International Journal of Research Studies in Biosciences (IJRSB)
Volume 11, Issue 1, 2025, PP 01-08
ISSN (Online) 2349-0365
https://doi.org/10.20431/2349-0365.1101001
www.arcjournals.org

Seaweed in Africa: A Mini Review of Industry, Benefits and Safety Concerns

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Received: 03 December 2024 Accepted: 20 December 2024 Published: 08 January 2025

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Abstract

Seaweed is a valuable commodity in Africa, providing a source of income and nutrition for millions. However, the safety of seaweed in Africa requires a collective immediate observation concerning the contents of heavy metals. This review provides an overview of the state of the seaweed industry in Africa, its benefits and the regulatory frameworks and safety standards in most countries. The review also discusses the need for greater investment in research and development, regional and international cooperation, and consumer awareness to promote the safe consumption of seaweed. The findings of this review have important implications for policymakers, researchers and consumers and the need for a coordinated effort to ensure the healthy utilization of seaweed in Africa.

1.0. INTRODUCTION

For centuries, Agriculture has played a dominant role in supplying Africa's food demands and economic growth [1], however in recent decades, Aquaculture has been reported to be an alternative source for the future global food security at large while improving environmental health [2]. Aquaculture is the cultivation of aquatic produce such as aquatic plants, fish and aquatic animals [3]. African coastlines comprise a variety of aquatic plants including macroalgae also known as seaweeds ranging from brown, red and green, with brown and red being the predominant cultivars. The seaweed categories are due to a region's biological and geographical characteristics. Although seaweed has significantly improved individuals' livelihoods and increased the gross domestic product in Africa, it is underexploited compared to its availability [4, 5]. Over decades Asia followed by Europe has been a vast healthy consumer of seaweed and the awareness has recently rapidly spread to Africa [6]. The increased health awareness has shifted the African consumer's diet pattern to focus on healthy food containing natural bioactive compounds [7]. Moreover, most replaced the functional components of synthetic food, such as antioxidants, antitoxic, and anticancer, from fruits and vegetables, and recently raised attention to seaweed [8]. From a nutritional perspective, seaweed is considered nutrient-dense due to its high composition of essential and non-essential nutrients [9-11]. Seaweed is an important protein source that contains all the essential amino acids with high bioactivity and potential functional properties. The total protein content in seaweed typically ranges from 5 % to 47 % of dry mass, representing a viable alternative to animal-derived protein in the diet [9]. The proteins and derivatives in seaweed can be categorized into: peptides, enzymes, glycoproteins, lectins, amino acids, and Phycobiliproteins (PBPs). all of which are an attraction to researchers in the food and pharmaceutical industry. Moreover, seaweed contains fat and water-soluble vitamins such as A, D, E, K, C, B_1, B_2, B_9, and B_{12} and essential minerals including Na, K, Ca, Mg, Fe, Zn, Mn, and Cu which play a vital role in maintaining bodily processes and well-being [12]. Some seaweeds contain 10 to 100 times more vitamins and minerals per unit dry mass than terrestrial plants or animal-derived foods [13]. The content of vitamins and minerals varies among species. For example, a study conducted by Qin and colleagues which involved the investigation

of five brown, eight red, and eight green seaweeds from northern European waters showed that total tocopherol (vitamin E) content ranged from 1.6 to 122 mg kg^{-1} in brown, 10–26 mg kg^{-1} in red, and 8.8–12.0 mg kg^{-1} in green species (dry mass, DW) [12, 13]. Seaweed is also well recognized as a nutraceutical due to its richness in dietary fibers, omega-3 fatty acids, carotenoids, and phenolic compounds [14]. Seaweed has been known for its rich nutritional profile and contribution to economic and environmental sustainability [15]. Seaweed has also been used to produce a range of functional food and food products including snacks, bread, gels, bakes and dairy. Eor and colleagues' research involved supplementing seaweed Ascophyllum nodosum extract, which showed an anti-obesity effect in the 3T3-L1 cell line and a high-fat diet-induced obesity rat model. The weight of the rats was reduced without affecting their feed intake [16], proving that seaweed-based extracts have the potential to be used as active food components in alleviating obesity and contributing to a healthy life since they can affect genes associated with lipid accumulation, lipogenesis, and lipid utilization. Besides nutritional, health, and nutraceutical benefits, seaweed cultivation also offers environmental advantages. They are used as biofuels, wastewater treatment, and as biofertilizers. Its cultivation requires less land and does not require freshwater irrigation [15]. Africa's rapidly emerging seaweed industry positions the continent to become a global dominant producer while adapting to be a top processor and consumer [17]. However, seaweed has shown promising benefits, its safety as a food ingredient and raw food is yet under-observed. Several seaweed-focused studies worldwide reported the presence of toxic heavy metals (Mn, Fe, Cu, Zn, Cd and Pb), and pathogenic microorganisms potentially toxic to consumer's health [18, 19]. This review discusses the rapidly growing seaweed industry, benefits, applications and heavy metals safety risks posed by seaweed to health concerns, and it concentrates on the gaps and necessity of activating and enacting the safety regulation frameworks addressing the seaweed hazards across Africa.

