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ALGAE - UNNECESSARY WASTE OR A VALUABLE RESOURCE [27]

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Abstract: *Can we see opportunities in problems? Can we use the principles of sustainable design and the circular economy as a basis for development and a philosophy of creation?*

In many parts of the world, the amount of algae, water plants, micro and macro seaweeds is increasing dramatically and turning beaches into inhospitable, dirty and even dangerous places. This organic waste should and can be used as a resource. As an example of what was said, the author is working on her own developments for insulation material based on green, brown and red algae from Black Sea..

Keywords*: R&D, algae, water plants, micro and macro seaweeds, building materials, insolation.*

INTRODUCTION

We are surrounded by natural resources that most of us carelessly consider annoying, even disgusting waste. Such is the case with seaweed on popular beaches – organic waste that someone has to clean up and dispose of somewhere. Due to the volume of seaweed washed up by the waves in some areas, mainly in Mexico, the Caribbean, but also in France, Spain, and sometimes even in the Black Sea, beaches get temporarily closed. There is strong evidence that climate change is contributing to an increase in the amounts of Sargassum and other types of algae in certain parts of the world (see Fig. 1), especially when combined with more nutrients coming from wastewater and changes in ocean circulation. Algae are used in many industries, such as food, cosmetics, medicine, and even textiles, but special farms, refineries, and reactors are built for them. But what is the natural solution to the problem of huge masses of algae accumulating on beaches?

Fig. 1. The Atlantic Sargassum belt often reaches record volumes. In May 2025, approximately 38 million metric tons were reported, exceeding even previous records.
Photo sources: https://akumaldiveshop.com/sargassum-the-what-where-and-why-of-this-seaweed/; https://geoblueplanet.org/turning-the-tide-on-sargassum/

EXPOSITION

Modern building materials have a high environmental footprint: cement and steel are highly energy-intensive and generate a large share of global CO_2 emissions, while aluminum and glass add further emissions and industrial waste. Petroleum-based asphalt, plastics, and insulation lead to air pollution and contribute to a number of diseases. Raw material extraction and long-distance transport destroy ecosystems and deplete resources, while mixed construction waste is rarely recycled. In the spaces we inhabit, paints,

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adhesives, panels, flooring, and various materials that emit volatile organic compounds degrade air quality and pose health risks.

In their attempts to solve a number of problems, scientists and entrepreneurs are creating more and more environmentally friendly materials that can be recycled or safely returned to nature, releasing useful substances. ***The circular economy*** is a relatively new concept, but it draws on experience from the past and traditions around the world. Building materials made from algae already exist - from traditional sea grass roofs and modern interior panels, through bio cements and “living” bricks, to bio reactive facades and bio-bitumen. Traditional roofs made of sea grass on the island of Læsø (see Fig. 2) are part of the living tradition there; today, they are part of a proactive conservation program and are included in the UNESCO tentative list (2023). Zostera roofs are durable, fire-resistant, and moisture-resistant thanks to the high mineral content of the material.

Fig. 2. Traditional roofs made of seaweed on the island of Læsø, Denmark.
Photo sources: Gert Pedersen/Flickr; Jörg-Dieter Langhans/Flickr

Another architectural example of the use of Zostera from the same island is "The Modern Seaweed House," built in 2013 (see Fig. 3). In it, seaweed is used as insulation, interior cladding, and exterior siding - a contemporary interpretation of tradition.

Fig. 3. “The Modern Seaweed House” on the island of Læsø, Denmark.
Photo source: https://archello.com/project/modern-seaweed-house

A completely modern and certified example of a building material is produced by the Danish company Søuld, which manufactures acoustic/thermal insulation interior panels and mats from Zostera (see Fig. 4). Fire reaction classes (e.g., D-s1, d2/D-s2, d1) and published technical data sheets/EPDs are provided; they are manufactured in Denmark and the products are designed to promote a healthy indoor climate due to low emissions, good moisture exchange, and sound absorption.

Fig. 4. Acoustic/thermal insulation panels from the Danish company Søuld.
Photo sources: https://www.sould.dk/

There are other promising examples of the use of different types of algae in the construction industry, which can currently be classified in the following table:

Table 1. Building materials, manufacturers and projects using seaweed. The table includes actual products, manufacturing and reference projects, R&D. The status "market" means available product; "pilot or R&D" means demonstrations, laboratory or single objects. The table was compiled in October 2025 and it is current at the moment.

