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Use of Ionizing Radiation Technology (Co^{60}) for treating crude water

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Abstract:

Water is the essential element for forming societies, the emergence and prosperity of cities. Therefore, water treatment is one of the essential processes in daily life to obtain water safe for human health and reduce the damage from liquid waste resulting from human and industrial activities for possibility of its reuse. One of the most water quality treatment techniques is the Ionizing Radiation. Current study showed that the exposing raw water of Shatt al-Arab river to gamma rays (caused by the radioactive isotope of cobalt Co^{60}) in the intensity of the radiation (0.029, 0.087, and 0.70) mSv/y for different periods (1, 3, and 48 hrs). The result showed that treated samples for 48 hours have lower values of (turbidity, dissolved oxygen, biological oxygen demand, total suspended solids, and nitrite) as compared with control. The total number of fecal coliform bacteria decreased sharply in the treated samples for 3 hours, while the values of active nitrates increased after treatment for one hour. Also, the pH and active phosphates values were increased compared to the control treatments.

Keywords: Ionizing radiation, crude water, human health

Introduction

Conventional crude water treatment techniques include three types of treatments: physical, chemical, and biological treatments, such as sedimentation, sorption, filtration, chemical techniques, and membranes. These have high operating costs and can lead to the generation of toxic secondary pollutants in the ecosystem (Sevda *et al*.,2018).

In addition, the currently available water treatment techniques such as adsorption or coagulation involve concentrating the existing pollutants and transferring them to other stages without eliminating them or destroying those (Tegze *et al*.,2019).

In recent years, to reduce the exacerbation of the shortage of clean water and the problems caused by chlorine, work has been done to develop water treatment technologies that have low operating costs and high efficiency in the treatment of crude water and wastewater. Many countries have been researched to find alternatives. Others are used to remove pathogens or disinfectants (Song *et al*.,2016).

Therefore, the treatment processes have begun to take a new method that differs significantly from the traditional treatment, using physical treatments (Aymonier *et al*., 2002).

Raw water treatment aims to remove the floating material, degradable pollutants, and disease-causing agents to reduce risks to public health and the environment. Basic studies have shown that complete breakdown of bio-resistant compounds and water disinfection, as well as killing of microorganisms, can be achieved by ionizing radiotherapy

Radiation is the spread of energy through space or the surrounding medium. Radiation is divided into Ionizing radiation includes X-rays, high-energy radiation emitted from radioactive materials such as gamma, alpha, and beta rays, and neutrons from a nuclear explosion and non-ionizing radiation includes radio waves, microwaves, infrared, visible light, and ultraviolet radiation. Each of these rays differs in its ability to penetrate and the nature of its interactions with the material exposed to radiation.

Gamma rays (γ) consist of electromagnetic waves of nuclear origin similar to visible light, radio waves, and X-rays. This type of radiation can be produced using radioactive isotopes sources of cesium Cs^{137}, which is separated from the spent reactor fuel, or using an accelerator that generates a high-energy electron beam (EB) for producing the radioactive isotope cobalt by exposing the stable isotope coba2lt Co^{50}, which gives high energy from the energy of gamma photons.

High-energy irradiation of water using gamma rays produces an instantaneous transformation of the material. When exposed to a beam of accelerated electrons, the incident energy is transmitted to the orbital electrons of the water molecules. Then approximately 50% of the electronic energy goes to ionize the water molecules and form H_2O+. At the same time, the other 50% of the energy of beam power results in exciting water molecules. The electron goes to the formation of excited water molecules H_2O (Moran,1994).

The following diagram shows the incidental results of this type of interaction, which the following equation can represent.

$$\mathbf{H_2O\ \ Radiation} \longrightarrow e^{-}_{eq}, H, H_2, OH, \ H_2O_2$$

Materials and methods

Water Samples Collection

Crude water samples were collected from the Shatt al-Arab in 2020 and placed in graded glass cylinders with a volume of 1L for processing by other physical methods (irradiation). Standard methods were adopted in collecting, transporting, and preserving samples to conduct physical, chemical, and biological analyzes according to the standard methods of the American Public Health Organization (APHA, 2005).