2.0. Seaweed Health Potential Risks: Overview

Like other food industries, seafood has numerous reported cases that have compromised the quality and safety issues and hence caused health undesired outcomes to the consumers [20]. Aquaculture fish cases are the top reported problems in the seafood industry due to the high amount of lipids, protein and minerals, the composition with high susceptibility to deterioration and adverse health effects to individuals under-observing the quality measures [21]. These cases are caused by safety risks categorized as physical, chemical and biological risks. In the seaweed value chain, potential risks can occur along farming particularly in polluted areas, harvesting, processing and storage. Seaweed farming presents various safety risks including environmental, occupational and biological risks or hazards (Figure 1) in seaweed cultivation, such as physical (slips, trips, falls and heavy machinery), biological such as pathogenic microorganisms and chemicals [22]. Plenty of findings have shown the presence of seaweed pathogenic microbes, an awareness that is less compared to heavy metals. However, the available studies help contribute to knowledge about seaweed heavy metal and safety; more research concerning bioaccessibility is in demand [18].

Figure 1. *Environmental, Occupational and Biological Risks in Seaweed Farming*

2.1. Heavy Metals

Ongoing activities by humans and nature impact environmental health day by day [23]. Anthropogenic activities including industrial activities, mining, agriculture and construction increase the availability of heavy in the environment [24]. Figure 2 shows the source categories of anthropogenic and natural activities and the respective particular examples contributing to the heavy metal accumulation in seaweed. These metals bind to free functional groups forming new compounds [25]. Heavy metals can generally be defined as earth crust-originated metals with high atomic weight, contrasting with other common metallic metals [26]. Seaweeds, aquatic macroalgae contain Carboxyl (-COOH), Hydroxyl (-OH), Sulfate (-OSO3-) and Amino (-NH2) in their structure, the functional groups with a renowned binding capacity to highly toxic heavy metals (Cd^{2+}, Pb^{2+}, As^{3+}, As^{5+} Zn^{2+}) [27].

Heavy metals are continuously closed followed-up seaweed safety concerns as they have notable bioaccessibility and challenge health [28]. Heavy metal binding affinity can be defined as the measure of the easiness of heavy metal to be attached to a particular molecule such as protein, polysaccharide or lipid. This affinity variation is due to the chemical structure of the molecule, the charge and size of the heavy metal ion and the presence of other ions or molecules that can compete for binding [29]. In addition, the large affinity capacity of highly toxic heavy metals such as As, Pb, Cd, and Hg can result in health-deleterious effects at the lowest dosage [30-34]. Heavy metals accumulation in seaweed is a function of the season, sampling location and type of species [35]. The conducted study for safety validation of two seaweed species *Ulvarigida* and *Halimeda opuntia* commonly used as a feed alternative protein source, found a significant difference among four analyzed heavy metals Arsenic, Cadmium, Lead and Mercury due to their sampling area and respective seasons [36]. “These heavy metals are known to cause multiple and complicated health problems such as brain and lung damage, cancer, nausea, and vomiting” [37, 38] as quoted in [27].

