Alqalam Journal of Medical and Applied Sciences. 2025;8(4):2341-2349
https://doi.org/10.54361/ajmas.258435

Original article

The detection of Heavy Metal Concentrations by Inductively Coupled Plasma (ICP) in Libyan Cocoa Samples and Associated Health Risk Assessment

Hamad Hasan[1]*, Amaal Yousuf[2], Marwa Khalifa[2], Monira Saleh[1]

[1]*Chemistry Department, Faculty of Science, Omar Al-Mukhtar University, Libya*
[2]*Higher Institute of Medical Sciences and Technology, Al-Marj, Libya*
Corresponding email. *hamad.dr@omu.edu.ly*

Abstract
Cocoa (Theobroma cacao L.) is one of the most widely consumed agricultural products worldwide, used in the production of chocolate and various beverages. Despite its nutritional and health-promoting properties, concerns have arisen due to contamination with heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), and aluminum (Al), which may pose health risks. In this study, ten cocoa samples from local markets in Derna, Libya, were analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to determine heavy metal concentrations. Results revealed elevated levels of Cd (7.06 µg/g), Cr (10.97 µg/g), and Cu (10.62 µg/g), all significantly above the permissible Maximum Residue Limits (MRLs), while Zn and Al also exceeded safety thresholds. Risk assessment showed a Target Hazard Quotient (THQ) of 1.17 for Cd, indicating potential health hazards, and a Hazard Index (HI) of 1.49, suggesting cumulative non-carcinogenic risks from chronic exposure. These findings highlight the importance of continuous monitoring and strict regulation of cocoa products to minimize public health risks associated with heavy metal contamination.
Keywords: Heavy metals, ICP-MS, Cocoa, Libya.

Introduction

Cocoa trees, are mostly grown in Asia, South America, Central America, and West Africa. Ghana, Indonesia, Nigeria, Brazil, Ecuador, Malaysia, and the Ivory Coast are the top eight cocoa-producing nations in the world. Around 8.0% of the world's 3.972 million tons of cocoa were produced in Indonesia [1]. A valuable luxury commodity, cocoa is essential to chocolate and other cocoa-based items that are eaten globally [2]. Cocoa-based products are among the most widely eaten foods in the world. Cocoa beans are used to make several popular items, including chocolate, cocoa powder, and beverages. However, there aren't enough studies on these beans' nutritional value, particularly when it comes to important components like proteins, carbohydrates, lipids, and other essential minerals.

Despite the established health advantages of cocoa, current concerns over food safety have been raised by the presence of heavy metals, including nickel (Ni), cadmium (Cd), chromium (Cr), and lead (Pb) in cocoa beans and in various cocoa products like cocoa butter, cocoa paste, cocoa powder, and chocolate. Research on the chemical makeup and characteristics of cocoa has revealed that its high quantity of polyphenolic components, especially flavonoids, which function as antioxidants, may enhance human health when consumed in moderation. These substances are important for supporting general health. According to certain studies, cocoa has a higher antioxidant capacity than red wine and green tea [3]. One of cocoa's health advantages is its capacity to scavenge free radicals [4-6].

The amounts of cadmium, nickel, and lead were found to vary from 0.001 to 2.730 grams/kg, 0.041 to 8.290 grams/kg, and 0.049 to 8.040 grams/kg, respectively. 42 out of 69 samples had lead levels over the allowable limit of 0.30 grams/kg, according to the Polish national standard for lead established by the Polish regulatory body. Nineteen samples had levels of cadmium above the allowable limit of 0.05grams/kg. A class of metallic and non-metallic elements having an atomic density higher than 4 g/cm³ is usually referred to as "heavy metals". Arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), mercury (Hg), nickel (Ni), and vanadium (V) are among these metals, which are hazardous and non-essential elements. On the other hand, some heavy metals, like copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn), are necessary for life [7]. When exposed to heavy metals in large quantities or over extended periods of time, they can harm humans, animals, and plants. Their pervasive discharge from residential, industrial, agricultural, chemical, and technical sources, which pollutes the air, water, and land, makes them even more dangerous. Although human activities frequently speed up the release and transit rates of certain metals, increasing their concentrations in nature, natural occurrences like volcanic eruptions and ocean movements also help recycle these metals in the environment [8].

Water, food, and the air are some of the ways that heavy metals can enter the human body. Even while some heavy metals are essential to the operation of living things, there is a serious risk when they are present in amounts above what is considered safe. These metals can pass through the placenta and build up in the growing baby's tissues. Furthermore, because heavy metals have a lengthy biological half-life, they might build up in different human organs and result in harmful side effects [9,10].

Induction-coupled plasma mass spectrometry (ICP-MS). It is a useful analytical technique for figuring out

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

https://doi.org/10.54361/ajmas.258435

the multiforming (qualitative) elements, their concentration (quantitative), and the abundance of isotopes of different matrices. One method for very sensitive metal and multielement metal analysis is induction-coupled plasma mass spectrometry (ICP-MS). It may be used for many different activities, such as environmental research, health care product analysis, the food and chemical industries, and, of course, clinical biology [11].

In Libya, the study of the contents of heavy metals was carried out in different samples [12-41], the evaluation of the effect of some hazardous compounds was estimated in many samples, Hydrocarbons [42-50], pesticides [51-52], plants [53-84], and others [86-95]. This study aims to measure the concentration of heavy metals in imported cocoa samples collected from some Libyan markets by using inductively coupled plasma [ICP].

