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Studying the Effects of Heavy Metals Concentrations on selected Water Treatment Plants in Babylon Governorate

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Abstract

With its high population density, Iraq faces numerous health problems due to pollution resulting from population activities affecting various components of the environment, particularly heavy metals in rivers. Unfortunately, most water treatment plants in Iraq lack a chemical treatment stage to remove heavy elements. To address this issue, the current study was conducted to measure the concentrations of toxic trace metals in drinking water, which can pose serious health risks, including cancer. The study focused on the Abi-Gharaq water project, the Al-Tayyara water plant project, and the unified Al-Hillah water project in Al-Hilla City. Experimental and analytical methods were applied to assess Samples taken from raw water before entering the projects, from sedimentation and filtration basins within the projects, and after adding chlorine for sterilization. The heavy elements studied were Aluminum, Copper, and Zinc. The study found a high concentration of copper in raw water before entering the Abi-Gharaq water project. In contrast, Aluminium in the water purification stages in the Al-Tayyara water plant project and the Abi-Gharaq water project exceeded the permissible limit of 0.20 mg/L according to the Iraqi Standard No. 417, 2001. Copper concentration also exceeded the permissible limit of 1.0 mg/L. The elevated levels of Aluminum may be related to the use of alum during the mixing basin stage of the purification process. Meanwhile, Zinc concentrations remained within the permissible limits of 3 mg/L for all stages.

Keywords: Drinking water contamination; Heavy metals; Pollution; Rivers; basins; Purification process.

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دراسة تأثيرات تراكيز المعادن الثقيلة في محطات معالجة مياه مختارة في محافظة بابل

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الخلاصة

بكثافته السكانية العالية، يواجه العراق العديد من المشاكل الصحية نتيجة التلوث الناتج عن الأنشطة السكانية التي تؤثر على مختلف مكونات البيئة وخاصة المعادن الثقيلة في الأنهار. وللأسف فإن أغلب محطات معالجة المياه في العراق تفتقر إلى مرحلة المعالجة الكيميائية لإزالة العناصر الثقيلة. ولمعالجة هذه المشكلة، أجريت الدراسة الحالية لقياس تركيزات المعادن الثقيلة السامة في مياه الشرب والتي يمكن أن تشكل مخاطر صحية خطيرة بما في ذلك السرطان. ركزت الدراسة على مشروع مياه أبي غرق ومشروع مياه الطيارة ومشروع مياه الحلة الموحد في مدينة الحلة. وتم تطبيق طرق تجريبية وتحليلية لتقييم العينات المأخوذة من المياه الخام قبل دخولها إلى المشاريع ومن أحواض الترسيب والترشيح داخل المشاريع وبعد إضافة الكلور للتعقيم. العناصر الثقيلة المدروسة هي الألمنيوم والنحاس والزنك. ووجدت الدراسة تركيزًا عاليًا للنحاس في المياه الخام قبل دخولها إلى مشروع مياه أبي غرق. بينما تجاوزت تراكيز الألمنيوم في مراحل تنقية المياه في مشروعي محطة مياه الطيارة ومشروع مياه أبي غرق الحد المسموح به وهو 0.20 ملغم/لتر حسب المواصفة القياسية العراقية رقم 417 لسنة 2001، كما تجاوزت تراكيز النحاس الحد المسموح به وهو 1.0 ملغم/لتر، وقد يكون ارتفاع تراكيز الألمنيوم مرتبطاً باستخدام الشب خلال مرحلة حوض الخلط في عملية التنقية، في حين بقيت تراكيز الزنك ضمن الحدود المسموح بها وهي 3 ملغم/لتر لجميع المراحل.

الكلمات المفتاحية: تلوث مياه الشرب، المعادن الثقيلة، التلوث، الأنهار، الاحواض، عملية التنقية.

1. Introduction

Human health is closely associated with drinking water quality, and one of the critical public health priorities is providing safe drinking water. Almost 80 % of diseases and more than one-third of diseases in third-world regions are caused by the utilization of polluted water, and it is estimated that as much as one-tenth of the productive time of each person is caused by water-related diseases (Zuthi, et al., 2009). For humans, water is a life-sustaining drink and is vitally important to the survival of organisms. Water comprises approximately 70% of the human body mass (Gyamfi, et al., 2012). Water serves as a solvent for many bodily solutes and is a crucial component of metabolic processes. Water is related to human biological processes and is very useful for the human body's growth and preservation (Gyamfi, et al., 2012). A metallic element with a relatively high density that is poisonous or toxic at low concentrations is termed a heavy metal. Heavy metals are found in the earth's crust as natural constituents, and because of their persistent nature in the environment, they cannot be degraded (Lenntech, 2004). The contamination of drinking water by heavy metals would lead to a critical threat to human health because of their toxicity, persistent nature, and bioaccumulation in the environment (Rajeshkumar, et al., 2018). Third-world countries usually face this challenge due to their restricted economic abilities to remove heavy metals using advanced technologies (WHO, 2011). The scarcity of water resources, population growth, civilization, and climate change are severe challenges to drinking water supply. By 2025, most of the world's population will live in water-stressed zones, especially low- or middle-income regions (WHO, 2013). Understanding the heavy metal concentration in water sources is crucial for assessing potential health risks, making our research particularly significant (WHO, 2013). This work aimed to determine the concentrations of some heavy metals (Al, Cu, and Zn) for the collected drinking water samples and compare the results with Iraqi standards specifications no. 417 for the year 2001.

