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Trace Elements and Radioactivity Levels in Water near Assiut Thermal Power Plant, Egypt

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Abstract: A preliminary study on the trace elements (Al, Ca, Fe, Mg, Si, V and Na) and natural radioactivity has been performed to estimate the effect of water discharged from Assiut Thermal Power Plant (ATPP) to the aquatic environment. Attention has been focused in particular on trace elements for most of which no data were available in the studied area. The obtained results showed that, in general, the trace elements concentration in all samples did not exceed the WHO limits except for V, Fe and Mg, where a significant concentration was observed in some samples. It was found that the activity concentrations of natural radionuclides in some of the collected samples are lower the WHO limits, while for the rest of samples the concentrations are higher than the WHO limits by several order of magnitudes. This indicates to a remarkable effect of water discharged from ATPP to the surrounding aquatic environment.

Keywords: Radioactivity levels, trace elements, ATPP, Ground water

1. Introduction

Environmental pollution by the power plants all over the world is cited to be one of the major sources of pollution affecting the general environment in terms of land use, health hazards and air, soil and water in particular (Asokan et al., 2005). Beside major pollutants such as particulates, carbon, sulfur and nitrogen oxides, heavy fuel oil combustion generates emissions of potentially toxic trace elements (Reddy et al., 2005; Petaloti et al., 2006; Nelson et al., 2007; Guo et al., 2007) and enhanced the emission of radioisotopes to the surrounding environment.

The water has an importance in environmental studies because of its daily use for human consumption and its ability to transport pollutants. The occurrence of natural radionuclides in drinking water poses a problem of health hazard, when these radionuclides are taken to the body by ingestion (Malanca et al., 1998). Radionuclides in drinking water causes human internal exposure, caused by the decay of radionuclides taken into the body through ingestion and inhalation indirectly when they are incorporated as part of the human food chain.

Since the doses from these pathways are strongly related to the amount of radionuclides present, an important objective from the point of view of the radioecological protection of the population is the accurate evaluation of the amounts received in dietary intake (Meltem and Guersel 2010).

The measurement of radioactivity in drinking water allows the determination of population exposure to radiation by the habitual consumption of water. Measurements of natural radioactivity in drinking water have been performed in many parts of the world, mostly for assessment of the doses and risk resulting from consuming water.

Although many studies have been performed worldwide dealing with the radioactivity levels and heavy metals concentration of the deposited matter, attributive measurements of pollutants in other possible environmental pathways and releases in the surrounding areas are considerably less. As an example, ash from the boiler and ash removed by the precipitators are flushed with water to ash ponds, where elements may be leached from the ash and enter the aquatic environment in runoff (Karamanis et al., 2009). Moreover, a power plant uses enormous amounts of water for cooling purposes, which after its use, flows to nearby rivers. Therefore, water discharged from power generation may cause significant environmental impact to surrounding areas in addition to atmospheric emissions.

The water demand is supplied by surface water and underground water. Surface and underground water sources are known to contain trace elements, some of which have been widely implicated in human health and disease. A measurement of the concentrations of trace elements in deferent water supplies in Egypt is extremely important for proper assessment of the hazards associated with their intake.

According to our literature survey, no data were obtained on the quality of drinking water supplies in any city in the country. For this reason, water samples were collected from several sampling sites in

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Assiut city to measure the concentration of Al, Ca, Fe, Mg, Si, V and Na and radioactivity levels.

The aim of this study was to evaluate metals pollution and radioactivity levels in water samples near Assiut Thermal Power Plant (ATPP) to ascertain the water quality for human consumption using the EEC and WHO values and to evaluate any environmental impact in the surrounding area of the plant.

In Egypt, oil is the largest source of energy providing close to 90% of the entire power needs (Mahmoud et al. 2011). Assiut Thermal Power Plant (ATPP) consists of two units with a maximum power of 2×312 MW. The two units consume about 8.76×10^5 ton yr^{-1} of heavy oil; the combustion of this amount produces about 0.6×10^5 ton yr^{-1} of ash. However, burning oil in electric utility plants produces, in addition to power, residues that contain harmful constituents.

2. Materials and methods

2.1 Chemistry

The samples were chemically analyzed using different techniques. The determination of silica, aluminum and iron concentration was performed using the Hach DR/2000 spectrophotometer instrument in accordance with the procedure details in the DR/2000 spectrophotometer operating manual. For determining Al, Si and Fe Hach methods number 8012, 8185 and 8008 were used and the results were obtained at 522, 452 510 nm for Al, Si and Fe, respectively.