Methods

Sampling

In this study, ten different commercial cocoa samples were collected from local markets in Derna city Libya, (2024). The samples were analyzed for the determination of heavy metals by Ionic Coupling Plasma (ICP) for metals: zinc, chromium, Iron, copper, cobalt, and magnesium. The types of samples were given in (Table 1):

Table 1: The studied cocoa samples

Sample. No	Name sample
1	Nesquik
2	Said
3	Ovaltine
4	Darlet
5	Corona
6	ALwdaq
7	CaCao Drink
8	Katsan Ovalite Cocoa powder
9	Raw cocoa
10	Dutch cocoa

Digestion of samples

For the determination of selected metals, about(0.5 g) powder sample was weighed and transferred into a (100 ML) beaker then dissolving it in (20 ml) of distilled water in a Beaker, then adding(5 ml)of concentrated nitric acid, heating and continuing to heat until the sample is almost dry, then leaving the solution to cool, then we filter the solution and take the leachate and add distilled water to a volume of (100 ml) then lifted aside to lose the heat, Leave the solution to cool [14-16]. Finally, stored in a polyethylene bottle for measuring metals. Measured by Inductively coupled plasma mass spectrometry (ICP-MS) at Cairo University, Egypt.

Risk assessment

The EDI of cocoa was computed by dividing the consumption rate by an average body weight of 60 kg to assess the possible health concerns for users. The acceptable daily intake (ADI) of cocoa was then compared to the EDI to calculate a risk index. The target hazard quotient (THQ), a technique created by the US Environmental Protection Agency, was used to evaluate the possible health concerns associated with prolonged exposure to chemical contaminants and was used to calculate the risk. Taking body weight, frequency, length of exposure, and amount consumed into consideration, the THQ compares the observed concentration to the oral reference dosage. A possible health concern is indicated by a THQ greater than 1.

$$THQ = ([\ EFr * ED\ tot * IFR * C]\ )\ /\ ([RfD0 * BWa * ATn]) * 10^{-3}$$

Where:

EF_r: the exposure frequency (365 days/year); ED_{tot}: exposure duration (80 years for both Italian and Pakistani populations, based on survey results from ISTAT 2013). FIR: is the food ingestion rate (g day-1); C: is the concentration (µg g-1); RfD_o: is the oral reference dose (µg g-1 day-1). BWa: is the adult body weight (60 kg). ATn: is the average time for non-carcinogens (it is equal to EFr × EDtot). The HRI assesses the potential danger associated with pesticide and metal residues detected in cocoa samples.

Results

Heavy metal contents

In this study some heavy metals were detected in cocoa samples by I.C.P.M.S The metals includes: Fe, Zn, Mn, Al, Cu, Ag, Pb, Cd, Cr and Sr on the other side these metals of Co, Ni, As, Ca and Sb were not detected in the studied samples, the contents were given in the Tables (2&3) and Figures (1&2). The contents of detected metals were fluctuated in the ranges of (0.34-12.31), (0.15-7.25), (ND-70.55), (ND-0.54), (0.11-1.04), (1.34-56.15), (0.14-3.39), (0.01-0.16), (0.12-1.19), (0.58-4.87 µg/g) For Ag, Al, Cd, Cr, Cu, Fe, Mn, Pb, Sr and Zn, respectively. Comparison of the arithmetic mean and standard deviation values of the metals in

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

the studied cocoa samples with the minimum contaminant limits (MRLs) as determined by the Agency for Toxic Substances and Disease Registry and the minimum risk levels (MRLs). High concentrations of cadmium, chromium, and copper were obtained, followed by zinc and aluminum, except for strontium, which had a low concentration, compared to the minimum contaminant limits. The results of this study for the studied samples recorded contamination and toxicity. The values of the metal's cadmium, chromium, copper, zinc, and aluminum were (21.16±7.06), (10.87±10.97), (10.62±10.09), (1.25±1.88), and (2.05±1.24) µg/g for the metals, respectively, higher than the minimum contaminant limits. Tables (2 -4) show the contents of heavy metals in the studied cocoa samples:

Table 2. The contents of (Al, Fe, Mn, and Zn) in the studied cocoa samples.

Solution Label	Al 396.152 nm	Fe 238.204 nm	Mn 257.610 nm	Zn 213.857 nm
Sample 1	0.67	3.12	0.45	1.17
Sample 2	0.4	2.03	0.48	1.27
Sample 3	0.47	5.3	1.01	4.87
Sample 4	0.15	2.58	0.6	0.98
Sample 5	0.34	1.89	0.37	1.07
Sample 6	0.39	1.99	0.27	1.03
Sample 7	0.32	1.34	0.14	0.58
Sample 8	0.52	11.11	1.69	2.22
Sample 9	1.97	7.69	1.41	2.53
Sample 10	7.25	56.15	3.39	3.16
±SD	2.058	15.88	0.93	1.259
Average	1.248	9.32	0.981	1.888

Table 3: The contents of (Cu, Sr, and Ag) in the studied cocoa samples.

Solution Label	Cu	Sr	Ag
Sample 1	0. 51	0.23	3.96
Sample 2	0.53	0.21	12.31
Sample 3	0.37	0.69	2
Sample 4	0.41	0.23	0.82
Sample 5	0.29	0.24	0.62
Sample 6	0.31	0.18	0.81
Sample 7	0.11	0.12	0.56
Sample 8	1.04	0.61	0.94
Sample 9	0.8	1.03	0.38
Sample 10	0.94	1.19	0. 34
±SD	10.09	0.365	3.50
Average	10.62	0.473	2.274

Table 4. The contents of (Cr, Cd, and Pb) in the studied cocoa samples

Solution Label	Cr	Cd	Pb
Sample 1	0.05	0.01	0.1
Sample 2	0.03	0.02	0.11
Sample 3	0.05	70.55	0.13
Sample 4	0.06	0.01	0.12
Sample 5	0.03	0.01	0.13
Sample 6	0.02	0.01	0.14
Sample 7	0.03	0.01	0.01
Sample 8	0.13	0.01	0.12
Sample 9	0.03	0.01	0.11
Sample 10	0. 54	0.03	0.16
±SD	10.87	21.16	0.037
Average	10.97	7.067	0.113

Comparison of the detected metal values with the Minimum Residual Limit (MRL) shown in (Table 5):

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

Table 5. Compared to the detected heavy metals with Minimum Residual Limit values.