Category, material	Product, project	Manufacturer, institution	Status	Country, region
Eelgrass panels for interior use (acoustics/insulation)	Søuld Acoustic Boards / Mats	Søuld	Market	Denmark (manufacturing) (Søuld)
Traditional eelgrass roofs	Seaweed Houses (traditions, restorations)	Community, museums on the island of Les	Actual use, cultural heritage	Denmark – Lesø (UNESCO tentative) (whc.unesco.org)
Contemporary house with seaweed	Modern Seaweed House (2013)	Vandkunsten + Realdania Byg	Completed project	Denmark – Lesio realdaniabyogbyg.org
Bioreactive facade with microalgae	SolarLeaf / BIQ House (2013)	Arup + partners	Completed pilot project	Germany – Hamburg (arup.com)
"Biocement"/algae-based additive	ProZERO™	Prometheus Materials	Market (industrial additive/blocks)	USA – Colorado (Prometheus Materials)
Alginate binders in biocomposites	Wood/textile panels with sodium alginate	University/R&D teams (e.g., Lacoste et al.)	Pilot project/ R&D	EU (France, etc.) (ScienceDirect)
Alginate insulation composites	Fibrous insulation with alginate binder	TU Delft and partners	R&D	Netherlands (proceedings.open.tudelft.nl)
Bio-bitumen/asphalt with algae	Mixtures with microalgae	UN teams (MDPI 2024)	R&D/pilot project	EU (Greece, etc.) (MDPI)
Asphalt modifiers (carrageenan)	Additives for regional asphalts	University research (SEA/ASEAN, 2024–2025)	R&D	Indonesia/SEA (ScienceDirect)
Bioregional panels/algae coatings (prototypes)	Material systems at Atelier LUMA	Atelier LUMA	Prototypes/pilot installations	France – Arles (luma.org)

The Black Sea and its algae differ from other seas and oceans

The Black Sea is the largest meromictic basin in the world, meaning that the upper ~0–150/200 m are relatively rich in oxygen, while deeper down the water is anoxic and sulfide-rich - the layers hardly mix. This sharply limits the productive zone and the depth limit of organisms living on or at the bottom (benthic communities) compared to, for example, the Mediterranean Sea or the Atlantic Ocean. The surface salinity is significantly lower than that of the ocean due to the massive freshwater inflow from the Danube and other large rivers. This favors the population of green macro algae and stresses typical ocean groups such as kelp forests, for example, which are typical of colder and saltier ocean coasts.

Specific seasonal sequence of phytoplankton with pronounced coccolithophore blooms. The “milky white” patches of Emiliania Huxley are an almost annual phenomenon on satellite images in May - July, associated with the recycling of nutrient salts after the spring diatom wave, high summer light intensity, and characteristic nitrogen (N) and phosphorus (P) ratios. Such regular and strong coccolithophore blooms are rarer in many other seas.

The Black Sea has a rich and coastal-concentrated diversity of green (Ulva, Cladophora), brown (Cystoseira/Gongolaria barbata, etc.) and red (Phyllophora, etc.) macroalgae; in the water column – seasonal communities of diatoms, dinoflagellates, coccolithophores (Emiliania Huxley) and cyanobacteria.

Algae - science and scientific research and business development in Bulgaria

Institute of Plant Physiology and Genetics – BAS (Lab. "Experimental and Applied Algology") is one of the oldest Bulgarian schools in algology, which built one of the first facilities for microalgae cultivation in Bulgaria, and today the team is working on algal biotechnology, cultivation, and applications.

Institute of Microbiology – BAS (Bioremediation and Biofuels Laboratory). The focus is on microalgae cultivation in photo bioreactors, CO_2 capture or utilization from industrial gases, and the synthesis of high-value products such as biofuels and additives.

Marine biology and aquaculture in the Black Sea. A number of Bulgarian reviews and reports outline the development of marine aquaculture, mainly mussels, assessment of algal blooms and ecosystem impacts along the Bulgarian coast.

Application of algae in animal feed. In 2023, the State Center for Risk Assessment in the Food Chain in Bulgaria published a review of microalgae as a raw material for sustainable animal feed, reflecting regulations, safety, and their nutritional potential.

Algae Bulgaria Ltd. is a farm for fresh spirulina (Spirulina platensis) for food and supplements with an industrial bioreactor and it is absolute pioneer of its kind in Bulgaria. The factory is based in the village of Zimnitsa, Stara Zagora.

Water plants in the river Danube, existing practices

River systems carry a variable load of sediments, pathogens, and heavy metals, which makes industrial harvesting of algae from the river for food and cosmetics undesirable. However, this is not the case for the production of various types of paper.

