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Iodine's Role in Public Health: Review

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Abstract
Iodine is one of the essential micronutrients in the formation of thyroid hormones in the body, and its deficiency causes pathological problems due to insufficient production of this hormone. The aim of this article is to review important topics related to iodine deficiency and its impact on public health. Iodine deficiency is the main cause of endemic goiter, and eating some foodstuffs in quantities exceeding the permissible amounts may interfere with the absorption of iodine in the thyroid gland. Hypothyroidism caused by iodine deficiency early in life can irreversibly impair neuromotor development, leading to poor cognition and growth in children. The prevalence of iodine deficiency disorders worldwide occurs mostly in low- and middle-income countries. A healthy, balanced diet is the ideal solution to provide sufficient iodine. The most common foods that contain iodine are dairy products, seafood, and iodized salt.
Keywords: Iodine deficiency, pathological problems, hypothyroidism, public health.

1. Introduction

Micronutrients are essential for the body to perform its vital functions properly. A deficiency of these rare nutritional elements, or the occurrence of an overlapping of the elements and the loss of their nutritional value, can incite disturbances in the body's nutritional metabolism, ruining the body's health [1,2]. As any of these nutrients is deficient, disease problems appear, worsen, and ultimately lead to death [3]. Iodine is a rare and essential element in the synthesis of thyroid hormones, which are necessary for the metabolism of all body cells [4]. In addition to its crucial role in the neurological development of the fetus and child, therefore adequate iodine nutrition is imperative for all mammals [5,6]. Iodine is often found in very small concentrations in the body fluids and tissues of animals and humans. It has been proven that five grams of iodine is sufficient for a person's needs for seventy years of life [7,8]. Dietary iodine is incorporated by intestinal epithelial cells into the blood and then into the thyroid gland, where 80% of the body's total iodine is stored and used for the synthesis of the thyroid hormones 3,3-5triiodothyronine (T3) and thyroxin (T4). A healthy adult body contains 15-20 mg of iodine, approximately 70-80% of which is found in the thyroid gland [9-11]. Iodine deficiency is the main cause of thyroid disorders and a host of other health problems; it also causes lifelong brain damage, mental retardation, infertility, and lower infant survival rates [12,13]. This review presents the topics of the element iodine and its cycle in nature, the sources of obtaining it, the body's needs, and the disorders resulting from its deficiency, and provide better information about that.

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2. Iodine element

Iodine is a non-metallic chemical element located in group seventeen and has the symbol (I), atomic number 53, and atomic mass 126.9 g/mol, nearly black solid at standard conditions (figure 1). It is the heaviest of the stable halogens [14,15]. It is mono-isotopic and has only one stable isotope, I-127. It melts to form a deep violet liquid at 114°C, and boils to a foul-smelling violet gas at 184°C. It is non-flammable and toxic, and does not combine with oxygen directly. In nature, it does not exist in its free state and forms diatomic molecules [16,17]. Iodine and iodate are the most common inorganic forms of iodine in the environment [18]. In 1811, it was discovered by French chemist Bernard Courtois when he accidentally added concentrated sulfuric acid to Fucus vesiculosus, seaweed used to treat goiter. A few years later, specifically in 1813, iodine was named by the French scientist Joseph Louis Gay-Lussac as a new element, and its name is derived from the Greek word iodes, which means "violet color" [19]. Iodine is primarily used in medicine to disinfect external wounds, especially recent wounds, due to its high ability to kill germs and other microorganisms that may be harmful [20]. It is also used to improve the functioning of a sluggish thyroid gland, while its solution is used to treat swelling of the thyroid gland [21]. For several years, iodine has been used in the manufacture of some anti-radiation drugs because it is the only element capable of preventing the accumulation of radioactive iodine and iodide salts in the thyroid gland [22]. In addition, silver iodide is used in photography, as well as in the manufacture of dyes [23].