Metal	Al	Cd	Cr	Cu	Pb	Sr	Zn
Concentration	1.24±2.05	7.06±21.16	10.97±10.87	10.09±10.62	0.11±0.03	0.47±0.36	1.88±1.25
MRLs	1	0.0005	0.0009	0.02	-	2	0.3

The results showed that all of the samples had high amounts of iron, while the other metals varied from sample to sample. The findings also revealed variations in the percentage distribution of the minerals under investigation. Iron (Fe) and manganese (Mn) are the primary minerals found in the cocoa samples, but there are also comparatively large concentrations of zinc and silver. The cocoa samples 1, 4, 5, 6, 6, 7, 8, 9, and 10 had the greatest percentage of aluminum values (32, 43, 38, 39, 42, 60, 48, and 78%) out of all the heavy metals found in the samples used in this investigation. Higher percentages of silver (41 and 71%) were found in samples 1 and 2. However, with values of 83%, Sample (3) had the highest cadmium proportion found. Other metals, including strontium, copper, lead, chromium, and cadmium, were also detected in trace amounts. The cocoa samples under investigation also showed a relative rise in manganese, zinc, silver, and aluminum levels.

Health Risk Assessments

The health risks associated with consuming chemical pollutants (heavy metals) were evaluated using the Target Hazard Quotient (THQ) and the Hazard Index (HI) to ascertain the health hazards of heavy metals in cocoa samples. Regulatory agencies like the US Environmental Protection Agency (EPA) employ these fundamental ideas in risk assessment to explain the dangers of chemicals.

Target Hazard Quotient (THQ)

The connection between the oral reference dosage and the observed concentration is represented by the target hazard ratio, which is weighted by body weight, amount ingested, and frequency and duration of exposure to the chemical. Potential health risks are indicated by a THQ value of 1 or above, but no health risks are indicated by a value less than 1. The THQ findings for this investigation are displayed in (Table 6).

Table 6. The results of the Target Hazard Quotient (THQ).

Metal	THQ
Al	0.0002
Cd	1.17
Cr	0.203
Cu	0.044
Fe	0.002
Mn	0.001
Ag	0.075
Zn	0.001
Sr	0.0001

There is a chance of negative health impacts since the target hazard quotient (THQ) value for cadmium (1.17), which is greater than the acceptable limit for the target hazard quotient (1), is higher. There were no negative health impacts because the remaining values were within the safe limit of 1.

Hazard Index (HI)

The hazard index for each food type is the sum of the values of all the target hazard components. Chronic exposure to a group of toxic components from consuming a particular food type may lead to cumulative adverse health effects even if the hazard index is less than 1. However, if the target hazard ratio is greater than 1(HI ≤1), it may lead to adverse health effects, but not carcinogenic ones. The hazard index equation for the target

is: HI=THQ1+THQ2+THQ3

In this study, the hazard index showed that the value of (1.49) was higher than the safe limit of one, meaning there is a potential non-carcinogenic health risk.

Discussion

In many nations, cocoa is a staple crop. It is utilized in the production of chocolate and several other culinary items, and it makes a substantial contribution to the world economy. Chocolate is a very nutrient-dense and high-energy dietary item, apart from the bioactive substances. Consuming cocoa in moderation can lower the incidence of cardiovascular disease and several risk factors. Despite all its advantages, eating a lot of cocoa might be bad for your health since it naturally includes a number of heavy metals [96]. Concerns over these metals' prevalence in a variety of food goods, including chocolate, have grown in recent years.

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

Both human and natural activity determine its source and amounts [3]. Because cocoa and its derivatives are consumed in large quantities, it is crucial to keep an eye on and assess the amounts of these toxins in different cocoa brands to guarantee their safety. Because of the World Health Organization's emphasis on the significance of studying medicinal plants, such as cocoa, food levels of heavy metals are often tracked to guarantee consumer safety. This study sought to evaluate and measure the levels of certain heavy metals in a range of meticulously and randomly chosen cocoa samples to address this requirement and investigate heavy metal contamination. Both branded and locally sourced cocoa goods were included in the tastings. By examining these samples.

To guarantee the safety and quality of this beverage, our study aimed to offer insightful information on possible exposure to heavy metals through cocoa intake. The amounts of heavy metal buildup in the examined cocoa samples varied, and these quantities exceeded the Agency for Toxic Substances and Disease Registry's allowable limits. It was found that, except for strontium and aluminum, the amounts of cadmium, chromium, copper, and zinc were all over the allowable limits. [4&5] This outcome suggests that pollutants and poisons are present. Cadmium is categorized as a carcinogenic chemical in humans by the International Agency for Research on Cancer (IARC).

This conclusion was supported by research [8], which found that the cocoa and chocolate samples from various parts of India had significant levels of lead and cadmium. These findings were different from those of the research, which examined six different kinds of heavy metals in Ghanaian cocoa beans. While the amounts of vital elements like iron and zinc were high, the findings revealed low levels of lead and cadmium. Heavy metal levels in cocoa products were evaluated by some studies [7&8], and the findings showed significant quantities that were over the permissible limits. The amounts of several heavy metals in cocoa products were compared to the exposure limits allowed by international health agencies, and revealed that all sample results fell below the acceptable range. Some of the samples under study had acceptable levels of lead and cadmium.

