MACROALGAE COLLECTION AND STORAGE TECHNOLOGIES ANALYSIS

Developed by: Foundation “Attīstības fonds “Stari””

Project customer: Kurzeme planning region

Liepaja, 2020

Report has been developed on request of Kurzeme planning region for the Interreg Baltic Sea Region Programme 2014-2020 financed project Nr. R097 „Growing Algae Sustainably in the Baltic Sea "(GRASS) supported by the European Regional Development Fund.

Table of Contents

List of Tables and Figures

Summary

The present study has been developed on request of Kurzeme planning region for the Interreg Baltic Sea Region Programme 2014-2020 financed project No R097 „Growing Algae Sustainably in the Baltic Sea "(GRASS) supported by the European Regional Development Fund. Research has been implemented by foundation "Attīstības fonds "Stari"" which has summarized information on different technologies used worldwide (including Baltic Sea region) for collecting and storage of seaweed / macroalgae washed ashore. Besides, this study has analysed various technologies' potential suitability for specific environmental conditions of Kurzeme coast (wide sandy beaches). According to the present study it can be concluded that the most economically advantageous macroalgae collecting technology in Kurzeme is communal or agricultural technics – front loaders; for transportation – tractor trailers or motor transport. This technology can be used together with roll press. That kind of technology is economical and universal (i.e. suitable for different types of algae). It is also productive enough and does not require application of specialized machines. Thus, front loader with mean relative cost 0.92 EUR/m^3/h has been recently used on Liepaja beach. Roll press utilization possess an additional advantage for algae gathering projects – it ensures separation of considerable amounts of water obtaining, thus, easily transportable algae material. In its turn, the most convenient way for algae storage is using ensiling towers or – if such towers are not available – utilization of wrapping (in film) for silage.

Introduction

The present study is aimed to summarize information on different technologies used worldwide (including Baltic Sea region) for collecting and storage of seaweed / macroalgae washed ashore. Besides, this study is intended to analyse various technologies' potential suitability for specific environmental conditions of Kurzeme coast (wide sandy beaches) as well as to identify the most economically advantageous macroalgae collecting technology.

The following tasks have been implemented in the framework of this study:

1. Literature review. Expert interviews in order to characterize current situation and define research objectives;
2. Literature analysis (including review on relevant research done so far) in order to develop methodology for evaluation of algae collecting and storage technologies;
3. Using secondary databases – evaluation of worldwide used technologies, implementation of relevant experience analysis, identification of algae gathering and storage knowledge in Baltic Sea region;
4. Critical evaluation of data followed by development of relevant arguments and proposals for algae collecting and storage technologies which would be most suitable for Kurzeme region;
5. Development of research report (in Latvian and English).

In order to identify the most suitable one for Kurzeme coast the method of analysis of relative values of comparisons (which follows from the theory of relative advantage) has been used.

The theory of relative advantage grounds on abilities to produce goods and services with the lowest possible relative cost which would ensure the efficient use of resources. The present study evaluated mean costs per unit for each technology used in Liepaja and Trelleborg beaches – more concretely, it has been calculated what volume (m^3) of algae biomass could be gathered in 1 hour by particular technology. Besides, operation costs per hour have been estimated for each technology.

Research data are summarized in Tables 6 and 7.

Description of current situation

Seaweeds (marine macroalgae) washed ashore have been used by humankind for thousands of years: people utilize them as a food, fodder, soil fertilizer, biofuel, medical feedstock.

In Baltic Sea region (especially on coasts of Sweden, Denmark, Germany and Poland as well as on Lithuanian, Latvian and Estonian beaches) the gathered seaweeds have been represented predominantly by Black carrageen *Furcellaria lumbricalis* (henceforward – Furcellaria), according to CODIF RECHERCHE & NATURE.

Low salinity reduces algae diversity in Baltic Sea as well as causes decreased growth rate and development of dwarf forms for many species[1] - accordingly, brackish water environment could partially explain traditionally low seaweed resource use in this region.