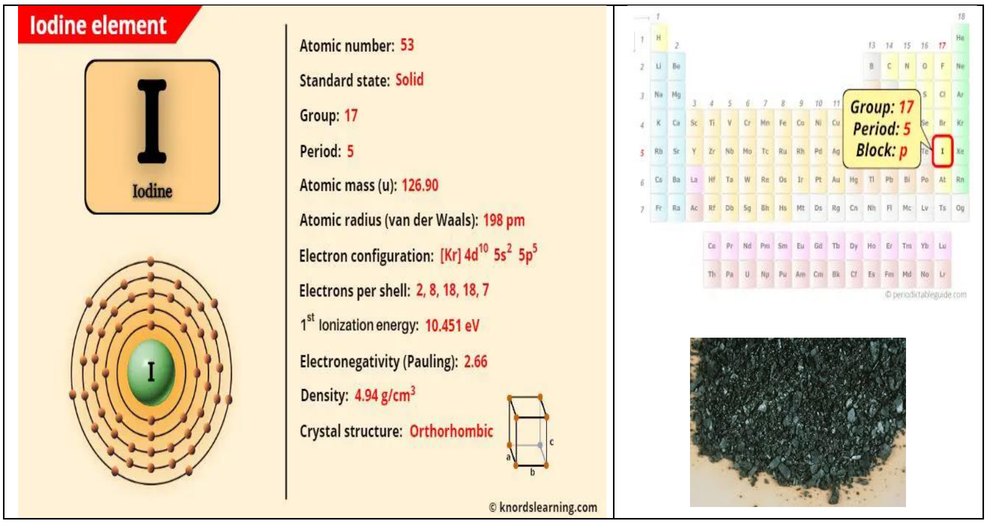

Figure 1: Iodine (I) element.

3. Iodine in nature

Iodine (as iodide) is unevenly present in the Earth's environment and can be found in many geological formations. Although iodine is concentrated in seawater, the biosphere, and the atmosphere, but seawater represents by far the biggest reservoir of iodine[24] .Topsoils have been depleted of iodide due to leaching from glaciation, flooding and erosion in many areas, so most of

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the iodide in the natural environment is concentrated in the oceans. In natural iodine cycle (figure2), marine iodide ions are oxidized to elemental iodine, which evaporate and volatilize through the atmosphere and when rain falls, it returns to the soil [25,26]. Thus, many cases of iodine deficiency disorders have been found to occur in areas of high mountain ranges, rain shadows, and central continental regions. In general, little iodine in the secondary environment is derived from weathering of the lithosphere, and most of the iodine is derived from volatilization from the oceans and later transported to land [27,28]. However, iodine cycles are often slow and incomplete, leaving soil and drinking water depleted of iodine. Iodine-deficient soils are common in mountainous areas and areas where flooding is common [29]. Crops grown in these soils will therefore be low in iodine and people and animals who consume food grown in these soils will become iodine deficient [30]. On the other hand, iodine was found to be concentrated in sulfur-containing minerals, which led to its classification as a chalcophilic element. The iodine content of the various rock-forming minerals is homogeneous and fairly low, with some enrichment found only in the chlorine-containing minerals sodalite and iodialite. Because of the large ionic radius of the iodide ion (220 μm), iodine does not enter the crystal lattices of most rock-forming minerals [31]. Sedimentary rocks have a wider range of iodine content with clay-rich rocks or clay rocks being more enriched than sand-rich sandstones [32]. Soils in coastal areas are higher in iodine than mountain soils (0.24 μg iodine/g of soil), since they evaporate from the sea and deposit in the surrounding areas [33].

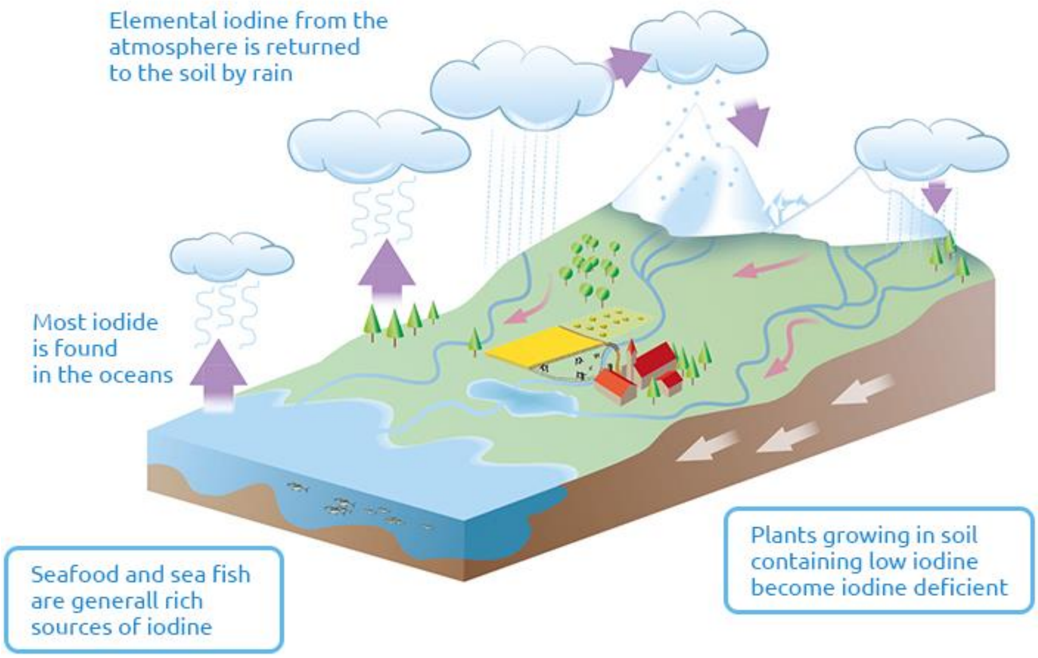

Figure 2: The natural iodine cycle.