According to research, the quantities of harmful metals were over the allowable limit, with lead and cadmium having the highest levels and chromium having the lowest. Lead, cadmium, and nickel are just a few of the dangerous substances that can contaminate raw cocoa resources and products. [96] The conditions under which the cocoa trees are cultivated or the conditions under which the cocoa beans undergo different procedures like fermentation, drying, and grinding might be the cause of this. The metal tools used for mixing, grinding, and storing materials may potentially be the source of contamination. The cocoa plant's geographic origin and the production environment also affect the amounts of these components. According to certain research, these outcomes have been shown (Nickel and McMillan). Cadmium is taken up by cocoa trees from the soil, and as the tree grows, it builds up in the cocoa beans. Toxic amounts of pollution are quickly attained.

According to previous studies [1], cocoa goods stated to originate from Latin America had greater cadmium content than those coming from Africa, confirming that regional diversity affects cadmium levels. Samples were taken from eight cocoa-producing farms on the cadmium content of cocoa plants and soil properties in the city of Almirante, Bocas del Toro province. In addition to samples of cocoa tree leaves and fruits, soil samples were collected at a depth of 30 cm. The findings indicated that the soil's pH was 5.1, which is acidic, and that its organic matter content was over 3%, both of which are appropriate for the soil's ability to fix cadmium. The mean levels of bioavailable and total cadmium were 0.02 and 0.10 mg/kg, respectively [10]. Cocoa leaves had cadmium concentrations above the suggested threshold of 0.5 mg/kg. Cocoa beans have a low quantity of cadmium (0.25 mg/kg). The Hazard Index (HI) and the Target Hazard Quotient (THQ) were also used to calculate health hazards. Apart from cadmium, which had a value of 1.17, over the safe level, suggesting the presence of toxins in the examined samples, the Target Hazard Quotient readings were within the safe range. The Hazard Index score of 1.49 exceeded the internationally advised safe threshold. Suggesting that ingesting these goods in large quantities may pose a health risk. These findings align with the research conducted by some studies [9], which demonstrated that consistent cocoa eating, Chocolate that has been contaminated, can have major negative health impacts, such as an elevated risk of cancer and renal disease. It is advised to use aqueous extracts sparingly to get vital nutrients and safeguard consumers. To guarantee that daily consumption restrictions are not exceeded and to safeguard the public's health from potential hazards related to heavy metals, it is crucial to monitor and examine cocoa samples from Libya and other areas.

Different cocoa brands and geographical areas have been found to contain varying levels of heavy metals, underscoring the necessity of routine testing and food product quality management [1-3]. Differences in the fundamental physical and chemical properties of various agricultural regions can account for the notable diversity in metal levels throughout these locations. Soil type, water quality, mineral content, climate, pesticides, and the processes utilized to change the product into its consumable form are a few examples of these variables. The accumulation of metal in plant components is significantly influenced by each of these factors [5]. Thus, the levels of metals in different chocolate brands were significantly influenced by their place of origin. It is crucial to remember that the water solubility of various metals varies. Previous studies have reported similar variations in metal levels across different chocolate brands [7-9]. To ensure the safety of food products and consumers, further research and quality control in this area are suggested.

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

Conclusion

The analysis using ICP-MS revealed elevated concentrations of metals in cocoa samples collected from Derna, Libya. Metals exceeding the Maximum Residue Limits (MRLs) include: Cadmium (Cd): Average concentration of 7.06 µg/g, far above the permissible limit of 0.0005 µg/g. Chromium (Cr): 10.97 µg/g vs. the limit of 0.0009 µg/g. Copper (Cu): 10.62 µg/g, exceeding the limit of 0.02 µg/g. Zinc (Zn) and Aluminum (Al) also surpassed safe thresholds. The Target Hazard Quotient (THQ) for cadmium was 1.17, indicating potential health risks. The Hazard Index (HI) for all metals combined was 1.49, suggesting chronic exposure could be harmful.

Acknowledgment

The authors highly appreciated the collaboration of the staff members of the Central Laboratory of Chemical Analysis, Faculty of Science, Omar Al-Mukhtar University.

Conflict

The authors provided that no conflict of the results given in this study with those reported in any other study.

