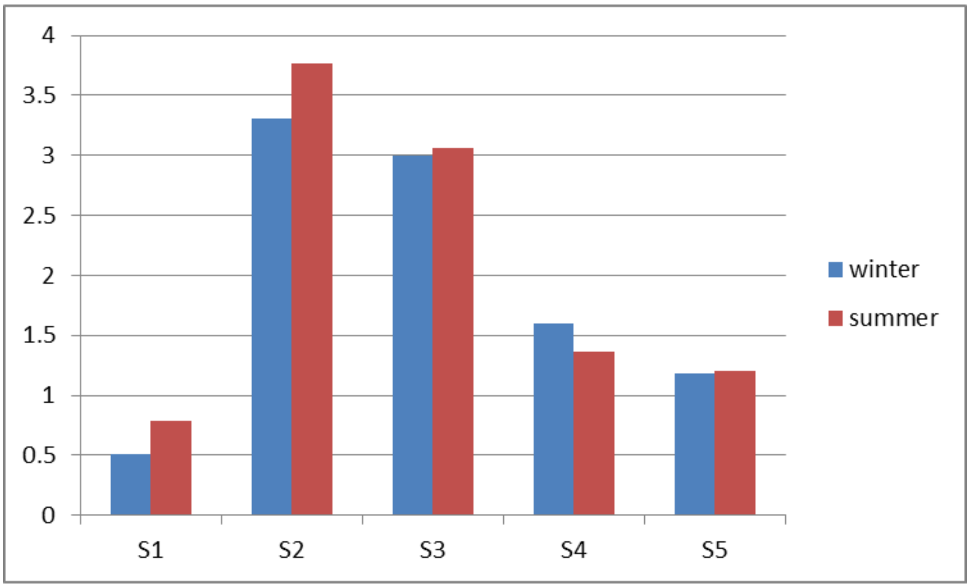
HQs were calculated by using the mean concentrations of NO_3, NO_2, Cu, Pb, Zn and Cr for both the oral exposure route and the dermal contact pathway. Table 3 and **graph no.2** show all individual HQs are less than 1 except that of NO_3 in S_2 and S_3 which show HQ> 1 during both winter and summer seasons, where the non-carcinogenic adverse health effects may appear due to NO_3 contamination. The highest HQs recorded for NO_3 (2.318), NO_2 (0.588), and Cr (0.524) are observed in S_2 during summer season, while Pb shows its highest HQ (0.727) in S_2 during winter season. The highest HQs recorded for Cu (0.112) and Zn (0.1166) are observed in

S_4 during winter season. Overall HIs in the five sampling sites are more than 1 except that of the reference site (S_1), where HI followed the sequence $S_2 > S_3 > S_4 > S_5 > S_1$. Human population that lives nearby the area of study may be exposed to non-carcinogenic adverse health effects with the continuous and excessive ingestion of this contaminated water.

Table 3: Hazard quotient (HQ) and hazard index (HI) of the ingestion of the surface water from the current sampling sites (S_1 to S_5) during winter and summer seasons of the study period from December 2014 to August 2015

HQ	S_1	S_2	S_3	S_4	S_5
NO_3					
W	0.122	1.943	2.298	0.548	0.497
S	0.049	2.318	2.151	0.083	0.088
NO_2					
W	0.151	0.245	0.236	0.125	0.141
S	0.094	0.588	0.261	0.094	0.094
Cu					
W	0.011	0.039	0.021	0.112	0.031
S	0.097	0.057	0.048	0.053	0.061
Pb					
W	0.126	0.727	0.251	0.368	0.35
S	0.377	0.278	0.476	0.673	0.593
Zn					
W	0.0053	0.0296	0.0191	0.1166	0.0039
S	0.0037	0.0039	0.0057	0.0058	0.0037
Cr					
W	0.094	0.325	0.168	0.325	0.157
S	0.168	0.524	0.115	0.4505	0.367
HI					
W	0.5093	3.3086	2.9931	1.5946	1.1799
S	0.7887	3.765	3.0567	1.3593	1.2067

W, winter season; S, summer season; NO_3, Nitrate; NO_2, Nitrite; Cu, Copper; Pb, Lead; Zn, Zinc; Cr, Chromium.



Graph No.2:HI via ingestion of contaminated water from the sampling sites during winter and summer seasons.