2. Trace Metals

Heavy metals, also called trace metals, normally exist in nature and are not damaging to the environment due to their very small amounts (Sanayei, et al., 2009). However, if the concentrations of these metals exceed the recommended limits, their functions change to a negative role. Human beings might be exposed to heavy metals through direct and indirect exposure, such as drinking water, industrial activities, and vehicles (Ghaedi, et al., 2005). Most of these limited amounts of metals are essential for any living form on the planet due to their participation in numerous critical physiological processes in humans and animals. When these trace metals exceed their safe limit, this leads to an increased risk for cancer, heart issues, and many other diseases, such as endocrine, arthritis, and liver problems. Toxic levels or doses of heavy metals may cause harmful effects like bronchial asthma, pneumonia, eyesight problems, vomiting, and other health issues (Al-Mezori and Hawrami, 2013). The issue of environmental contamination due to trace metals is a global problem that requires collective action. The alarming results reported by various agencies have sparked widespread worries. The increasing growth in mining, melting, and various industrial activities has made trace metals a significant pollutant of water sources. This pollution not only affects the quality of crops, but also poses a threat to the atmosphere, water bodies, and food chains, thereby endangering the lives of animals and humans (Islam, et al., 2014). Cobalt, Copper, Iron, Manganese, Zinc, and some other trace elements in small quantities are essential for almost all life forms on Earth, including humans and animals. Also, these heavy metals are critical to Nitrogen-fixing organisms and some other Microorganisms that need these elements for metabolism and development. However, they can cause digestion failure like other trace metals when these elements' levels exceed a specific limit. When the concentration of these elements exceeds these certain levels, it could be hazardous for human well-being (Al-Mezori and Hawrami, 2013). Some trace metals like chromium in high concentrations and hexavalent forms are found to be carcinogenic, very toxic, and can cause severe contamination of water supplies. Nickel with concentrations exceeding certain levels is considered a human carcinogen in its soluble and sparingly soluble forms of compounds, which could cause harmful effects in muscles, brain, lungs, liver, and kidneys in addition to giving rise to cancer (Kwon, et al., 2023). In the aqueous system, many heavy metals, such as Copper, received great attention due to their toxic and harmful effects on life forms. A variety of inorganic and organic Arsenic compounds with varying toxicity reflect the physio-chemical properties of this trace metal with different valence (Islam, et al., 2014), (Li, et al., 2022). Heavy metals, with specific weights of more than $5g/cm^3$, form a diverse group of trace elements with varied chemical and biological functions. Some of these heavy metals, like Arsenic (AS), Cadmium (Cd), Lead (Pb), and Mercury (Hg), are cumulative poisons that persist in nature. The urgent need to address these metals, which are part of the environmental contamination group due to their toxic, harmful effects on plants, animals, humans, and food chains, should motivate us to take action (Li, et al.), (WHO, 2011).

3. Description of The Projects

Abi-Gharaq water project in Babylon governorate began operating in 2019. Its capacity is 4000 m^3/hr. The project is fed with water from the Euphrates River and serves multiple areas, including Abi-Gharaq district, its neighborhoods and regions, and some villages within the district. Al-Tayyara water plant project is located in the center of Al-Hilla City in Iraq. It started operating in 1975 and has a capacity of 1400 m^3/h. The project's intake is Al-Hilla River, a branch of the Euphrates River. The project served by Abi-Gharak and Al-Tayyara Districts Babylon Water Office in 2012. Unified Al-Hillah water project (Al-Hillah Al-Mouahad Project) is installed directly on the southern bank of Al-Hilla River near the main northern entrance of Al-Hillah City, which is 100 km south of Baghdad. The plant started operating in 1993 and supplies Al-Hilla city with a 6000 m^3/hr capacity. See figure (1). The water in this plant is treated conventionally and stored before it is pumped to consumers (Chabuk, 2009).