References

1. Assa A, Noor A, Yunus MR, Misnawi A, Djide MN. Heavy metal concentrations in cocoa beans (Theobroma cacao L.) originating from East Luwu, South Sulawesi, Indonesia. J Phys Conf Ser. 2018;979:012011. doi:10.1088/1742-6596/979/1/012011.
2. Godebo TR, Stoner H, Kodsup P, Bases B, Marzoni S, Weil J, et al. Occurrence of heavy metals coupled with elevated levels of essential elements in chocolates: Health risk assessment. Food Res Int. 2024;187:114360. doi:10.1016/j.foodres.2024.114360.
3. Arlorio M, Bottini C, Travaglia F, Locatelli M, Bordiga M, Coïsson JD, et al. Protective activity of Theobroma cacao L. phenolic extract on AML12 and MLP29 liver cells by preventing apoptosis and inducing autophagy. J Agric Food Chem. 2009;57(22):10612-8. doi:10.1021/jf902419t.
4. Bertoldi D, Barbero A, Camin F, Caligiani A, Larcher R. Multielemental fingerprinting and geographic traceability of Theobroma cacao beans and cocoa products. Food Control. 2016;65:46-53. doi:10.1016/j.foodcont.2016.01.013.
5. Keen CL, Holt RP, Oteiza PI, Fraga CG, Schmitz HH. Cocoa antioxidants and cardiovascular health. Am J Clin Nutr. 2005;81(1):298S-303S. doi:10.1093/ajcn/81.1.298S.
6. Selmi C, Cocchi CA, Lanfredini M, Keen CL, Gershwin ME. Chocolate at heart: The anti-inflammatory impact of cocoa flavanols. Mol Nutr Food Res. 2008;52(11):1340-8. doi:10.1002/mnfr.200700435.
7. Latif U, Younus I. Gamma Ray Spectroscopy. Department of Physics Lahore University of Management Sciences; 2014.
8. Dahiya S, Karpe R, Hegde AG, Sharma RM. Lead, cadmium and nickel in chocolates and candies from suburban areas of Mumbai, India. J Food Compos Anal. 2005;18(6):517-22. doi:10.1016/j.jfca.2004.05.002.
9. Hawkes SJ. What Is a 'Heavy Metal'? J Chem Educ. 1997;74(11):1374. doi:10.1021/ed074p1374.
10. Mazarakioti EC, Zotos A, Thomatou AA, Kontogeorgos A, Patakas A, Ladavos A. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), a Useful Tool in Authenticity of Agricultural Products' and Foods' Origin. Foods. 2022;11(22):3705. doi:10.3390/foods11223705.
11. Cavey T, Ropert M, Loréal O, Bendavid C, Peoc'h K. Metals: Common clinical applications in inductively coupled plasma mass spectrometry. Ann Biol Clin (Paris). 2019;77(5):495-504. doi:10.1684/abc.2019.1480.
12. Hasan JA, Hasan HMA. Potential human health risks assessment through determination of heavy metals contents in regularly consumed yogurta in Libya. World J Pharm Pharm Sci. 2024;13(12):100-12.
13. Mamdouh SM, Wagdi ME, Ahmed MA, Alaa EA, Essam AM, Hamad MIH. Rice husk and activated carbon for waste water treatment of El-Mex Bay, Alexandria Coast, Egypt. Arab J Chem. 2016;9 Suppl 2:S1590-S1596. doi:10.1016/j.arabjc.2016.01.007.
14. Mamdouh SM, Wagdi ME, Ahmed MA, Alaa EA, Hamad IH. Heavy metals accumulation in sediments of Alexandria coastal areas. Bull Fac Sci. 2012;47(1-2):12-28.
15. Mamdouh SM, Wagdi ME, Ahmed MA, Hamad MIH. Chemical studies on Alexandria coast sediment. Egypt Sci Mag. 2005;2(4):93-102.
16. Mamdouh SM, Wagdi ME, Ahmed MA, Alaa EA, Hamad MIH. Distribution of different metals in coastal waters of Alexandria, Egypt. Egypt Sci Mag. 2010;7(1):1-19.
17. Mohamed AE, Afnan SA, Hamad MA, Mohammed AA, Mamdouh SM, Alaa RE, et al. Usage of natural wastes from animal and plant origins as adsorbents for the removal of some toxic industrial dyes and heavy metals in aqueous media. J Water Process Eng. 2023;55:104192. doi:10.1016/j.jwpe.2023.104192.
18. Mohamed HB, Mohammed AZ, Ahmed MD, Hamad MAH, Doaa AE. Soil heavy metal pollution and the associated toxicity risk assessment in Ajdabiya and Zueitina, Libya. Sci J Damietta Fac Sci. 2024;14(1):16-27.
19. Nabil B, Hamad H, Ahmed E. Determination of Cu, Co and Pb in selected frozen fish tissues collected from Benghazi markets in Libya. Chem Methodol. 2018;2:56-63.
20. Wesam FAM, Hamad MAH. Detection of heavy metals and radioactivity in some bones of frozen chicken samples collected from Libyan markets. Int J Adv Multidiscip Res Stud. 2023;3(3):761-4.
21. Wesam FAM, Hamad MAH. Study the accumulation of minerals and heavy metals in Ulva algae, Cladophora, Polysiphonia and Laurencia algae samples at eastern north region of Libya coast. GSC Biol Pharm Sci. 2023;23(03):147-52.

Received*: 13-08-2025 -* ***Accepted****: 12-10-2025 -* ***Published****: 20-10-2025* https://doi.org/10.54361/ajmas.258435