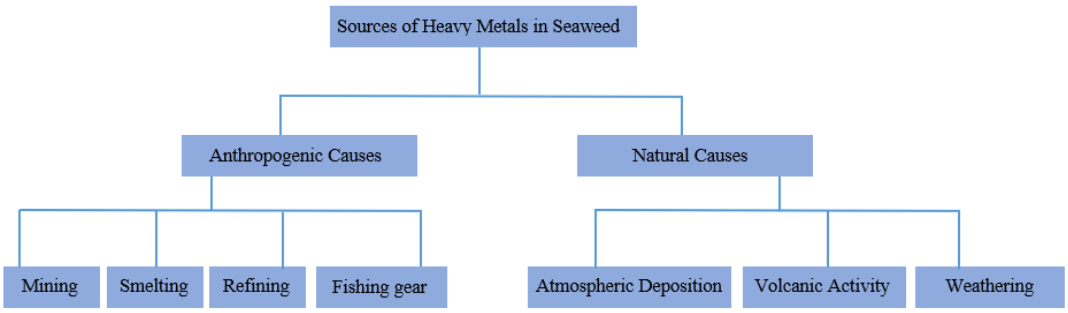

Figure 2. *Sources of Heavy Metals Accumulation in Seaweed*

Table 1 shows the study conducted to analyze the levels of heavy metals in various regions across Africa. The results showed that several countries had high concentrations of heavy metals, including arsenic, cadmium, lead, and mercury, which exceeded accepted levels set by national and international health agencies. The regions with high levels of heavy metals included Senegal, South Africa (KwaZulu-Natal and Eastern Cape coasts), Ghana (West Coast), Kenya, Tunisia, and Egypt. The study highlights the need for extensive research in heavy metals across Africa and the need for monitoring and regulation of heavy metal levels in these regions to ensure public health and safety.

Table 1. *The study’s results on Africa’s seaweed heavy metal analysis*

Sampling location/Region	Study findings		Reference
	Heavy Metal (s)	Results	
Senegal	• Arsenic	Surpassed accepted level as per the Norwegian National Institute of Nutrition and Seafood Research (NIFES, 2016)	[39]

	• Cadmium	Surpassed accepted level as per French health agencies	
South Africa *(KwaZulu-Natal coast)*	Lead, Arsenic, Chromium, Cobalt, Copper, Manganese, Nickel, Selenium and Zinc.	The concentrations of Arsenic were particularly high (94.70 ± 6.6 μg g^{-1} in winter to 65.10 ± 2.3 μg g^{-1} in summer)	[40]
South Africa *(Eastern Cape coast)*	Cadmium, Arsenic, Lead and Mercury.	Cadmium (Cd), arsenic (As), lead (Pb), and Hg measured were above the maximum limits set by the South African Department of Health.	[41]
Ghana West Coast	Mercury, Arsenic, Cadmium, Lead Iron, Zinc, Potassium and Copper.	Only zinc was found to be below the toxic range [42]	[43]
Kenya	Mercury, Lead, Arsenic and Cadmium.	*Caulerpa taxifolia* had the highest levels of Lead and Cadmium overall.	[44]
Tunisia	Arsenic, Cadmium, Copper, Mercury and Lead.	Lead (Pb) (0.39–0.51 mg/kg), Arsenic (As) (0.11–0.40 mg/kg), Cadmium (Cd) (0.01–0.02 mg/kg), and Mercury (Hg) (0.00–0.02 mg/kg).	[45]
Egypt	Zinc, Barium, Copper, Chromium, Nickel, Lead, Vanadium, Cadmium, Cobalt and Molybdenum	Cadmium and Zinc contents were at the borderline as per WHO and CEVA.	[46]

3.0. Regulatory Frameworks and Safety Standards

The innovation and research towards stable food security have not only raised the enlightenment to the use of sustainable nutritious foods but also the consciousness towards safety concerns. The food regulatory frameworks and safety standards at particular ranks such as continental, regional and national are formulated with a central focus on protecting consumer health. In Africa, the majority of Governance bodies regarding food safety are short of seaweed safety specificity guidelines and concentrate on general food standards [47]. This overlook of seaweed safety regulatory frameworks and safety standards increases the chance of seaweed as an emerging global food security candidate to be a potential cause for upcoming non-communicable diseases.

For instance, in South Africa, the Department of Agriculture, Forestry and Fisheries has established regulations for the harvesting of seaweed including permitted personnel, areas and methods of harvesting however these regulations do not specifically address the issue of heavy metals management and their minimum acceptance level [48]. [44] explored the need for the Kenyan regulatory bodies to set heavy metal seaweed safety standards for effective nutritional and medicinal utilization since numerous researched farming species showed the overpassing of allowed limits by set international standards including WHO, FAO and JESFA. Although Nigeria through the National Agency for Food and Drug Administration and Control (NAFDAC) has guidelines for food labeling, it hasn't described the Seaweed metallic concerns. In addition to seaweed unlabeled, also encouraged the consumption of seaweed by children, grouping seaweed as fresh and frozen fruits and vegetables, legumes, roots and tubers and setting the permitted guidelines for total fat, saturated fat, total sugars, added sugar, Sodium and energy, and unaddressed the heavy metal and limits. [49] suggests the need for updating the need of food safety policy in Nigeria.