The Flame Atomic Absorption Spectroscopy (FAAS) technique was used for the analyses of Magnesium, Calcium, Sodium and Vanadium. This technique describes the determination of these elements by an acid dissolution procedure; the reagents used are HCl, HF, $HClO_4$ (70%) and Lanthanum solution, 5% (w/v) La. All standard solutions are prepared by suitable dilution of the stock standard solutions described under the standard conditions for each element. The test solutions were prepared according to the methods described in the FAAS operating manual and then analyzed by FAAS to measure the concentration of each element. The wavelengths absorbed by Magnesium, Calcium, Sodium and Vanadium are ranged from 202.6 to 285.2 nm, 239.9 to 422.7nm, 330.2 to 589 nm and from 305.6 to 438.5 nm, respectively. In both techniques, the equipment was calibrated at the beginning and end of each testing session by injecting various volumes of the standard solution by the analyst. The obtained results were presented in the paper as metal oxides.

2.2 Radioactivity

The water samples were collected in standard (1 liter) polyethylene Marinelli beakers. Before use, the containers were washed with dilute hydrochloric acid and rinsed with distilled water. Each beaker was filled up to its brim and a tight cap was pressed on to it so that air was completely removed. Samples were acidified by adding 0.5 ml of conc. HNO3 per liter to prevent any loss of radium isotopes around the container walls, and to avoid growth of micro-organisms (Navratil et al., 1997). These samples were also stored in the laboratory for a minimum of 1 month to allow daughter products to come into radioactive equilibrium with their parents ^{226}Ra and ^{232}Th before radiometric analysis. Measurements of the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq l^{-1} of the collected samples were carried out using a gamma ray spectrometric system described by (Abd El-Mageed et al., 2011).

3. Results and discussion

3.1 Radioactivity

During combustion of heavy fuel oil in ATPP, most of the radium, thorium, and their decay products are released and distributed between the gas phase (fly ashes) and solid combustion products (bottom ashes). Ash from the boiler and ash removed by the precipitators are flushed with water and then removed to the pond which is quite close to the plant, where the radionuclides and other elements may be infiltrated and entered to the aquatic environment in runoff. Moreover, a power plant uses enormous amounts of water for cooling purposes, which after its use, flows to the stream of River Nile.

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K together with their average values in water samples are given in Table 1. The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K vary from 0.28±0.18 to 11.60±5.70 Bq^{-1} with an average value of 3.76±2.10 Bq^{-1} and from 0.14±0.01 to 6.79±1.03 Bql^{-1} with a mean value of 2.65±0.38 Bql^{-1}, and from 1.66±0.13 to 65.18±4.60 Bql^{-1} with a mean value of 25.21±1.82 Bql^{-1}, respectively. It has been observed that the average activity concentrations of ^{232}Th are less than those of ^{226}Ra and ^{40}K in water samples. Table 1 shows that about 65% of samples have activity concentrations more than 1 Bql^{-1} which are much higher than the world average reported by WHO e.g. the maximum value observed in USA for ^{226}Ra was 1.85 $mBql^{-1}$ (EPA, 1999), these samples are located quite close to ATPP e.g. samples G13, G14 and G15 which have the highest activity concentrations were collected around the pond where the discharge water from ATPP was collected. The rest of samples about 35% have activity concentration in the range of the world wide average, the location of these samples are far away from the pond.

In general, it has been observed that the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K are much higher than the world average reported by WHO, these results apparently confirm the presence of actual harmful impacts of the plant on the surrounding aquatic environment.

Table 1: Activity concentrations in Bql^{-1} of ^{226}Ra, ^{232}Th, and ^{40}K in ground water samples near Assiut thermal power plant **(ND means not detectable)**

Sample code	^{226}Ra	^{232}Th	^{40}K
G1	0.50±0.33	0.77± 0.12	1.66± 0.13
G2	0.45±0.32	0.79±0.10	10.47±0.80
G3	1.94±1.05	1.74±0.19	7.56±0.62
G4	3.79±1.19	2.26±0.11	7.75±0.27
G5	1.55±0.69	0.14±0.01	4.68±0.15
G6	0.28±0.18	3.79±0.59	11.08±0.51
G7	ND	ND	ND
G8	ND	ND	ND
G9	0.60±0.32	0.23±0.042	7.39±0.53
G10	0.60±0.28	0.89±0.16	23.70±1.28
G11	ND	ND	ND
G12	4.65±1.25	2.77±0.14	9.47±0.39
G13	10.40 ± 7.51	5.72± .0.74	65.18± 4.60
G14	11.60± 5.70	5.22 ± 1.19	55.45± 4.19
G15	10.20± 5.40	6.79± 1.03	57.74 ± 4.24
G16	5.05± 4.31	3.08 ± 0.42	55.16± 4.00
G17	1.05±0.91	2.99 ± 0.52	47.17 ± 3.82
Average	3.76±2.10	2.65±0.38	25.21±1.82