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4. Food sources of iodine

The amount of iodine found in natural foods varies greatly depending on the soil in which plants and animals grow. Foods that contribute to high iodine intake are usually (figure 3) bread, dairy products, iodized salt, eggs, fish and seaweed [34]. Seaweed has a great ability to store iodine from the sea, so it is considered one of the foods richest in iodine [35]. Although lettuce and spinach contain less iodine than seaweed, they are a valuable source of iodine for humans. Serving size should be taken into consideration when evaluating the actual contribution of foods naturally high in iodine to dietary intake [36]. On the other hand, fortified foods can contribute more iodine in smaller portions, as observed with bread samples made with iodine dough improvers. Changing dietary patterns and food processing techniques in the modern era may contribute to increased iodine deficiency [37]. Iodine-containing compounds used in fertilizers and irrigation affect plants that are consumed by livestock for feed [38]. Reducing the use of iodophors as sterilizing agents in milk processing may affect the iodine content of dairy products [39]. As well as increased avoidance of dairy products, along with the emergence of plant-based alternative milk sources, contributes to a decrease in iodine status [40]. Also, reduced use of dietary salt for health reasons that consider salt a risk factor for blood hypertension is a contributing factor to reduced intake of iodized salt [41]. However, up to 20% of the iodine in salt may be lost during processing and another 20% during food preparation. To overcome poor iodine intake, strategies have been developed, including fortification programs aimed at incorporating iodine into common foods such as milk, bread, water and salt. According to the World Health Organization (WHO), the most successful strategy is the Universal Salt Iodization (USI) program. Since salt is consumed fairly by most of the population throughout the year [42-44].

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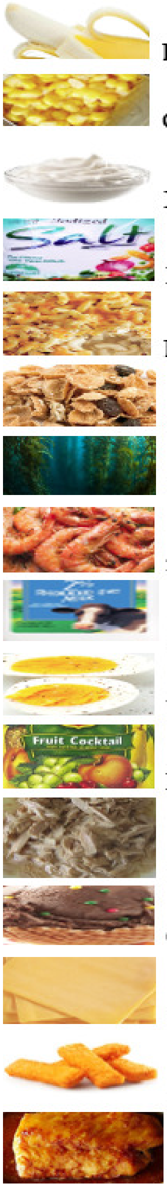

Food Item	Amount	Approximate (mcg) per Serving	Percent of Daily Value
Banana	Medium one	3	2
Canned Corn	Half cup	14	9
Plain Yogurt low fat	One cup	75	50
Iodized Salt	One and half gram	71	47
Boiled Macaroni	One cup	27	18
Raisin Bran Cereal	One cup	11	7
Seaweed	One gram	16 to 2984	11 to 1989
Shrimp	Three ounces	35	23
Reduced Fat Milk	One cup	56	37
Egg	One piece	24	16
Fruit Cocktail	Half cup	42	28
Canned Tuna Fish	Three ounces	17	11
Chocolate Ice-cream	Half cup	30	20
Cheddar Cheese	One ounce	12	8
Fish Sticks	Three ounces	54	36
Baked Cod	Three ounces	99	66

Figure 3: Food sources of iodine and their value.

5. Iodine nanoparticles (INPs) applications

Nanotechnology has revolutionized the field of medicine, just like many other fields [44-46]. Nanoparticles (NPs) have unique features due to their small size (1-100 nm) and their larger