22. Citrine E, Hamad H, Hajer Af. Contents of metal oxides in marine sediment and rock samples from the eastern Libyan coast, utilizing the X-ray method. AlQalam J Med Appl Sci. 2015;1(1):1316-21.
23. Hanan MA, Hamida E, Hamad MAH. Nitrogen, phosphorus and minerals (Sodium, Potassium and Calcium) contents of some algae's species (Anabaena and Spirulina platensis). Int J Curr Microbiol App Sci. 2016;5(11):836-41.
24. Mardhiyah F, Hamad H. Assessment of soil contamination by heavy metals in the Al-Fatayeh Region, Derna, Libya. AlQalam J Med Appl Sci. 2025;8(3):1081-91.
25. Abdelrazeg A, Khalifa A, Mohammed H, Miftah H, Hamad H. Using melon and watermelon peels for the removal of some heavy metals from aqueous solutions. AlQalam J Med Appl Sci. 2025;8(3):787-96.
26. Abdul Razaq A, Hamad H. Estimate the contents and types of water well salts by the Palmer Roger model affecting the corrosion of Al-Bayda city (Libya) network pipes. AlQalam J Med Appl Sci. 2025;8(3):744-53.
27. Abdulsayid FA, Hamad MAH, Huda AE. IR spectroscopic investigation, X-ray fluorescence scanning, and flame photometer analysis for sediments and rock samples of Al-Gabal Al-Akhder coast region (Libya). IOSR J Appl Chem. 2021;14(4):20-30.
28. ALambarki M, Hasan HMA. Assessment of the heavy metal contents in air samples collected from the area extended between Albayda and Alquba cities (Libya). AlQalam J Med Appl Sci. 2025;8(3):695-707.
29. Al-Nayyan N, Mohammed B, Hamad H. Estimate of the concentrations of heavy metals in soil and some plant samples collected from (near and far away) of the main road between Al-Bayda city and Wadi Al-Kouf region. AlQalam J Med Appl Sci. 2025;8(3):816-26.
30. Hasan HMI. Studies on physicochemical parameters and water treatment for some localities along coast of Alexandria [dissertation]. [Alexandria, Egypt]: Alexandria University; 2006.
31. Hamad MAH, Hager AA, Mohammed EY. Chemical studies of water samples collected from area extended between Ras Al–Halal and El Haniea, Libya. Asian J Appl Chem Res. 2022;12(3):33-46.
32. Hamad M, Mohammed AA, Hamad MAH. Adsorption and kinetic study for removal some heavy metals by use in activated carbon of sea grasses. Int J Adv Multidiscip Res Stud. 2024;4(6):677-85.
33. Hamad MAH, Hamad NI, Mohammed MYA, Hajir OAA, Al-Hen dawi RA. Using bottom marine sediments as environmental indicator state of (Tolmaitha – Toukra) region at eastern north coast of Libya. Sch J Eng Tech. 2024;2(14):118-32.
34. Hamad MIH. The heavy metals distribution at coastal water of Derna city (Libya). Egypt J Aquat Res. 2008;34(4):35-52.
35. Hamad MIH, Islam Mu. The concentrations of some heavy metals of Al-Gabal Al-Akhdar Coast Sediment. Arch Appl Sci Res. 2010;2(6):59-67.
36. Hamad MAH, Amira AKA. Estimate the concentrations of some heavy metals in some shoes polish samples. EPH Int J Appl Sci. 2016;2(2):24-7.
37. Hamad MAH, Hussien SSM, Basit EEM. Accumulation of some heavy metals in green algae as bio indicators of environmental pollution at Al-Haniea region: Libya coastline. Int J Adv Multidiscip Res Stud. 2024;4(5):188-90.
38. Hamad MIH, Ahmed MA. Major cations levels studies in surface coastal waters of Derna city, Libya. Egypt J Aquat Res. 2009;35(1):13-20.
39. Hamad MIH, Masoud MS. Thermal analysis (TGA), diffraction thermal analysis (DTA), infrared and X-rays analysis for sediment samples of Toubrouk city (Libya) coast. Int J Chem Sci. 2014;12(1):11-22.
40. Hamad R, Ikraiam FA, Hasan H. Estimation of heavy metals in the bones of selected commercial fish from the eastern Libyan coast. J Rad Nucl Appl. 2024;9(1):47-51.
41. Hasan HAH. Estimate lead and cadmium contents of some archeological samples collected from ancient cities location (Cyrene and Abolonia) at Al-Gabal Al-Akhder Region, Libya. Univ J Chem Appl. 2021;12(21):902-7.
42. Hamad IH, Nuesry MS. The poly cyclic hydrocarbons levels in some fishes tissues collected from Derna City (Libya) Coast. In: International conference on chemical, agricultural and medical sciences; 2014 Dec 4-5; Antalya, Turkey. 2014. p. 52-6.
43. Hamad MAH, Mounera AAE, Baseet ESM, Eman E, Al-Badri M. Identification and detection the aromatic and aliphatic hydrocarbons in Epinephelus Marginatus fish samples collected from Benghazi coast. Int J Adv Multidiscip Res Stud. 2023;6(3):107-13.
44. Mohammed A, Hamad MAH, Mounera AAE, Eman IHE. Extraction and identification of aliphatic hydrocarbons in marine sediment samples at Benghazi city and Dyriana town coasts (Libya). J Res Humanit Soc Sci. 2023;11(10):168-74.
45. Hasan MAH, Muftah HS, Abdelghani KA, Saad SI. Poly aromatic hydrocarbon concentrations in some shell samples at some Tobrouk city coast regions: could the oil industry be significantly affecting the environment. Ukr J Ecol. 2022;12(3):21-8.
46. Habel AMA, Mohamed NIH, Mohammed MA, Hamad MAH. The levels and sources of aliphatic and polycyclic aromatic hydrocarbons in blue runner fish from Benghazi coast, Libya. Afr J Biol Sci. 2024;6(3):1-10.
47. Hasan HMI, Mohamad ASA. A study of aliphatic hydrocarbons levels of some waters and sediments at Al-Gabal Al-Akhder coast regions. Int J Chem Sci. 2013;11(2):833-49.
48. Salem GM, Aljidaemi FF, Hwisa SA, Hamad MIH, Zaid AA, Amer IO. Occupational exposure to benzene and changes in hematological parameters in East Tripoli, Libya. Nanotechnol Percept. 2024;20(S5):358-64.
49. Habil Z, Ben arous N, Masoud N, Hasan H. Using GC-mass method for determination the hydrocarbon compounds in some vegetable samples at Derna city, Libya. Libyan Med J. 2025;17(3):374-83.
50. Hasan H, Habil Z, Ben arous N. Estimate the types and contents of phenolic acid in C.Paviflorus lam and C.salviiflolius L plants growing at Al –Gabal Al-hder regions. AlQalam J Med Appl Sci. 2025;8(3):1646-56.
51. Mohamed FH, Salah MIH, Omukthum AAA, Hamad MAH. Sensitive and Rapid Method to Estimate Residual Pesticides in Some Local and Imported Apple Cultivars Collected from Eastern North Side of Libya. Int J Adv Multidiscip Res Stud. 2023;3(6):100-6.