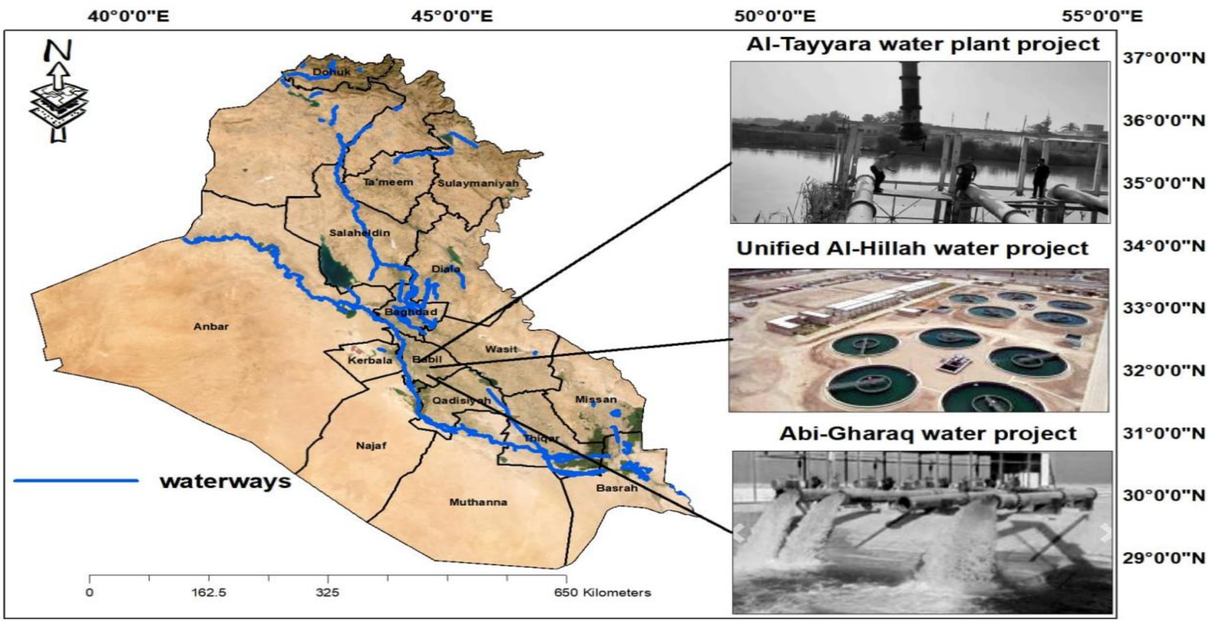

Figure (1): Location of selected water treatment plants on Al-Hilla River.

4. Samples Collection and methodology

The team took a great care during the collecting of samples, ensuring the accuracy of the laboratory results. As a precaution, The researchers added 5 ml of sulfuric acid to each sample, preventing the elements from sticking to the tubes' walls. These samples were then carefully preserved in black-colored glass containers, a measure against the influence of the sun's rays on the heavy elements. The samples were taken from the raw water before entering the project, within the project from the sedimentation basin, within the project from the filtration basin, and after adding chlorine (after sterilization). The heavy elements studied in this research are Aluminum, Copper, and Zinc. The samples were tested in the Ibn Sina laboratory in Alwazirya, Baghdad, and the Al-Kufa Office for Scientific Qualifications Services, Al-Najaf. The test were conducted using the Buck Scientific - 210VGP Atomic Absorption Spectrophotometer see figure (2).

Figure (2): Buck Scientific - 210VGP Atomic Absorption Spectrophotometer.

The samples were digested to analyze the heavy metal content for the study samples. Filtration was performed using a 0.45 µm pore filter paper, followed by the addition of a few drops of nitric acid to the filtered samples. The digested samples were then analyzed using an atomic absorption spectrophotometer to determine the concentrations of heavy metals. The parameters were analyzed according to the standard method of water testing (Ghaedi, et al., 2005). See fig (3) for the study flowchart. The data from the conducted tests are summarized in Tables 1, 2, 4, 5, 6, 7, 8 and 9.