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surface area to volume ratio[47,48], in addition to their physicochemical properties,[49] which allowed them to be exploited in various medical applications, as a drug delivery system[50], biosensors[51], and diagnosis and treatment of malignant tumors [52,53]. In the current era, researchers are interested in the applications of these particles [54-57], especially iodine nanoparticles (INPs), as therapeutic agents in the field of cancer diagnosis and treatment [58].Among the strategies used in cancer treatment is radiotherapy using radiopharmaceutical agents, especially radioisotopes of iodine, and there are investigations conducted to develop the new structure of INPs [59]. It is worth noting that iodine nanoparticles can be used in nuclear medicine imaging and may be effective with high voltage (MV) photons in treating cancer, but it requires evaluation using different cancer cells. Combining iodine with other therapeutic techniques has increased the effectiveness of diagnosing and treating malignant tumors. The use of various radioisotope-labeled nanoparticles, especially iodine-125, has been reported in several research works as a nuclear imaging agent for in vivo imaging and bio-distribution analysis. Recently, INPs have attracted increasing attention due to their potential applications in both imaging and therapy [60].Previously, during the past two decades; nano-based contrast agents have revolutionized preclinical imaging science, facilitating early, rapid and effective cancer detection. Imaging techniques can also be used in conjunction with nanotechnology-based contrast agents to investigate drug interactions at the preclinical stage and at the cellular level [61].Iodine nanoparticles have been used by intravenous injection into human TNBC tumors growing in the brains of thymic nude mice. High uptake in the vicinity of the tumor was found by micro-CT, reaching 4.5% of iodine by weight. A better treatment for human brain metastases may be achieved by combining INP-RT with synergistic chemotherapy and other treatments, such as immunotherapy, oncolytic virus therapy, using optimized irradiation equipment [62].

6. Iodine deficiency disorders

Iodine deficiency has devastating effects on the growth and development of the body and causes a group of diseases called iodine deficiency disorders (IDD), which are considered one of the most important human diseases and have the most impact on public health [63]. These disorders result from insufficient production of thyroid hormone due to a lack of sufficient iodine (Figure 4). It is the most common cause of goiter, and it is estimated that it affects approximately 2 billion people in the world's population, and the incidence of goiter depends on the degree of iodine deficiency. In general, it was more common in females [64,65]. Hypothyroidism, one of the symptoms of severe iodine deficiency, in Southeast Asia and the Eastern Mediterranean, studies have shown that iodine deficiency disorder exists in 36% and 43% of the total population, respectively. Individuals with mild deficiency are at risk for goiter, the formation of benign thyroid nodules with or without goiter, and the formation of endemic goiter [66]. As iodine intake decreases, the secretion of pituitary thyroid-stimulating hormone increases to maximize the uptake of circulating iodine by the thyroid gland, and thus thyroid-stimulating hormone stimulates thyroid enlargement and enlargement [67]. In adults, severe iodine deficiency manifests as mental disability, and decreased fertility. Breast cancer in women is associated with low levels of iodine in the body, and the use of iodine improves the adaptations that occur in some women's breasts [68]. In children, goiter, impaired intellectual and physical development, deafness and cretinism can occur.

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Cretinism is the most serious neurological damage resulting from hypothyroidism in the fetus and is characterized by gross mental retardation with varying degrees of short stature, deafness, mutism, and spasticity [69]. Multi-nodular goiter can be classified as hypothyroid and toxic depending on the clinical presentation and molecular pathology. Mutations that facilitate the growth of thyroid cells can lead to thyroid cancer in multi-nodular goiter [70]. One of the consequences of goiter is obstruction of the trachea and esophagus, which incites damage to the recurrent laryngeal nerves [71]. Severe iodine deficiency during pregnancy increases the risk of stillbirth, miscarriage, and birth defects [72]. In general, iodine deficiency leads to adverse health effects at all ages, and reduces learning ability and productivity [73].

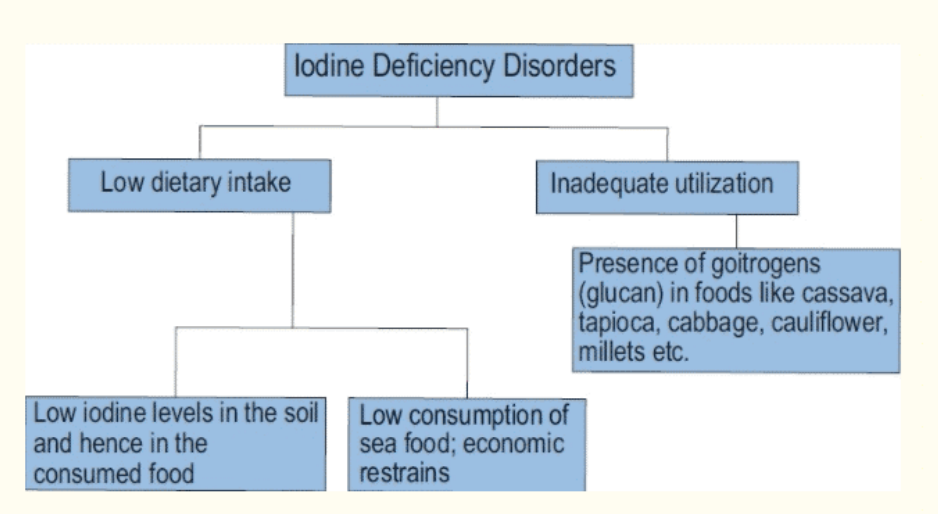

Figure 4: Causes of iodine deficiency.