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*

52. Hasan S, Abduljalil O, Mohamed F, Hasan H. Detection of residual pesticides (Imidacloprid ,Aldicarb,Metalaxyl,Cypermethrin ,Chlorpyrfos,DDA, and Endrin) in peach Samples collected from Jabal al Akhder farma,Libya. AlQalam J Med Appl Sci. 2025;8(4):2099-106.
53. Eltawaty SA, Abdalkader GA, Hasan HM, Houssein MA. Antibacterial activity and GC-MS analysis of chloroform extract of bark of the Libyan Salvia fruticosa Mill. Int J Multidiscip Sci Adv Technol. 2021;1(1):715-21.
54. Aljamal MA, Hasan HM, Al Sonosy HA. Antibacterial activity investigation and anti-biotic sensitive's for different solvents (Ethanol, propanol, DMSO and di Ethel ether) extracts of seeds, leafs and stems of (Laurus azorica and Avena sterilis) plants. Int J Curr Microbiol App Sci. 2024;13(11):175-90.
55. Hamade MH, Abdelraziq SA, Gebreel AA. Extraction and determination the of Beta carotene content in carrots and tomato samples collected from some markets at ElBeida City, Libya. EPH Int J Appl Sci. 2019;1(1):105-10.
56. Hasan HM, Ibrahim H, Gonaid MA, Mojahidul I. Comparative phytochemical and antimicrobial investigation of some plants growing in Al Jabal Al-Akhdar. J Nat Prod Plant Resour. 2011;1(1):15-23.
57. Hasan H, Jadallah S, Zuhir A, Ali F, Saber M. The Anti-Cancer, Anti-Inflammatory, Antibacterial, Antifungal, Anti-Oxidant and phytochemical investigation of flowers and stems of Anacyclus Clavatus plant extracts. AlQalam J Med Appl Sci. 2025;8(3):415-27.
58. Hasan H, Zuhir A, Shuib F, Abdraba D. Phytochemical investigation and exploring the Citrullus Colocynthis extracts as antibacterial agents against some gram and negative bacteria species. AlQalam J Med Appl Sci. 2025;8(3):392-400.
59. MdZeyaullah R, Naseem A, Badrul I, Hamad MI, Azza SA, Faheem AB, et al. Catechol biodegradation by Pseudomonas strain: a critical analysis. Int J Chem Sci. 2009;7(3):2211-21.
60. El-Mehdawy MF, Eman KS, Hamad MI, Hasan H. Amino acids contents of leafs and stems for two types of herbal plants (Marjoram and Hybrid tea rose) at AL-Gabal AL-Akhder region. Der Pharma Chem. 2014;6(6):442-7.
61. El-Mehdawy MF, Eman KS, Hamad MIH. Amino acid contents of leafs and stems for three types of herbal plants at Al-Gabal Al-Akhder region. World J Chem. 2014;9(1):15-9.
62. Hamad MH, Noura AAM, Salem AM. Phytochemical screening, total phenolic, anti-oxidant, metal and mineral contents in some parts of plantago Albicans grown in Libya. World J Pharm Res. 2024;13(3):1-17.
63. Anees AS, Hamad MIH, Hasan H, Mojahidul I. Antifungal potential of 1,2-4triazole derivatives and therapeutic efficacy of Tinea corporis in albino rats. Der Pharm Lett. 2011;3(1):228-36.
64. Hamad Hasan, Marwa Mohammed, Amal Haroon. Determining the contents of antioxidants, total phenols, carbohydrate, total protein, and some elements in Eucalyptus gomphocephala and Ricinus communis plant samples. Libyan Med J. 2015;1(1):222-31.
65. Hamad Hasan, Zuhir Akrim, Farag Shuib, Dala Abdraba. Efficiency of Cynara Cornigera fruits on antibacterial, antifungal and its phytochemical, anti-oxidant screening. Libyan Med J. 2025;3(1):120-8.
66. Hamad Hasan, Ashour Sulayman, Ahmed Alehrir. Estimation of amino acid composition, total carbohydrate, and total protein content in Ballota pseudodictamnus plant extracts from Al Jabal Al Akhdar Region, Libya. Libyan Med J. 2025;3(1):266-71.
67. Hamad Hasan, Ahmed Hamad, Wafa Abdelsatar. Evaluation of anti-oxidant capacity, total phenol, metal, and mineral contents of Ziziphus lotus plant grown at some regions of AlGabal AlKhder, Libya. Libyan Med J. 2025;3(1):137-43.
68. Ben Arous NA, Naser ME, Hamad MAH. Phytochemical screening, anti-bacterial and anti-fungi activities of leafs, stems and roots of C. parviflorus Lam and C. salviifolius L plants. Int J Curr Microbiol App Sci. 2014;13(11):262-80.
69. Anas FAE, Hamad MAH, Salim AM, Azza MH. Phytochemical screening, total phenolics, antioxidant activity and minerals composition of Helichrysum stoechas grown in Libya. Afr J Biol Sci. 2024;3(6):2349-60.
70. Naseer RE, Najat MAB, Salma AA, Hamad MAH. Evaluation of metal and mineral contents of leafs, stems and roots of C. Parviflorus Lam and C. Salviifolius L plants growing at Al Ghabal Al-Khder (Libya). Int J Adv Multidiscip Res Stud. 2024;4(5):191-4.
71. Hamad MAH, Salem AM. Total carbohydrate, total protein, minerals and amino acid contents in fruits, pulps and seeds of some cultivars of muskmelon and watermelon fruit samples collected from Algabal Alkhder region. Sch J Appl Med Sci. 2024;12(1):1-7.
72. Gonaid MI, Ibrahim H, Al-Arefy HM. Comparative chemical and biological studies of Salvia fruticosa, Ocimum basillicum and Pelergonium graveolans cultivated in Al-Jabal Al- AkhdarAkhdar. J Nat Prod Plant Resour. 2012;6(2):705-10.
73. Rinya FMA, Hamad MAH, Ahlam KA, Hammida MEH. Phytochemical screening of some herbal plants (Menthe, Origanum and Salvia) growing at Al-Gabal Al-akhder Region-Libya. Afr J Basic Appl Sci. 2017;9(3):161-4.
74. Anas FAA, Hamad MAH, Salim AA, Azza MH. Phytochemical screening, total phenolics, antioxidant activity and minerals composition of Helichrysum stoechas grown in Libya. Afr J Biol Sci. 2024;3(6):2349-60.
75. Haroon A, Hasan H, Wafa AAS, Baset ESM. A comparative study of morphological, physiological and chemical properties of leafs and steam samples of (E.gomphocephala) (Tuart) plant growing at coastal (Derna city) and …. J Res Environ Earth Sci. 2024;9(12):10-8.
76. Hamad MAS, Ali AR. Separation and identification the speciation of the phenolic compounds in fruits and leaves of some medicinal plants (Juniperus phoenicea and Quercus coccifera) growing at Algabal Al Akhder region, Libya. Indian J Pharm Educ Res. 2016;51(3):299-303.
77. Enam FM, Wesam FAM, Hamad MAH. Detection the contents of minerals of (Sodium, Potassium and Calcium) and some metals of (Iron, Nickel and Copper) in some vegetable and soil samples collected from Al-Marj. Int J Adv Multidiscip Res Stud. 2023;5(3):304-9.
78. Hamad MIH, Mousa SR. Synthesis and (IR and TEM) characterization of leafs and stem nanoparticles of Artemisia plant: comparative study for the evaluation of anti-bacterial efficiency. Int J Adv Multidiscip Res Stud. 2024;4(5):195-9.