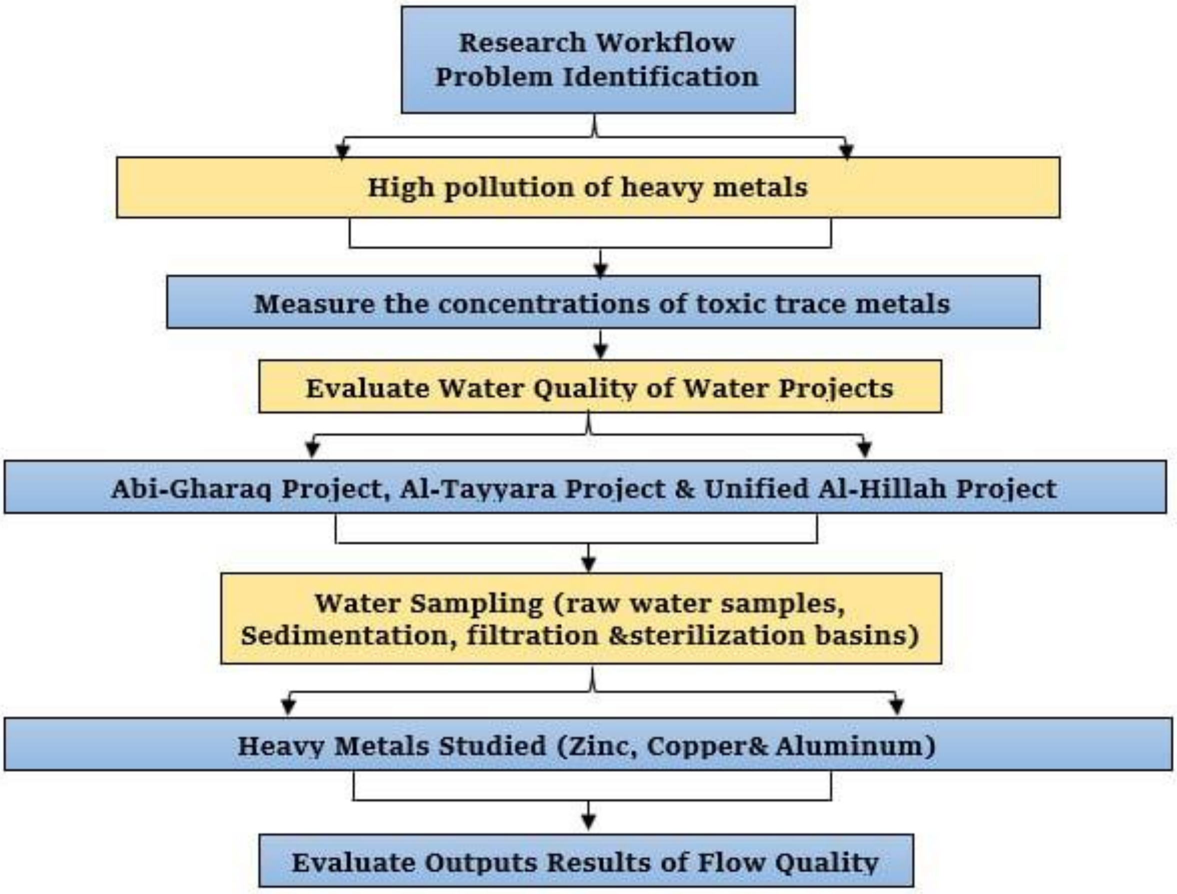

Figure (3): Flowchart of the study

Table (1): Test results for Aluminum in Abi-Gharaq water project

No.	Location	Al (mg/L)	Specification limit (mg/L)
1	before entering the project	0.1734	0.2
2	from the sedimentation basin	2.1531	0.2
3	from the filtration basin	1.2317	0.2
4	From sterilization basin	1.2107	0.2

Table (2): Test results for Aluminum in Al-Tayyara water plant project

No.	Location	Al (mg/L)	Specification limit (mg/L)
1	before entering the project	0.001	0.2
2	from the sedimentation basin	0.7	0.2
3	from the filtration basin	-	0.2
4	From sterilization basin	0.691	0.2

Table (3): Test results for Aluminum in Unified Hillah water project

No.	Location	Al (mg/L)	Specification limit (mg/L)
1	before entering the project	0.074	0.2
2	from the sedimentation basin	0.044	0.2
3	from the filtration basin	0.029	0.2
4	From sterilization basin	0.162	0.2

Table (4): Test results for Copper in Abi-Gharaq water project

No.	Location	Cu (mg/L)	Specification limit (mg/L)
1	before entering the project	2.531	1.0
2	from the sedimentation basin	0.2793	1.0
3	from the filtration basin	0.2997	1.0
4	From sterilization basin	0.1531	1.0

Table (5): Test results for Copper in Al-Tayyara water plant project

No.	Location	Cu (mg/L)	Specification limit (mg/L)
1	before entering the project	0.054	1.0
2	basin sedimentation	0.038	1.0
3	from the filtration basin	-	1.0
4	From sterilization basin	0.169	1.0

Table (6): Test results for Copper in Unified Hillah water project

No.	Location	Cu (mg/L)	Specification limit (mg/L)
1	before entering the project	0.333	1.0
2	from the sedimentation basin	0.267	1.0
3	from the filtration basin	0.152	1.0
4	From sterilization basin	0.136	1.0

Table (7): Test results for Zinc in Abi-Gharaq water project

No.	Location	Zn (mg/L)	Specification limit (mg/L)
1	before entering the project	0.308	3
2	from the sedimentation basin	0.176	3
3	from the filtration basin	0.103	3
4	From sterilization basin	0.098	3

Table (8): Test results for Zinc in Al-Tayyara water plant project

No.	Location	Zn (mg/L)	Specification limit (mg/L)
1	before entering the project	0.513	3
2	from the sedimentation basin	0.769	3
3	from the filtration basin	-	3
4	From sterilization	0.885	3

Table (9): Test results for Zinc in Unified Hillah water project

No.	Location	Zn (mg/L)	Specification limit (mg/L)
1	before entering the project	0.308	3
2	from the sedimentation basin	0.077	3
3	from the filtration basin	0.090	3
4	From sterilization basin	0.051	3

5. Results

Water treatment plants are vital in providing safe drinking water to communities. In Iraq, the Abi-Gharaq, Al-Tayyara, and Unified Hillah water plant projects are major water treatment plants catering to thousands of people's needs. In March and June, water samples were taken from these treatment plants and analyzed in the laboratory for trace metals. The results of the laboratory tests were compared to the permissible limits set by the Iraqi standard specifications No. 417 in 2001. The allowable limits for Aluminum, Copper, and Zinc are 0.20 mg/L, 1.0 mg/L, and 3 mg/L, respectively. The laboratory tests revealed that the raw water, before entering the treatment plants, had a low concentration of Aluminum. However, the addition of alum in high percentages during water purification, to address the high turbidity of the raw water, led to a significant increase in Aluminum concentration in the Al-Tayyara and Abi-Gharaq water treatment projects. This increase was a direct result of the alum's role in the purification process. Although the concentration of Aluminum decreased gradually in the subsequent stages of water treatment, it remained above the permissible limits (0.2 mg/L) when exiting the treatment plants. The aluminum concentration remained within the permissible limits both inside and outside the Unified Hillah water plant project. This may be attributed to the use of precise and well-calculated doses suitable for the water quality, as well as the efficiency of mixing process in the plant. Figures (4), (5), and (6).