7. Conclusions and recommendations

Iodine is necessary for the thyroid gland to function properly and avoid its enlargement, and thus plays a pivotal role in cognitive and physical maturity. Iodine deficiency disorders can lead to mental impairment in children. Cretinism is one of the most severe forms of iodine deficiency disorder, which poses a major threat to the health and development of the world's population. Therefore, this article recommends improving diets to prevent iodine deficiency by diversifying food sources, especially eating seafood, which is effective in reducing iodine deficiency. As well as iodized salt and adding iodine to animal and poultry feed to contribute to increasing the amount of iodine present in milk and eggs, and thus contributing to raising dietary iodine levels.

References

1- Kumar M, Kumar D, Sharma A, Bhadauria S, Thakur A, Bhatia A. Micronutrients throughout the Life Cycle: Needs and Functions in Health and Disease. Current Nutrition & Food Science. 2024 Jan 1;20(1):62-84.

The Peerian Journal
Open Access | Peer Reviewed
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ISSN (E): 2788-0303
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

2- Islam MR, Akash S, Jony MH, Alam MN, Nowrin FT, Rahman MM, Rauf A, Thiruvengadam M. Exploring the potential function of trace elements in human health: a therapeutic perspective. Molecular and Cellular Biochemistry. 2023 Jan 13:1-31.
3- Godswill AG, Somtochukwu IV, Ikechukwu AO, Kate EC. Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. International Journal of Food Sciences. 2020 Jan 7;3(1):1-32.
4- Olanrewaju OA, Asghar R, Makwana S, Yahya M, Kumar N, Khawar MH, Ahmed A, Islam T, Kumari K, Shadmani S, Ali M. Thyroid and Its Ripple Effect: Impact on Cardiac Structure, Function, and Outcomes. Cureus. 2024 Jan 3;16(1).
5- Candido AC, Azevedo FM, Silva DL, Ribeiro SA, Franceschini SD. Effects of iodine supplementation on thyroid function parameter: Systematic review and meta-analysis. Journal of Trace Elements in Medicine and Biology. 2023 Jul 29:127275.
6- Mégier C, Dumery G, Luton D. Iodine and Thyroid Maternal and Fetal Metabolism during Pregnancy. Metabolites. 2023 May 6;13(5):633.
7- Fu M, Zhang H, Gao Y, Yang R, Meng Q, Jin Q, Qi Y, Shi N, Zhang W. Mechanism of multi-organ compensation under different iodine intake in pregnant rats: results from a repeated-measures study of iodine metabolism. European Journal of Nutrition. 2024 Jan 3:1-0.
8- Opazo MC, Coronado-Arrázola I, Vallejos OP, Moreno-Reyes R, Fardella C, Mosso L, Kalergis AM, Bueno SM, Riedel CA. The impact of the micronutrient iodine in health and diseases. Critical reviews in food science and nutrition. 2022 Feb 16;62(6):1466-79.
9- Sorrenti S, Baldini E, Pironi D, Lauro A, D'Orazi V, Tartaglia F, Tripodi D, Lori E, Gagliardi F, Praticò M, Illuminati G. Iodine: Its role in thyroid hormone biosynthesis and beyond. Nutrients. 2021 Dec 14;13(12):4469.
10- Bertinato J. Iodine nutrition: Disorders, monitoring and policies. In Advances in Food and Nutrition Research 2021 Jan 1 (Vol. 96, pp. 365-415). Academic Press.
11- Al-Suhaimi EA, Khan FA. Thyroid Glands: Physiology and Structure. In Emerging Concepts in Endocrine Structure and Functions 2022 Apr 21 (pp. 133-160). Singapore: Springer Nature Singapore.
12- Cherim A, Petca RC, Dumitrascu MC, Petca A, Candrea E, Sandru F. Thyroid Disorders in Systemic Sclerosis: A Comprehensive Review. Journal of Clinical Medicine. 2024 Jan 11;13(2):415.
13- Fu M, Ren Z, Gao Y, Zhang H, Guo W, Zhang W. Study of iodine transport and thyroid hormone levels in the human placenta under different iodine nutritional status. British Journal of Nutrition. 2024 Jan 15:1-22.
14- Li Y, Younis MH, Wang H, Zhang J, Cai W, Ni D. Spectral computed tomography with inorganic nanomaterials: State-of-the-art. Advanced Drug Delivery Reviews. 2022 Sep 2:114524.
15- Schmid JR, Matschke C, Riedel S. 13.1. 3 Iodine-based disinfection materials. From Magnetic to Bioactive Materials. 2022 Dec 5:345.
16- Humphrey OS, Young SD, Bailey EH, Crout NM, Ander EL, Watts MJ. Iodine soil dynamics and methods of measurement: a review. Environmental Science: Processes & Impacts. 2018;20(2):288-310.