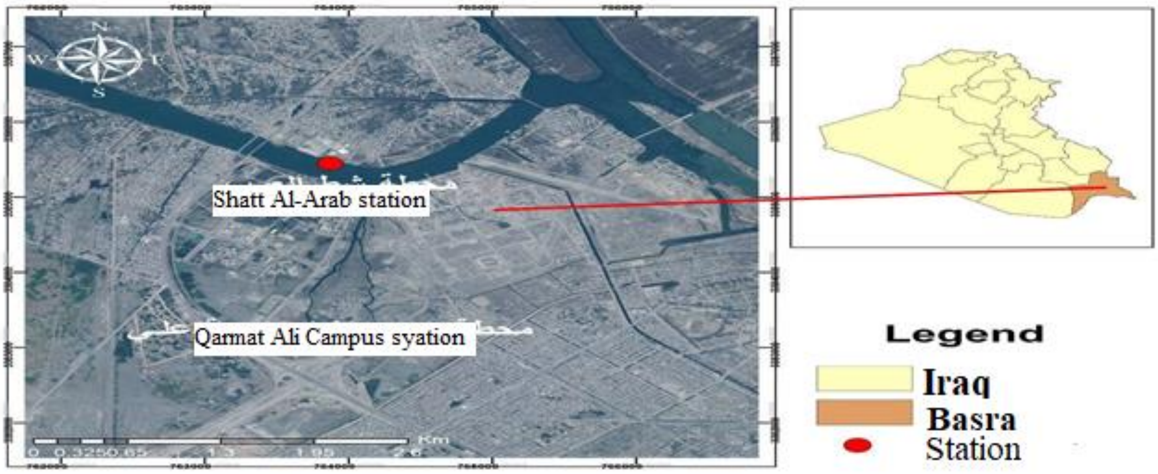

Figure 1: Sample collection map (Shatt al-Arab River)

Radiation Treatment

Conducting radioactive method experiments by placing crude water samples in graduated cylinders with a volume of 1000 ml for exposure. At the bottom of the cylinder, radioactive sources (the radioactive isotope of cobalt Co^{60}). The volume of exposed water was 500 ml to concentrate the radioactive energy for a greater impact on the water, the amount of radiation was measured using Geiger-Muller counters. Samples that were not exposed to radiation (control samples) were fixed. The experiment included measuring the background radiation of water (without a radioactive source), then exposing the sample to different times (1, 3, and 48) hours. The source was adjacent to the glass cylinder. Note that the radiation from the source can only be stopped by using lead plates with a thickness exceeding (4 - 6) mm.

Laboratory analysis

Water temperature(°C) and Electrical Conductivity were measured by Water quality multimeter. pH was measured using a pH meter, and turbidity was measured using a Turbidity meter as described in (APHA 2005). Fecal Coliform Bacteria were calculated using the membrane filter technique described in APHA (2005). Dissolved oxygen (DO) and Biochemical oxygen demand (BOD) were measured using the modified Winkler method, using the 5-day method for BOD. Total Suspended Solids (TSS) were determined by filtrating a known volume of sample by (Millipore) and evaporating at 105 ° C. and Total Dissolved Solids (TDS) were measured by evaporating a known volume of well-mixed sample at a water bath is a (100 °C) until dryness, then for one hr. at 180°C using the oven. In addition, Reactive nitrite (NO^{-}_{2}) was determined according to the colorimetric method described in (APHA 2005) using a spectrophotometer at a wavelength of (543) nm. In addition, Reactive nitrate (NO^{-}_{3}) detected Using a UV-spectrophotometer at wavelengths 220 and 275 nm (APHA, 2005) was adopted. Reactive phosphate (PO^{-3}_{4}) was determined according to the method described in (Strickland and Parsons, 1972).

Results and Discussion

The Radiation treatment values for crude water in addition to efficiency are represented in Table1. The temperature in samples treated with cobalt irradiation decreased after 1 and 3 h. At the same time, the temperature increased after treatment (48 h) compared to the control treatments. The study results showed no significant changes ($P > 0.05$) in the temperature of the water exposed to radiation with the element cobalt due to the nature of the water and short time of exposure because water except and the less short temperature slowly.