Received*: 13-08-2025 -* ***Accepted****: 12-10-2025 -* ***Published****: 20-10-2025*

79. Elsalhin H, Abobaker HA, Hasan H, El–Dayek GA. Antioxidant capacity and total phenolic compounds of some algae species (Anabaena and Spirulina platensis). Sch Acad J Biosci. 2016;4(10):782-6.
80. Hasan H, Mariea FFE, Eman KS. The contents of some chemical compounds of leafs and stems of some herbal plants (Thymy, Rosemary, Salvia, Marjoram and Hybrid Tea Rose) at Al-Gabal Al-Akhder region. EPH Int J Appl Sci. 2014;6(3):1-8.
81. El-Mehdawe MF, Eman KS, Hamad MIH. Heavy metals and mineral elements contents of leafs and stems for some herbal plants at AL-Gabal AL-Akhder region. Chem Sci Rev Lett. 2014;3(12):980-6.
82. Hamad MIH, Aaza IY, Safaa SHN, Mabrouk MS. Biological study of transition metal complexes with adenine ligand. Proc. 2019;41(1):77.
83. Ahmed ONH, Hamad MAH, Fatin ME. Chemical and biological study of some transition metal complexes with guanine as ligand. Int J New Chem. 2023;10(3):172-83.
84. Hamad MAH, Enas UE, Hanan AK, Hana FS, Somia MAE. Synthesis, characterization and antibacterial applications of compounds produced by reaction between Barbital with Threonine, glycine, lycine, and alanine. Afr J Biol Sci. 2024;6(4):1-10.
85. Emrayed H, Hasan H, Liser R. Corrosion inhibition of carbon steel using (Arginine –levofloacin-metal) complexes in acidic media. AlQalam J Med Appl Sci. 2025;8(3):1633-40.
86. Hasan H, Abdelgader I, Emrayed H, Abdel-Gany K. Removal of the medical dye safranin from aqueous solutions by sea grasses activated carbon: a kinetic study. AlQalam J Med Appl Sci. 2025;8(3):428-34.
87. Hasan HMA, Alhamdy MA. Adsorption and kinetic study for removal some heavy metals by using activated carbon of sea grasses. Int J Adv Multidiscip Res Stud. 2024;4(6):677-85.
88. Almadani EA, Hamad MAH, Kwakab FS. Kinetic study of the adsorption of the removal of bromo cresol purple from aqueous solutions. Int J Res Granthaalayah. 2019;7(12):1-10.
89. Mamdouh SM, Wagdi ME, Ahmed MA, Alaa EA, Essam AM, Hamad MIH. Rice husk and activated carbon for waste water treatment of El-Mex Bay, Alexandria Coast, Egypt. Arab J Chem. 2016;9 Suppl 2:S1590-S1596. doi:10.1016/j.arabjc.2016.01.007.
90. Hasan H, El-maleh C. Evaluation of some heavy metal levels in tissue of fish collected from coasts of susa region, libya. Attahadi Med J. 2025;1(1):118-22.
91. Balal A, Obid M, Khatab H, Hasan H. Determination of lead and cadmium marine water and crabs (pachygrapsus marmoratus) from tolmitha coast, Libya. AlQalam J Med Appl Sci. 2025;8(3):1670-7.
92. Abdull-Jalliel H, Sulayman A, Alhoreir M, Hasan H. The antimicrobial effect of some metal concentration on growth of staphylococcus and klebsiella bacteria species. AlQalam J Med Appl Sci. 2025;8(3):1646-56.
93. Abdull–Jalliel H, B Arous N, Alhoreir M, Hasan H. Using the extracts of the (Dodder) plant and the concentrations of some metals as inhibitors for growth, the (Pseudomonas) bacteria isolated from some hospital rooms in Derna and Al bayda. AlQalam J Med Appl Sci. 2025;8(3):1600-11.
94. Alfutisi H, Hasan H. Removing of thymol blue from aqueous solutions by pomegranate peel. EPH Int J Appl Sci. 2019;1(1):111-9.
95. Alaila AK, El Salhin HE, Ali RF, Hasan HM. Phytochemical screening of some herbal plants (Menthe, Origanum and Salvia) growing at al-gabal al-akhder region- Libya. Int J Pharm Life Sci. 2017;8(4):5500-3.
96. Rankin CW, Nriagu JO, Aggarwal JK, Arowolo TA, Adebayo K, Flegal AR. Lead contamination in cocoa and cocoa products: isotopic evidence of global contamination. Environ Health Perspect. 2005;113(10):1344-8. doi:10.1289/ehp.8009.

***Received**: 13-08-2025 - **Accepted**: 12-10-2025 - **Published**: 20-10-2025*