The Peerian Journal
Open Access | Peer Reviewed
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Website: www.peerianjournal.com Email: editor@peerianjournal.com

17- Xing M, Zhao ZZ, Zhang YJ, Zhao JW, Cui GL, Dai JH. Advances and issues in developing metal-iodine batteries. Materials Today Energy. 2020 Dec 1;18:100534.
18- Sanyaolu OM, Mouri H, Selinus O, Odukoya A. Sources, pathways, and health effects of iodine in the environment. Practical Applications of Medical Geology. 2021:565-613.
19- Pearce EN, Zimmermann MB. The prevention of iodine deficiency: A history. Thyroid. 2023 Feb 1;33(2):143-9.
20- Gmur MK, Karpiński TM. Povidone-iodine in wound healing and prevention of wound infections. European Journal of Biological Research. 2020 Jun 6;10(3):232-9.
21- Hope N, Kelly A. Pre-operative lugol's iodine treatment in the management of patients undergoing thyroidectomy for Graves' disease: a review of the literature. European Thyroid Journal. 2017 Feb 1;6(1):20-5.
22-Alaylar B, Aygün B, Turhan K, Karadayı M, Cinan E, Turgut Z, Karadayı G, Al-Sayyed MI, Güllüce M, Karabulut A. Investigation of radiation protective features of azadispiro derivatives and their genotoxic potential with Ames/Salmonella test system. International Journal of Radiation Biology. 2023 Feb 1;99(2):245-58.
23-Steeg E, Kirmse H, Rabe JP, Kirstein S. Silver iodide nanowires grown within tubular J-aggregates. Journal of colloid and interface science. 2018 Nov 15;530:424-32.
24-Antonyak H, Iskra R, Lysiuk R. Iodine. Trace Elements and Minerals in Health and Longevity. 2018:265-301.
25-Zimmermann MB. The remarkable impact of iodisation programmes on global public health. Proceedings of the Nutrition Society. 2023 May;82(2):113-9.
26-Muramatsu Y, Yoshida S, Fehn U, Amachi S, Ohmomo Y. Studies with natural and anthropogenic iodine isotopes: iodine distribution and cycling in the global environment. Journal of environmental radioactivity. 2004 Jan 1;74(1-3):221-32.
27-Fuge R. Soils and iodine deficiency. In Essentials of medical geology: revised edition 2012 Dec 1 (pp. 417-432). Dordrecht: Springer Netherlands.
28- Kumar P, Hemantaranjan A. Iodine: a unique element with special reference to soil-plant-air system. Advances in Plant Physiology. 2017 Apr 1;17:314.
29-Zimmermann MB. Iodine. Nutrition and Health in a Developing World. 2017:287-95.
30- Zimmermann MB. Iodine and the iodine deficiency disorders. In Present knowledge in nutrition 2020 Jan 1 (pp. 429-441). Academic Press.
31- Fuge R. Soils and iodine deficiency. In Essentials of medical geology: revised edition 2012 Dec 1 (pp. 417-432). Dordrecht: Springer Netherlands.
32-Claret F, Lerouge C, Laurioux T, Bizi M, Conte T, Ghestem JP, Wille G, Sato T, Gaucher EC, Giffaut E, Tournassat C. Natural iodine in a clay formation: Implications for iodine fate in geological disposals. Geochimica et Cosmochimica Acta. 2010 Jan 1;74(1):16-29.
33-Opazo MC, Coronado-Arrázola I, Vallejos OP, Moreno-Reyes R, Fardella C, Mosso L, Kalergis AM, Bueno SM, Riedel CA. The impact of the micronutrient iodine in health and diseases. Critical reviews in food science and nutrition. 2022 Feb 16;62(6):1466-79.
34-Knust KS, Leung AM. Iodine: basic nutritional aspects. In Molecular, Genetic, and Nutritional Aspects of Major and Trace Minerals 2017 Jan 1 (pp. 133-141). Academic Press.