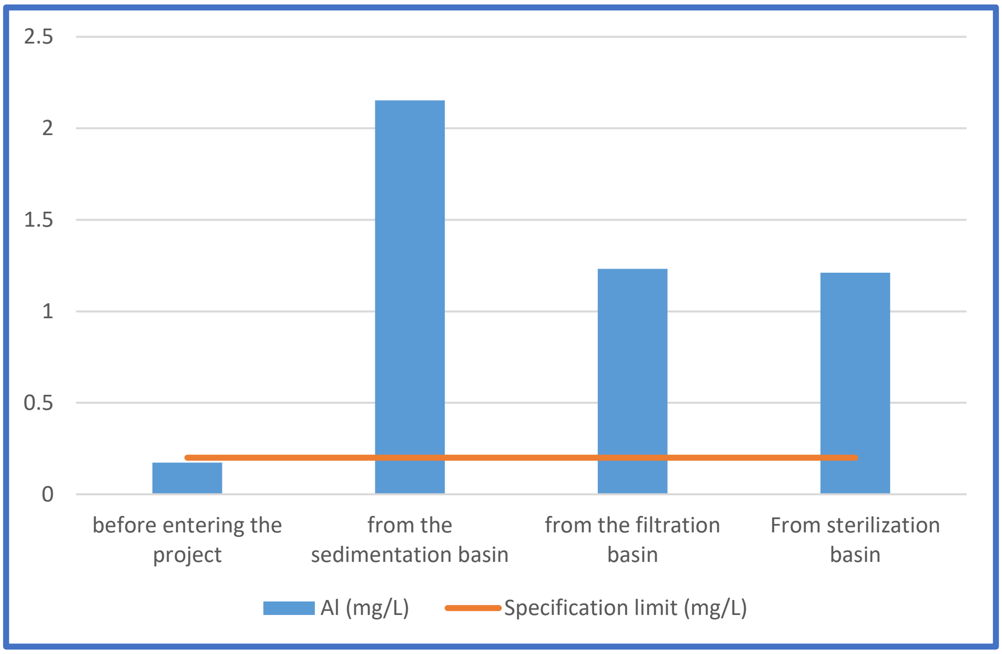

Figure (4): Aluminum concentration in Abi-Gharaq water project.