In 2020, nearly 2,600 tons of underwater plants were removed from the Danube in Vienna, in the part of the river that is used for recreation during the summer months. As is the case worldwide, for various reasons, the growth rate of aquatic plants in the Danube River has increased significantly. Around Vienna alone, about 4,000 tons are collected annually from an area of 170 hectares. The vegetation is collected regularly to prevent pollution of the banks and to allow the waters to be used for navigation. Until now, the collected biomass has been used primarily as compost. However, researchers at the University of Natural Resources and Life Sciences (BOKU) in Vienna are working on producing packaging material from the plants and using them as a raw material for biogas.

Author's developments of ecological insulation materials from Black Sea algae

As a creator and researcher in the field of industrial design and a person with a keen interest in ecology and the circular economy, the author of the scientific article is engaged in her own developments of insulation and building materials from algae. The University of Ruse is located on the Danube River, so it is logical that the experiments are conducted with Danube algae from this part of the river. However, the composition of Black Sea algae makes them more resilient, and the salinity of the environment in which they grow is what makes them difficult to burn, valuable qualities in the raw material for the production of insulation materials.

In the production of thermal and sound insulation materials other than EPS (expanded polystyrene, Styrofoam), XPS (extruded polystyrene), and polyurethane foam insulation (PUR, PIR), the binding element or "binding agent" depends on the type of insulation. Phenol-formaldehyde resins are most commonly used in mineral, glass, or rock wool, giving them mechanical strength and fiber stability. However, environmentally friendly alternatives are increasingly being developed, e.g., acrylic resins or biopolymers based on starch, lignin, and sugars. Natural insulation made from cellulose, hemp, flax, and sheep's wool is usually just mechanically pressed into panels, but starch adhesives or latex dispersions can also be used for mechanical compaction.

1. For the first attempts to create insulation material (see Fig. 5), polyvinyl acetate (PVA) dispersion was used as a binding agent between mechanically crushed pieces of seaweed. Polyvinyl acetate dispersion is a water emulsion of the polymer polyvinyl acetate **-** a white, milky-looking liquid material that is mainly used as an adhesive and binding agent.

Fig. 5. Mechanically cut mixture of Black Sea algae.
First attempts to obtain insulation material, sample.
Photos: personal archive

Polyvinyl acetate (PVA) is a synthetic polymer obtained by the polymerization of vinyl acetate monomer ($CH_2{=}CH{-}OCOCH_3$). A dispersion means that the polymer particles are finely distributed (dispersed) in water with the help of emulsifiers and stabilizers. After application, the water evaporates, the particles stick together and form a hard, transparent film. It is widely used in fillers, latex paints, primers and as a binding agent in plasters; It is used in woodworking and furniture manufacturing, in laminating and impregnating paper and textiles. The solution is simple and inexpensive, and the results with the material are promising.

2. After satisfactory results with materials obtained using PVA dispersion, experiments with methylcellulose MC (see Fig. 6) followed. Methylcellulose is a semi-synthetic derivative of cellulose - it is obtained when part of the hydroxyl groups in the cellulose molecule are replaced by methyl groups ($-CH_3$). Main properties: soluble in water, forms transparent, viscous solutions and insoluble in most organic solvents; non-toxic, biodegradable and completely safe for contact with food and skin. Methylcellulose is film-forming - it creates thin transparent coatings. It is used in the food industry (E461) - as a thickener, stabilizer, emulsifier in sauces, ice cream, baked goods; in pharmacy – as a binding agent, thickener and tablet coating; as an adhesive in bookbinding; as a thickener in creams, toothpastes, shampoos and in construction - as an additive to adhesives for wallpaper, plasters, putties, cement mixtures (improves water retention and adhesion). *Methylcellulose is one of the purest and most environmentally friendly adhesives* for paper and delicate materials.

Fig. 6. Variants of insulation materials made from Black Sea algae, samples.
Photos: personal archive

The experiments are in progress and give encouraging results such as density and necessary strength, which gives ideas for the development of other types of panels and building materials. Methodology and testing period are pending. The hope is that the materials can be certified and put into production in the foreseeable future.

CONCLUSIONS

At this stage, large-scale industrial cultivation of marine macroalgae in the open sea has not yet been established in Bulgaria - Black Sea aquaculture is dominated by mussels and fish; algae lines are mainly microalgae in freshwater or terrestrial systems. Apart from the use of algae in cosmetics and cooking, at this stage there is still no data on other developments in building materials involving or based entirely on algae. However, the problem of the growing amount of algae and their accumulation on beaches remains relevant.

With the right standards, local supply chains, and realistic economics, algae could become a key element of the low-carbon construction palette in many places around the world and in Bulgaria.

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