The pH value increased in samples treated with cobalt radiation after exposure for one hour and 48 hours compared to the control treatments, and these changes were significant ($P \leq 0.05$).

The pH is one of the environmental factors that influence the chemical and biological reactions and the growth of plants in the aquatic environment. In addition, values too high or too low are undesirable in the aquatic environment (Lumb *et al*., 2011; Al-Rikabi,1990). In general, the study results showed that the pH values were moving in the basal direction, and a rise was recorded in the samples treated with radiation when the dose and period of irradiation were increased. This increase resulted from an increase in hydroxyl radicals, when radioactive decomposition of water, and, consequently, increased pH value (Al-Ani and Al-Khalidy, 2006).

Table1. Radiation treatment values for crude water in addition to efficiency.

Parameters	Unit	Exposure / Crude Water				Efficiency		
		Control	Period 1 h	Period 3h	Period 48 h	Period 1 h	Period 3 h	Period 48 h
Water Temperature	**°C**	22.15	21.05	22.45	22.25	4%	____	____
pH		8.32	8.5	8.3	8.77	___	0.2%	___
Turbidity	**NTU**	9.03	7.58	2.47	1.26	16%	72%	86%
EC	**µs/Cm**	0.323	0.317	0.319	0.315	2%	1.2%	2.4%
FC	**CFU/100 ml**	2000	2000	1000	500	___	50%	75%
DO	**mg/L**	8.25	7.05	7.35	8.1	14%	10%	2%
BOD_5	**mg/L**	2.3	1.35	1.6	1.7	41%	30%	26%
TSS	**mg/L**	27.5	19	10	8	42%	64%	71%
TDS	**mg/L**	2424	2315	2405	2432	4.4%	0.3%	___
NO_2	**µgN/L**	1.73	0.89	0.64	0.83	48%	63%	52%
NO_3	**mgN/L**	1.27	1.79	1.12	1.01	___	12%	20%
PO_4	**µgP/L**	0.25	0.46	0.50	0.44	___	____	___

The turbidity values decreased in the samples treated with cobalt after 3 hours and 48 hours compared to the control treatments, and these changes were significant ($P \leq 0.05$).

The results showed a decrease in the turbidity values of the water treated with radiation, as the highest values were recorded in the control samples before exposure and the lowest in the samples treated with cobalt for 48 hours. This is because irradiation with gamma rays is an effective physical treatment and a feasible way to destroy organic compounds and reduce water turbidity, and this is in agreement with (Al-Ani and Al-Khalidy, 2006).

The electrical conductivity values decreased in the samples treated with the radioactive isotope of the element cobalt after three hours and 48 hours compared to the control treatments. These changes were not significant ($P > 0.05$).

This may be because conductivity and salinity values are correlated with the salts dissolved in water. It is known that organic salts do not conduct electricity, unlike inorganic salts. They are good materials when soluble in water because they are electrolytes. In addition, the doses of radiation do not break down and destroy inorganic materials, and thus this led to the stability of the conductivity values (Al-Ani and Al-Khalidy, 2006).

The fecal coliform bacteria in samples exposed to cobalt radiation for 48 hours significantly decreased ($P \leq 0.05$) compared to the control treatment, while no significant decrease was recorded in the samples exposed for one or three hours. This may be attributed to the dose used and the short exposure periods.

The dissolved oxygen values decreased in the samples treated with cobalt radiation after one hour, three hours and 48 hours compared to the control treatments. These changes in the dissolved oxygen values were significant ($P \leq 0.05$). The low values of the dissolved oxygen content in the treated samples may be attributed to the nature of the radiation as it affects the water molecules or by the occurrence of a neutralization reaction, so these electrons interact with oxygen in the presence of hydrogen (Anbar and Neta, 1967; Al-Shammari,2008).

The values of Biological Oxygen Demand (BOD_5) decreased in samples exposed to cobalt irradiation for periods (one, 3, and 48 hours) compared to the control treatment and these changes were significant ($P \leq 0.05$). The decrease is due to the ability of radiant energy to destroy organic compounds present in biological systems without the need for oxygen consumption, or it may be attributed to the effect of radiation in reducing the number of decomposing microorganisms.