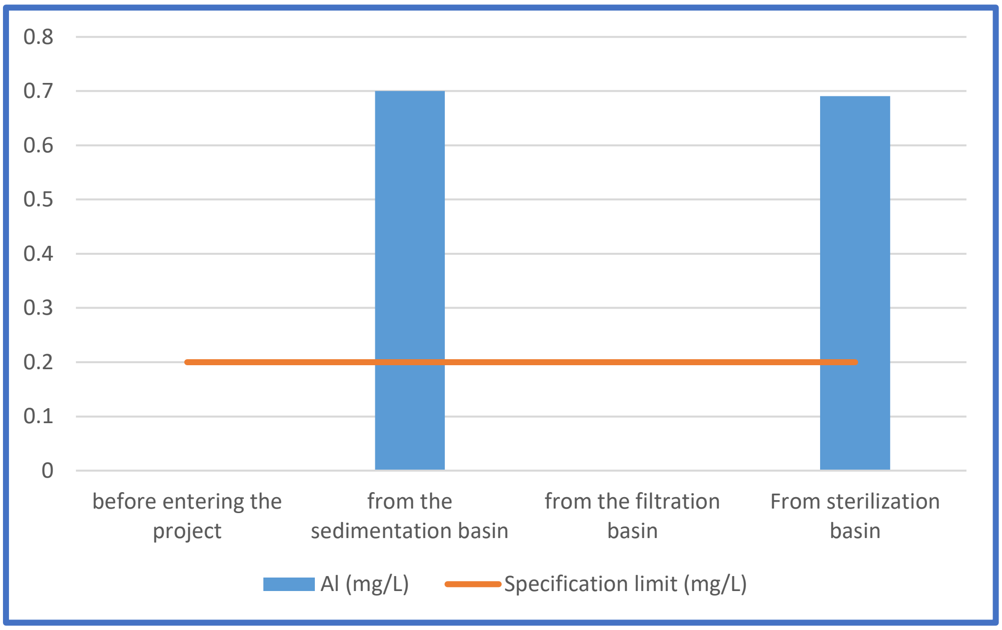

Figure (5): Aluminum concentration in Al-Tayyara water plant project

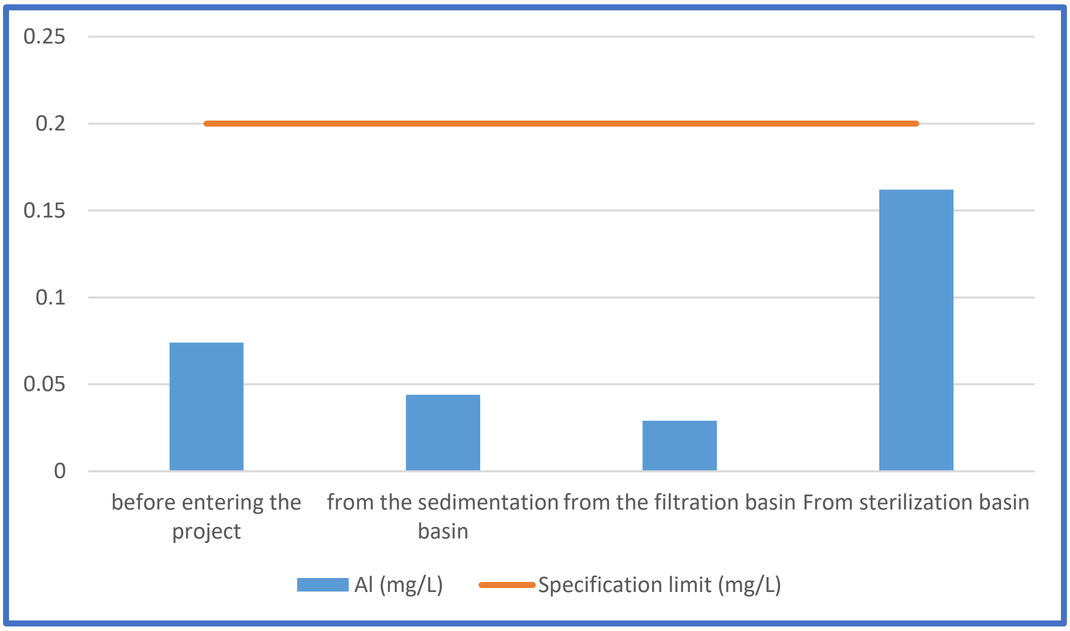

Figure (6): Aluminum concentrations in Unified Hillah water project

In the raw sample of the Abi-Gharaq water project, the concentration of Copper was found to be above the allowable limit of 1.0 mg/L, but it decreased in the subsequent stages of water treatment and remained below the permissible limits. The presence of Copper in pipes and tubes was identified as a possible cause of its transfer to the river. The concentration of Copper was also found to be lower than allowable limit in the Al-Tayyara water treatment plant, and it has remained within the permissible limit in Unified Hillah water project Figures (7), (8), and (9).