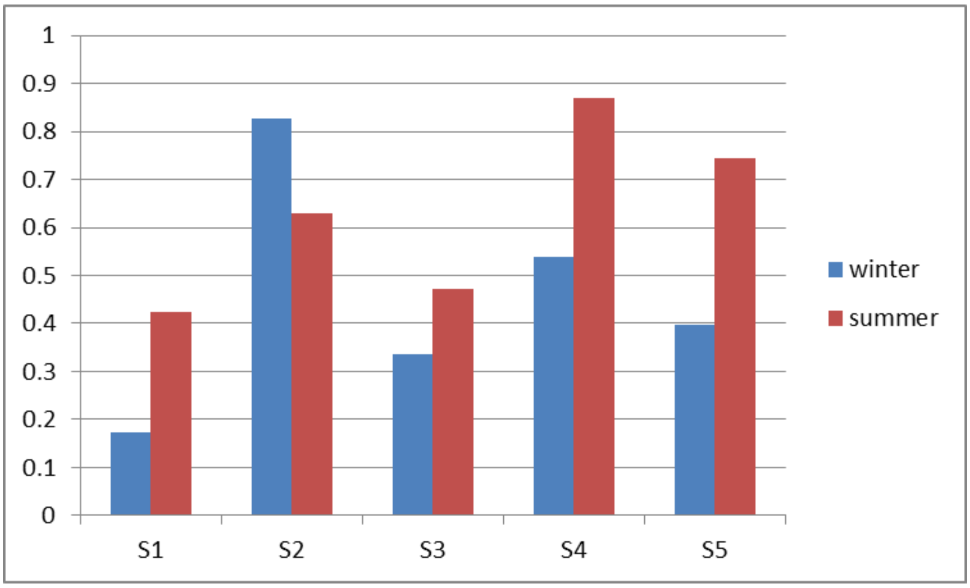
Table 4 presents the HQs and HIs of the chemical contaminated water via dermal contact pathway. Individually all HQs are less than 1, also cumulatively all HIs are less than 1 as seen in **graph no.3** The highest HQs recorded for NO_3 (0.01138), NO_2 (0.00288), and Cr (0.3956) are observed in S_2 during summer season, while Pb shows the highest HQ (0.57129) in S_2 during winter season. The highest HQs recorded for Cu (0.000548) and Zn (0.000343) are observed in S_4 during winter season. Non-carcinogenic adverse health effects are unexpected via the chronic dermal exposure pathway. Despite some of HIs values as those recorded in S_2

(0.827) and S_4 (0.869) should be taken into consideration especially for farmers and fishermen who are directly in contact with the contaminated water.

Table 4:HQ and HI of the dermal contact with the surface water from the current sampling sites (S_1 to S_5) during winter and summer seasons of the study period from December 2014 to August 2015

HQ	S_1	S_2	S_3	S_4	S_5
NO_3					
W	0.000597	0.00954	0.01128	0.00286	0.002496
S	0.000241	0.01138	0.01056	0.000405	0.000434
NO_2					
W	0.0007406	0.001203	0.001157	0.000616	0.000694
S	0.0000463	0.002885	0.001281	0.0000463	0.0000463
Cu					
W	0.000054	0.000193	0.000096	0.000548	0.0001504
S	0.000474	0.000282	0.000235	0.000262	0.0002931
Pb					
W	0.098743	0.571298	0.197486	0.289176	0.275069
S	0.296228	0.218645	0.373812	0.528979	0.4655502
Zn					
W	0.0000157	0.0000873	0.0000562	0.000343	0.0000117
S	0.0000108	0.0000117	0.0000166	0.0000169	0.0000179
Cr					
W	0.0712087	0.2452747	0.1265934	0.2452747	0.1186813
S	0.1265934	0.3956043	0.0870329	0.3402197	0.2769231
HI					
W	0.171845	0.827596	0.3366668	0.5388177	0.3971024
S	0.423583	0.628808	0.4729375	0.8699869	0.7432646

W, winter season; S, summer season; NO_3, Nitrate as N; NO_2, Nitrite; Cu, Copper; Pb, Lead; Zn, Zinc; Cr, Chromium.



Graph No.3:HI through dermal contact with contaminated water from the sampling sites during winter and summer seasons.

Table 5 reveals the estimated cancer risk from both ingestion and dermal contact with Pb and Cr contaminated water in the current study. Pb shows cancer risk for the two routes of exposure in the five sampling sites where CR> 1.0E-6. Cr shows cancer risk only for the oral exposure route, while for the dermal exposure route all CR values are < 1.0E-6. The chronic exposure to the contaminated water from the present sampling sites through ingestion or dermal contact may cause carcinogenic adverse health effects for the human population during their lifetime.

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Table 5:Cancer risk of the ingestion (CR_{ing}) and dermal contact (CR_{derm}) with Pb and Cr contaminated water from the current sampling sites (S_1 to S_5) during winter (W) and summer (S) seasons of the study period from December 2014 to August 2015

	S_1	S_2	S_3	S_4	S_5
CR_{ing}					
Pb					
W	5.2E-2	2.9E-1	1.0E-1	1.5E-1	1.4E-1
S	1.6E-1	1.1E-1	1.9E-1	2.8E-1	2.4E-1
Cr					
W	5.7E-4	1.9E-3	1.0E-3	1.9E-3	9.4E-4
S	1.0E-3	3.1E-3	6.9E-4	2.7E-3	2.2E-3
CR_{derm}					
Pb					
W	2.5E-5	1.5E-4	5.1E-5	7.4E-5	7.1E-5
S	7.6E-5	5.6E-5	9.6E-5	1.4E-4	1.2E-4
Cr					
W	7.2E-8	2.5E-7	1.3E-7	2.5E-7	1.2E-7
S	1.3E-7	4.0E-7	8.8E-8	3.5E-7	2.8E-7

CONCLUSION

The present study revealed considerable chemical contamination in the Torrent drainage channel and in the Nile River at Beni-Suef governorate due to the intensive anthropogenic activities as desert land reclamation, pesticides and fertilizers excessive application, and bad management of domestic and industrial waste water. The study also estimated the health risk assessment resulted from water ingestion and dermal contact and the carcinogenic risk was evaluated. The current findings show that human population in the area of study may experience carcinogenic and non-carcinogenic adverse health effects during their life time. The current study may help to estimate the sources of pollution in Beni-Suef governorate and how it affects the public health and ecosystem health status. The present study can be considered as a beginning for further investigation in the environmental pollution and the public health concerns at the eastern side of Beni-Suef governorate. The policy and decision makers should focus more on minimizing the sources of the Nile River pollution and control the risks that may affect nearby human populations.

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