The Peerian Journal
Open Access | Peer Reviewed
Volume 26, January, 2024
ISSN (E): 2788-0303
Website: www.peerianjournal.com
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35-Smyth PP. Iodine, seaweed, and the thyroid. European thyroid journal. 2021 Apr 1;10(2):101-8.
36-Medrano-Macías J, Leija-Martínez P, González-Morales S, Juárez-Maldonado A, Benavides-Mendoza A. Use of iodine to biofortify and promote growth and stress tolerance in crops. Frontiers in Plant Science. 2016 Aug 23;7:1146.
37-Pehrsson PR, Roseland JM, Patterson KY, Phillips KM, Spungen JH, Andrews KW, Gusev PA, Gahche JJ, Haggans CJ, Merkel JM, Ershow AG. Iodine in foods and dietary supplements: A collaborative database developed by NIH, FDA and USDA. Journal of Food Composition and Analysis. 2022 Jun 1;109:104369.
38- Ershow AG, Skeaff SA, Merkel JM, Pehrsson PR. Development of databases on iodine in foods and dietary supplements. Nutrients. 2018 Jan 17;10(1):100.
39-Ovadia YS, Chris Sabastian C, Dahl L, Troen AM, Mabjeesh SJ. The effect of iodophor post-milking teat disinfection on iodine content in goat milk. Isr J Vet Med. 2018 Dec 1;73(4):14-22.
40- Lawrence AS, Huang H, Johnson BJ, Wycherley TP. Impact of a Switch to Plant-Based Foods That Visually and Functionally Mimic Animal-Source Meat and Dairy Milk for the Australian Population—A Dietary Modelling Study. Nutrients. 2023 Apr 10;15(8):1825.
41-Bhattacharya S, Bera OP, Saleem SM, Hossain MM, Varshney DS, Kaur R, Rana RK, Tripathi S, Gokdemir O, Bacorro M, Mehta K. Dietary salt consumption pattern as an antecedent risk factor for hypertension: Status, vision, and future recommendations. Clinical Nutrition ESPEN. 2022 Feb 1;47:422-30.
42-Choudhry H, Nasrullah M. Iodine consumption and cognitive performance: Confirmation of adequate consumption. Food Science & Nutrition. 2018 Sep;6(6):1341-51.
43-Ali QA, Ghareeb OA. DRINKING WATER QUALITY AND ITS IMPACT ON PUBLIC HEALTH. Academia Repository. 2023 Sep 11;4(9):48-64.
44- World Health Organization. Salt reduction and iodine fortification strategies in public health: report of a joint technical meeting convened by the World Health Organization and The George Institute for Global Health in collaboration with the International Council for the Control of Iodine Deficiency Disorders Global Network, Sydney, Australia, March 2013.
45-Ghareeb OA, Ali QA. Pathotoxic Impact of Zinc Oxide Nanoparticles on Liver Function and Protective Role of Silymarin. Current Innovations in Disease and Health Research. 2023 Jul 24;3:153-161.
46- Ramadhan SA, Ghareeb OA. Clinicohematological Study of Gold Nanoparticles Toxicity and Ameliorative Effect of Allium Sativum. Annals of the Romanian Society for Cell Biology. 2021 Jan 31:597-602.
47-Ghareeb OA. Hematotoxicity Induced by Copper Oxide Nanoparticles and the Attenuating Role of Giloy In Vivo. Cureus. 2023 Oct 6;15(10):e46577.
48- Ghareeb OA, Ali QA. Hepatotoxicity Induced by Some Metal Nanoparticles In Vivo: Review. Global Scientific Review.2024 Jan; 23: 25–33.

The Peerian Journal
Open Access | Peer Reviewed
Volume 26, January, 2024
ISSN (E): 2788-0303
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