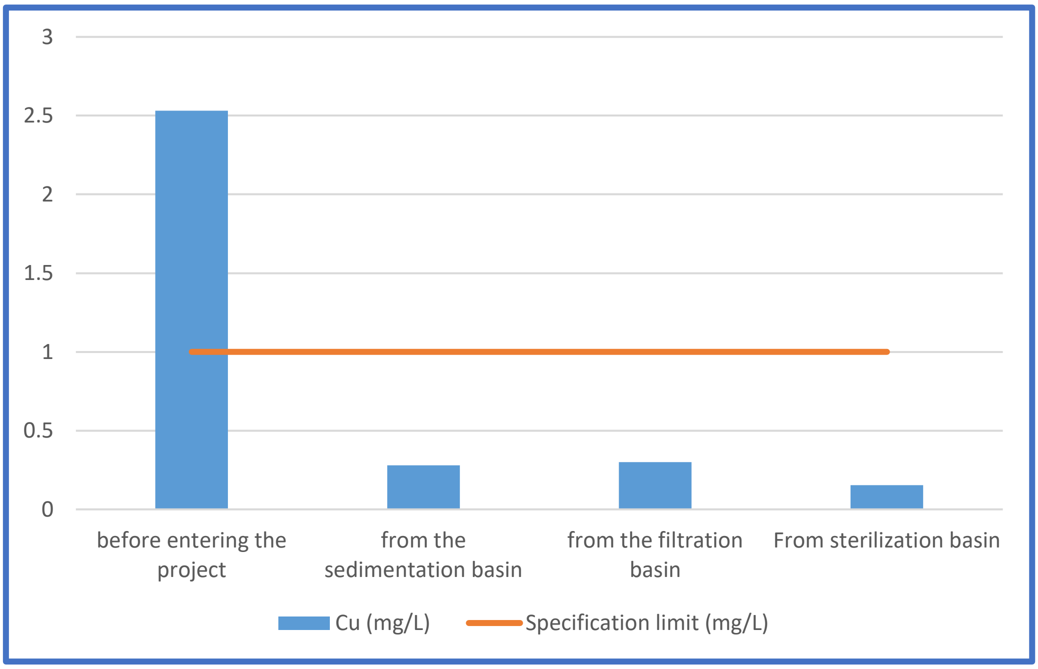

Figure (7): Copper concentrations in Abi-Gharaq water project

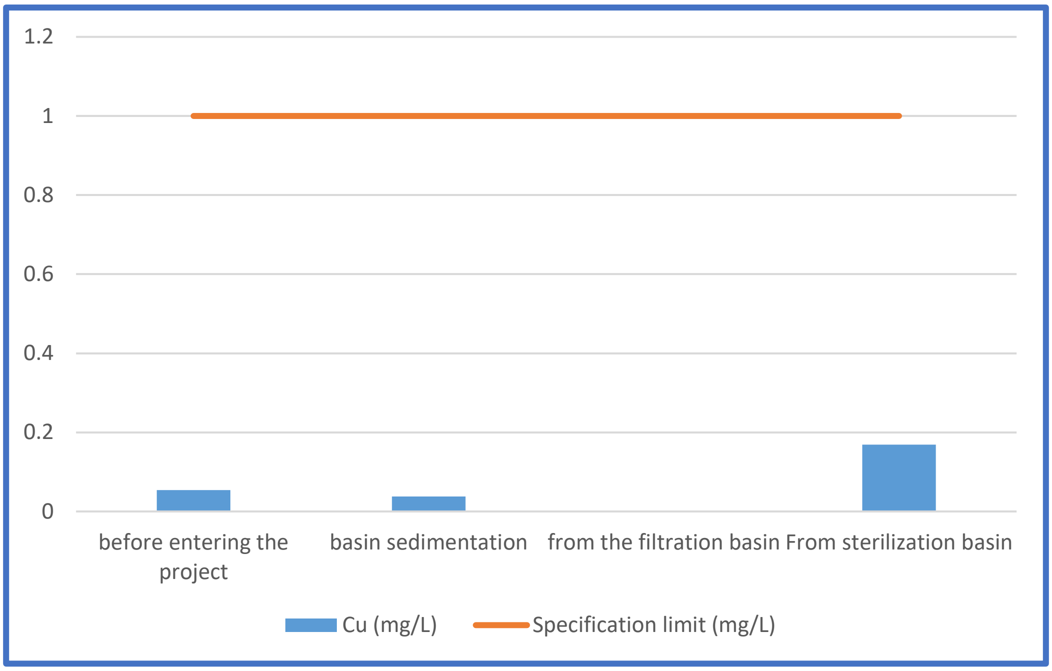

Figure (8): Copper concentrations in Al-Tayyara water plant project

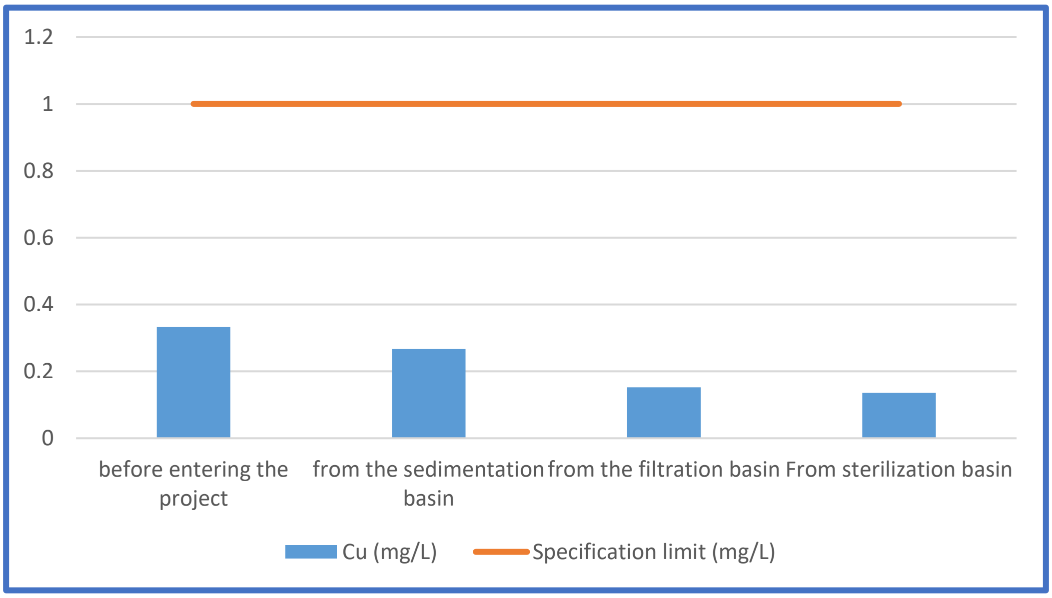

Figure (9): Copper concentration in Unified Hillah water project

The concentration of Zinc in the water samples was found to be within the permissible limits of 3 mg/L in all the water treatment plants. This indicates that the treatment process was effective in removing Zinc from the water. The concentration of Zinc was either few or nil in the water samples collected from the treatment plants and was within the limits of Iraqi standards Figures (10), (11) and (12).