Inadequate capacity to monitor and enforce existing regulations, leaving consumers vulnerable to the risks associated with heavy metal contamination in seaweed. For example, in Tanzania, the TANZANIA BUREAU OF STANDARDS, the responsible regulatory body for food risk assessment and safety monitoring including seaweed, lacks the human resources and enough laboratory facilities and offices to conduct regular zonal inspections and testing, resulting in many seaweed products being sold in markets without being tested for heavy metals or putting consumers at risk [50]. Also, In Ghana, there is a noticeable shortage of training for individuals related to implementing the National Quality

Policy. This policy plays a crucial role in the safety of end-product consumers. Additionally, local legislations are suggested to be reviewed while aligning with international standards [51].

The lack of regional and international cooperation also hinders efforts to ensure the safe trade of seaweed across borders. The African Union's (AU) African Continental Free Trade Area (AfCFTA) agreement aims to promote the free movement of people, services and goods including seaweed across the continent. However, the agreement does not establish common standards for goods acknowledging the inconsistency of safety standards and leaving the legitimate policy formulation and enacting within countries' territories [52]. In addition, insufficient knowledge of food laws concerning food safety to public officials, and a shortage of human and financial resources still pose a potential threat to public health among African Union members [53].

To address these challenges, there is a need for African countries to develop and implement specific regulations and guidelines for seaweed, including standards for heavy metal limits and labeling. Additionally, regional and international cooperation is necessary to harmonize standards and ensure the safe trade of seaweed across borders.

In addition, there is a need for greater transparency and accountability in the seaweed industry. For example, some seaweed producers and processors may not disclose the presence of heavy metals or in their products or may mislabel their products as "organic" or "natural" when they do not meet these standards. To address this, governments and regulatory agencies must establish clear guidelines for labeling and disclosure and must enforce these guidelines through regular inspections and testing. Consumers also have a role to play in demanding safer and more transparent seaweed products, by choosing products from reputable producers and processors, and by reporting any concerns or complaints to regulatory agencies.

4.0. Conclusion and Future Directions

In conclusion, the safety of seaweed in Africa is a pressing concern that requires immediate attention from governments, regulatory agencies and the private sector. The lack of consistent and effective regulations combined with inadequate monitoring and enforcement has created a situation in which consumers are vulnerable to the risks associated with heavy metal contamination and in seaweed. To address this, there is a need for African countries to develop and implement specific regulations and guidelines for seaweed, including standards for heavy metal limits and labeling. For example, the South African government could establish a maximum permissible limit for lead in seaweed, similar to the limit established by the European Union. Similarly, the Kenyan government could require seaweed producers and processors to label their products with information about such as iodine or carrageenan. There is a need for greater investment in research and development to improve our understanding of the risks associated with seaweed consumption in Africa. For instance, studies could be conducted to determine the levels of heavy metals in seaweed from different regions of Africa and to identify the most effective methods for reducing these levels. Additionally, research could be conducted to develop new technologies for detecting and removing from seaweed, such as advanced filtration systems or enzymatic treatments. The private sector also has a role to play in promoting the safe consumption of seaweed, by investing in research and development, and by adopting best practices for production and processing.

Regional and international cooperation is also essential for ensuring the safe trade of seaweed across borders. For example, the African Union could establish a common standard for the safety of seaweed, which would facilitate trade and reduce the risk of non-tariff barriers. Similarly, the World Health Organization (WHO) could provide technical assistance and guidance to African countries to help them develop and implement effective regulations and guidelines for seaweed. The WHO could also establish a global standard for the safety of seaweed, which would provide a framework for countries to follow. Consumers have a critical role to play in promoting the safe consumption of seaweed. By demanding safer and more transparent products, consumers can drive change in the industry and encourage producers and processors to adopt best practices. For example, consumers could choose to purchase seaweed products from companies that have been certified as safe and sustainable. Consumers could also report any concerns or complaints about seaweed products to regulatory agencies, which would help to ensure that these products are safe and compliant with regulations.

In the future, the demand for seaweed will likely continue to grow, driven by increasing awareness of its health benefits and its potential as a sustainable food source. However, this growth must be accompanied by a commitment to safety and sustainability, to ensure that the benefits of seaweed are shared by all. By working together, governments, regulatory agencies, the private sector and consumers can promote the safe consumption of seaweed and ensure that this valuable resource is used to improve the health and well-being of people across Africa.

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Citation: *Yusufu Kasato et al. Seaweed in Africa: A Mini Review of Industry, Benefits and Safety Concerns. International Journal of Research Studies in Biosciences (IJRSB). 2025; 11(1):01-08. DOI: https://doi.org/10.20431/2349-0365.1101001.*