49- Ghareeb OA. Pathological Changes in Liver Function Induced by Gold Nanoparticles and Protective Role of Tinospora Cordifolia: In Vivo. Annals of the Romanian Society for Cell Biology. 2021 Jan 31:660-665.
50- Ghareeb OA, Sulaiman RR, Ibrahim SH. Impact of silver nanoparticles on hematological profiles and hepatorenal functions in photosensitivity: In Vivo. Annals of the Romanian Society for Cell Biology. 2021 Apr 19:7448-59.
51- Ramadhan SA, Ghareeb OA. Efficiency of Cichorium Intybus in Reducing Hepatotoxicity Induced by Zinc Oxide Nanoparticles. Annals of Medical and Health Sciences Research. 2022; 12(3): 93-96.
52- Ghareeb OA, Ali QA. Pathological Disorders Caused by Atmospheric Nanoparticles: Review. The Peerian Journal. 2024 Jan; 26: 44–51.
53- Ghareeb OA. Hepato-Renal dysfunctions induced by Gold nanoparticles and preservative efficacy of black seed oil. Journal of Medicinal and Chemical Sciences. 2022;5(1):137-143.
54- Ali QA, Alhares HS, Abd-almohi HH, M-Ridha MJ, Mohammed SJ, Jabbar ZH. Enhancing microbial desalination cell performance for water desalination and wastewater treatment: experimental study and modelling of electrical energy production in open and closed-circuit modes. Journal of Chemical Technology & Biotechnology. 2024 Jan;99(1):294-306.
55- Ali QA, Shaban MA, Mohammed SJ, Abd-Almohi HH, Abed KM, Salleh MZ,Hasan HA. Date Palm Fibre Waste Exploitation for the Adsorption of CongoRed Dye via Batch and Continuous Modes. Journal of Ecological Engineering.2023 Oct 1;24(10).
56- Ali QA, Ghareeb OA. Proposed Solutions to Improve Deterioration of Drinking Water Quality. Global Scientific Review. 2024; 23: 34–46.
57- Ghareeb OA, Ramadhan SA. Prophylactic Efficacy of Silymarin upon Renal Dysfunction Induced by Copper Oxide Nanoparticle. Quantum Journal of Medical and Health Sciences. 2023 Oct 28;2(4):18-25.
58- Mahaki H, Mansourian M, Meshkat Z, Avan A, Hossein Shafiee M, Mahmoudian RA, Ghorbani E, Ferns GA, Manoochehri H, Menbari S, Sheykhhasan M. Nanoparticles Containing Oxaliplatin and the Treatment of Colorectal Cancer. Current Pharmaceutical Design. 2023 Oct 1;29(38):3018-39.
59- Wang Y, Li Z, Mo F, Chen-Mayfield TJ, Saini A, LaMere AM, Hu Q. Chemically engineering cells for precision medicine. Chemical Society Reviews. 2023.
60- Mansouri M, Shahbazi-Gahrouei D. A review on theranostic applications of iodine nanoparticles: Recent findings and perspectives. Nanomedicine J. 2021 Oct 1;8:234-40.
61- Ashwin Kumar N, Suresh Anand BS, Krishnamurthy G. Nanomaterials for Medical Imaging and In Vivo Sensing. Nanomaterials and Their Biomedical Applications. 2021:335-403.
62- Hainfeld JF, Ridwan SM, Stanishevskiy FY, Smilowitz HM. Iodine nanoparticle radiotherapy of human breast cancer growing in the brains of athymic mice. Scientific Reports. 2020 Sep 24;10(1):15627.
63- Smyth PP. Iodine, seaweed, and the thyroid. European thyroid journal. 2021 Apr 1;10(2):101-8.
64- Tovkai AO. Iodine deficiency and prevalence of nodular goitre in Ukraine. International Journal of Endocrinology (Ukraine). 2022 Jun 27;18(4):226-30.

65- Fu M, Zhang H, Gao Y, Yang R, Meng Q, Jin Q, Qi Y, Shi N, Zhang W. Mechanism of multi-organ compensation under different iodine intake in pregnant rats: results from a repeated-measures study of iodine metabolism. European Journal of Nutrition. 2024 Jan 3:1-0.
66- Hatch-McChesney A, Lieberman HR. Iodine and iodine deficiency: a comprehensive review of a re-emerging issue. Nutrients. 2022 Aug 24;14(17):3474.
67- Milanesi A, Brent GA. Iodine and thyroid hormone synthesis, metabolism, and action. In Molecular, Genetic, and Nutritional Aspects of Major and Trace Minerals 2017 Jan 1 (pp. 143-150). Academic Press.
68- Antonyak H, Iskra R, Lysiuk R. Iodine. Trace Elements and Minerals in Health and Longevity. 2018:265-301.
69- Dineva M, Hall A, Tan M, Blaskova A, Bath SC. Iodine status during child development and hearing ability: A systematic review. British journal of nutrition. 2023 Mar;129(5):795-812.
70- AlSaedi AH, Almalki DS, ElKady RM, ElKady R. Approach to Thyroid Nodules: Diagnosis and Treatment. Cureus. 2024 Jan 13;16(1).
71- Samra T. Anatomy, Physiology of the 29 Thyroid Gland and Classification of Thyroid Diseases. Long and Short Cases in Anesthesiology. 2020 Dec 31:387.
72- Zhao W, Li X, Xia X, Gao Z, Han C. Iodine nutrition during pregnancy: past, present, and future. Biological trace element research. 2019 Mar 15;188:196-207.
73- Choudhry H, Nasrullah M. Iodine consumption and cognitive performance: Confirmation of adequate consumption. Food Science & Nutrition. 2018 Sep;6(6):1341-51.