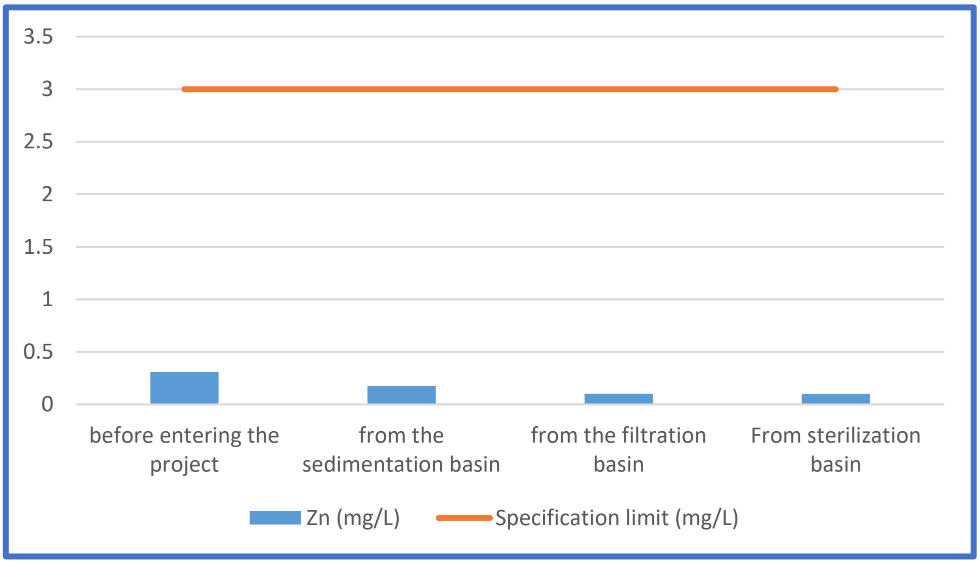

Figure (10): Zinc concentration in Abi-Gharaq water project

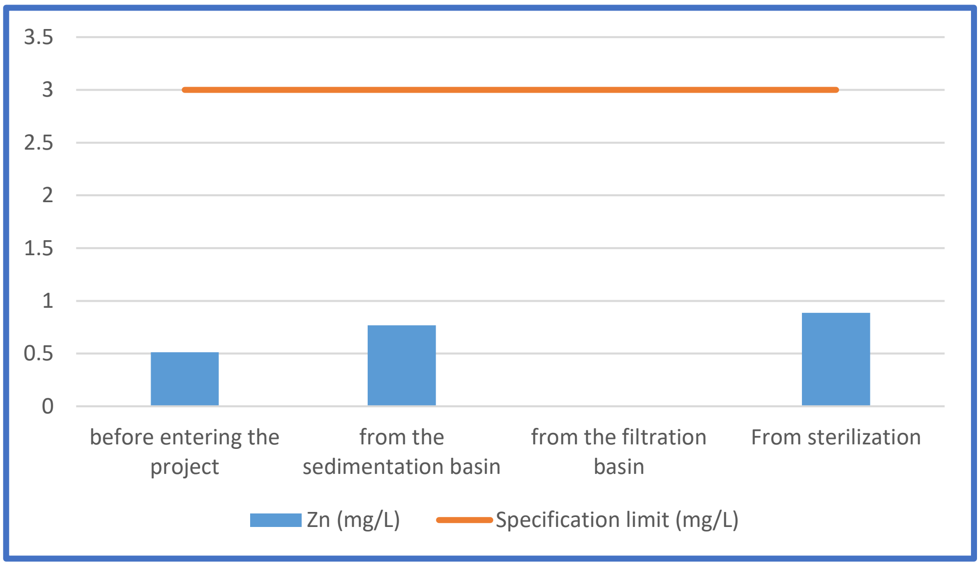

Figure (11): Zinc concentrations in Al-Tayyara water plant project

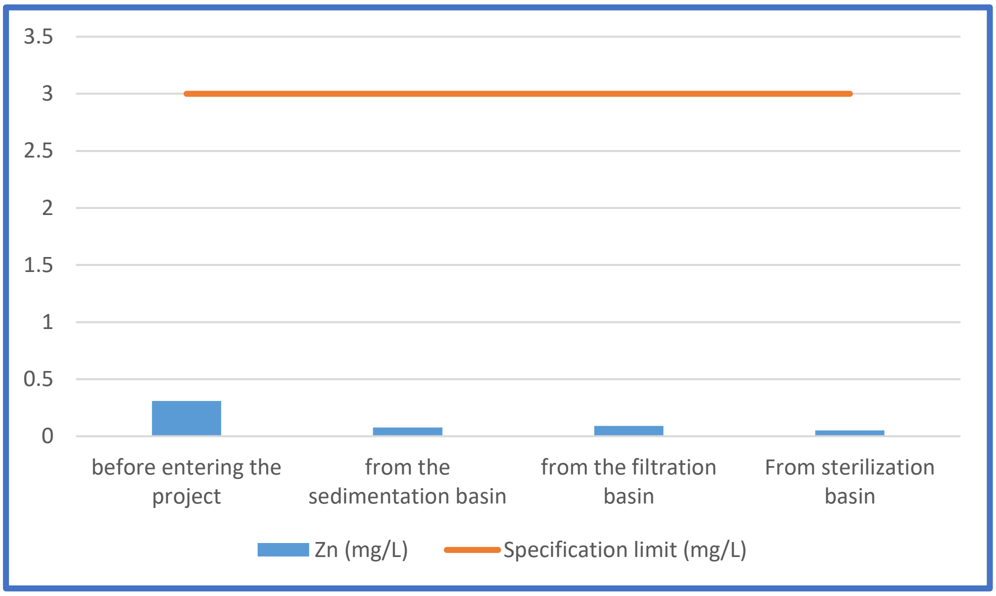

Figure (12): Zinc concentrations in Unified Hillah water project.

It is important to note that trace metals in drinking water, even in small concentrations, can adversely affect human beings. Therefore, it is crucial to continuously monitor drinking water quality and ensure that it meets the required standards. Heavy metals can be removed from drinking water treatment plants in Iraq by using natural coagulants such as "Moringa Oleifera seed and leaves" (a natural tree that is available in Al-Diwaniyah Governorate in Iraq) as an alternative to using alum, a substance very effective in removing the turbidity, heavy elements and does not have any influence on human health (Ghawi, 2017). Water treatment plants should also implement effective treatment processes to remove trace metals from the water and ensure they are safe for consumption. The results of the laboratory tests conducted on the water samples collected from the Abi-Gharaq, Al-Tayyara, and Unified Hillah water plant projects provide valuable information for the authorities to take steps to improve the quality of drinking.

6. Conclusions

The laboratory results that were obtained after measuring the heavy elements, Aluminum, Copper, and Zinc. The allowable limit for Aluminum is 0.20mg/L, 1.0mg/L for Copper and it is 3.0mg/L for Zinc concentration. The results showed that there was a high concentration of Aluminum in the purification basins in Al-Tayyara water plant project and Abi-Gharaq water project, as well as Copper in the raw water before entering the Abi-Gharaq water project more than what is allowed in the Iraqi standard specification No. 417 of 2001. This may be due to the presence of Copper in pipes and tubes, which causes its transfer to the rivers. As for Aluminum, its percentage in the river was low, but due to adding alum to the stages of water treatment (mixing basin), it increased above the permissible limits. It requires removing heavy metals like Aluminum from all water treatment plants. Concentrations of Zinc were few or nil and were within the limits of Iraqi standards. Heavy metals can be removed for drinking water treatment plants in Iraq using natural coagulants such as "Moringa Oleifera seed and leaves" as an alternative to alum. It is a substance that is very effective in removing turbidity or heavy elements and does not have any influence on human health. Water treatment plants should also implement effective treatment processes to remove trace metals from the water and ensure that it is safe for consumption.

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