3.2 chemistry

The results of dissolved trace elements concentrations in the discharge waters are presented in Table 2. Each individual metal displays a wide variation in concentration, while some of them display much higher values than the world average background concentrations or in River Nile water near APPT. However, the values are still lower than the criteria maximum concentrations and criterion continuous concentration (CCC) values of the US EPA water quality criteria.

Since trace elements occur in both organic material and inorganic ash ‘‘impurities” in heavy fuel oil, the likelihood of elemental release to the environment, and the effectiveness of ash washing as a means of mitigating this release, are controlled significantly by the mode of occurrence of an element and the size and textural relationships of the minerals that contain trace element in heavy fuel oil.

Table 2 shows that concentrations of trace elements in water varied from each other depending on the different site. V was not detected in sites G2, G4, G5, G10 and G17, these site are located far away from the pond, while Al and Ca was not detected in sites G13 and G15. The Al, Ca and Na concentrations in groundwater in all sampling sites are within the TSE-266, WHO and EC-1998 standards, which are 0.2, 200 and 200 mg/l respectively, while Mg concentrations in most sampling sites exceed the reference levels reported by TSE-266 which is 50 mg/l. The concentrations of Fe, Mg and V are much higher than the standard levels by several orders of magnitude in the sampling sites G13, G14 and G15. These three sampling site are located very close to the pond, so that one can easily detect that there is a great effect from the discharge water to the surrounding aquatic system.

The concentrations of these trace elements in River Nile water (table 2) are within the TSE-266, WHO and EC-1998 standards except for Fe which exceed the standard level by about several orders of magnitudes and this might be explained by the effect of ATPP on the River water.

Table 2 Concentrations of trace elements (ml/l) in groundwater samples around ATPP (DL: detection limit, RN: River Nile water)

Sample code	*Al*	*Ca*	*Fe*	*Mg*	*Si*	*V*	*Na (mg/l)*
G 2	0.337	1.408	0.493	17.458	192.163	≤DL	31.100
G3	0.070	4.824	0.753	101.841	345.247	0.004	45.450
G 4	0.039	4.380	4.906	41.586	279.503	≤ DL	46.850
G5	0.063	2.401	0.375	35.159	204.651	≤ DL	35.600
G6	0.093	1.787	0.434	36.951	150.072	0.010	30.600
G7	0.097	2.396	1.953	67.615	350.830	0.007	35.330
G9	0.063	3.434	2.642	95.314	214.420	0.005	35.600
G10	0.002	2.929	1.461	114.396	144.122	≤ DL	50.660
G17	≤ DL	4.086	1.883	101.503	130.239	≤ DL	31.450
G13	0.147	≤ DL	937.500	169.321	53.991	0.082	203.280
G14	0.016	0.250	1021.250	156.292	28.134	0.080	205.330
G15	≤ DL	≤ DL	1060.750	155.344	42.238	0.063	193.470
G16	0.080	3.119	0.674	101.977	71.620	0.009	99.350
RN	0.159	1.015	4.874	21.674	176.076	0.004	20.600

4. Conclusion

The determined values of radioactivity in the water samples collected from locations quite close to ATPP cannot be considered typical and comparable to that usually observed in the River Nile water, while that for water samples collected from locations far away from ATPP show a similar concentrations to that observed in the River Nile water e.g. The concentration of ^{226}Ra in the nearest locations from ATPP was at least one order of magnitude higher than in natural water bodies. Moreover, some of the values of the examined heavy metals in water samples displayed much higher values than the world average background concentrations or in River Nile water near ATPP. This contribution pathway should be taken into account in the elevated soil metals concentrations that are usually observed in areas around ATPP.

Due to the high content of radioactive elements and heavy metals concentrations in water samples near ATPP as a result of water discharged from the plant, it is advisable to reduce the use of this water as a drinking or irrigated water to avoid health risks arising from this type of water. The competent authorities must take the necessary procedures and measurements to manage the produced discharge water in order to minimize its negative effects on human beings and the environment.

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