The quantities of total suspended solids decreased significantly ($P \leq 0.05$) in samples exposed to cobalt irradiation for periods (1, 3, and 48) hours compared with the control treatments. This may be due to the breakdown and transformation of suspended organic materials by radiation. The current study results agree with (Al-Ani and Al-Khalidy, 2006).

The values of total dissolved solids in the samples treated with cobalt irradiation increased after one hour and three hours. At the same time, they decreased after 48 hours compared to the control treatment, and these changes were not significant ($P > 0.05$). The total dissolved solids concentrations showed different patterns of interaction with the absorbed doses. The rise in the solids values when increasing the irradiation period may be due to the decomposition of organic materials into simple materials, or small particles or the radioactive energy worked on the dissolution of those materials.

Nitrite values decreased in samples treated with cobalt radiation for periods (1 and 48) hours compared to the control treatment. At the same time, they increased after treatment for three hours, and these changes were significant ($P \leq 0.05$).

Nitrite is the reduced form of nitrate (Moyel,2010; Al-Hejuje, 2014; Rashid,2019). The nitrite values increased in the treated samples for 48 hours. The high nitrate values in the samples when the exposure period is increased are due to the effectiveness of radiation in destroying organic compounds and destroying bacterial cells. Containing DNA, proteins, and nitrogenous bases, nitrates are released, which are later reduced due to low oxygen concentrations (because of the irradiation process) and their transformation into nitrites.

Nitrate values increased in samples treated with cobalt irradiation after one hour, 48 hours compared with the control treatments, and these changes were significant ($P \leq 0.05$).

The study results showed that the effect of gamma rays using the cobalt source gives slight changes in the treated samples.

Effective phosphate concentrations increased in samples exposed to radiation with cobalt after (1, 3, and 48) hours compared to the control treatments, and these changes were significant ($P \leq 0.05$).

The study results showed an increase in nutrient concentrations, including phosphorous concentrations, in the case of radiation treatment with an increase in the exposure period on the analysis and destruction of organic compounds and the release of phosphorous from them.

Conclusions

The radioactive isotope of cobalt raises the pH values and lowers the values of electrical conductivity, dissolved oxygen, and BOD_5 and phosphate**.**The good efficiency of radiation treatment in reducing the number of fecal coliform bacteria and reducing the turbidityNO_2 and TSS values.Radiation treatment is a modern method that gives good and acceptable results in improving water quality.

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استخدام تقنية الإشعاع المؤين (Co^{60}) لمعالجة المياه الخام

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المستخلص:

الماء هو العنصر الأساسي في تكوين المجتمعات وظهور المدن وازدهارها. لذلك تعد معالجة المياه من العمليات الأساسية في الحياة اليومية للحصول على مياه آمنة لصحة الإنسان وتقليل الأضرار الناجمة عن المخلفات السائلة الناتجة عن الأنشطة البشرية والصناعية وإمكانية إعادة استخدامها. واحدة من أكثر تقنيات معالجة جودة المياه هي تعريض المياه للإشعاع المؤين والتي أظهرت أنه في تجارب تعريض المياه الخام (شط العرب) لأشعة جاما (الناتجة عن النظير المشع للكوبالت Co^{60}) ، شدة الإشعاع (0.029 ، 0.087 ، 0.70) ملي سيفرت / سنة) لفترات مختلفة (1 ، 3 ، 48) ساعة. أظهرت النتائج أن العينات المعرضة لمدة 48 ساعة تحتوي على قيم أقل من (العكارة ، الأكسجين المذاب ، المتطلب الحيوي للاوكسجين ، المواد الصلبة العالقة الكلية ، والنتريت) مقارنةً بعينات المقارنة. انخفض العدد الكلي لبكتريا القولون البرازية بشكل حاد في العينات المعالجة لمدة 3 ساعات ، بينما زادت قيم النترات النشطة بعد التعريض لمدة ساعة واحدة أيضًا ، وزادت قيم الأس الهيدروجيني والفوسفات النشط مقارنة بمعاملة التحكم.

الكلمات المفتاحية: الإشعاع المؤين ، الماء الخام ، صحة الإنسان