Fig 1. Algae gathering in Kurzeme in the '40s of the 20th century [2]

In Latvia in old times carrageen gathered has been used as a soil fertilizer (sometimes also as a fodder). In Western Latvia (Kurzeme coast), at the beginnings of XX century peasants have been even granted a coastal strip for placement of carrageen-catching sieves to increase amount of collected biomass. Usually algae have been gathered by forks and spoon-nets, and loaded in carts for removal.

[1] - Russell, G. 1988. The seaweed flora of a young semi-enclosed sea: the Baltic. Salinity as a possible agent of flora divergence. Helgoländer Meeresuntersuchungen 42: 243–250.

[2] - "Darbs un Zeme" , 1943.g.

Industrial processing of Furcellaria has been first commenced in Denmark where "Danish agar" or carrageenan has been produced; agar commercial production started in middle 1960s[3] and could be considered as a good model for sustainable use of bioresources[4]. Danish experience facilitated also industrial agar manufacturing in Latvia.

In Latvia, *Furcellaria* processing for agar production has been developed in kolkhoz "Nākotne" (Jelgava District), in 60-70s of the last century. Coastal farmers and fishermen gathered seaweeds and transported them to the factory gaining thus considerable additional income.

In order to diminish transportation costs algae have been compressed by feet with a help of specific frame.

However, in 80s when economic situation changed (mainly due to increase of electric energy prices) and, besides, seaweeds were harmfully affected by petroleum pollution agar production become unprofitable and, accordingly, has been ceased.

Recently regular seaweed gathering on Kurzeme coast has been carried out only on Liepaja and Ventspils city beaches where algae are recognized as a biological waste and, accordingly, regularly removed – mainly due to tourist complaints (limited access to beach, bad smells). There is no regular seaweed harvesting on the rest of Kurzeme coast – only individual farmers gather algae detritus (with municipality permission) and use it as a soil fertilizer.

Considerable macroalgae biomass quantities which would reflect industrial needs are available only in Liepaja Region, namely, in Liepaja City, Pavilosta, Jurmalciems. The highest seaweed volumes are available exactly in Liepaja City and on beaches located south to Liepaja Harbour Southern mole.

Table 1. Amounts of seaweed washed ashore over summer & autumn 2018 (m^3 / 100m) [5]

Nr.	Location	Amount in summer	Amount in autumn
1.	Jūrmalciems	0	0,88
2.	Liepāja	0.44	228.29
3.	Ziemupe	0	0

[3] - R. Tuvikene, K. Truus, M. Robal, O. Volobujeva, E. Melikov, T. Pehk, A. Kollist, T. Kailas and M. Vaher, "The extraction, structure, and gelling properties of hybrid galactan from the red alga Furcellaria lumbricalis (Baltic Sea, Estonia)," Journal of Applied Phycology, pp. 51-63, 2010.

[4] Zhanjiang Fisheries College People's Republic of China and organized by the Regional Seafarming Development and Demonstration Project (RAS/90/002) "Training Manual on Gracilaria Culture and Seaweed Processing in China", Viewed in 10.10.2019. Retrieved from http://www.fao.org/3/AB730E/AB730E03.htm

[5] - "Jūras aļģu sanesumu izvērtēšanas un apsaimniekošanas plāns Latvijas piekrastē" (Biedrība „Baltijas krasti")

Nr.	Location	Amount in summer	Amount in autumn
4.	Pāvilosta	16.64	0.11
5.	Jūrkalne	0	2.54
6.	Užava	0	0.3
7.	Ventspils	0	0
8.	Miķeļbāka	0	0
9.	Sīkrags	0	0
10.	Kolka (*open sea*)	0	21.77
11.	Kolka (*bay*)	0	0
12.	Roja	0	0
13.	Mērsrags	0.1	0.19
14.	Engure	0.02	0.08
15.	Lapmežciems	13.21	0.02
16.	Jaunķemeri	61.85	0,08
17.	Melluži	9.22	21.77
18.	Saulkrasti	10.97	0
19.	Dunte	0.27	0
20.	Tūja	1.68	0
21.	Vitrupe	1.73	0
22.	Salacgrīva	112.2	0
23.	Ainaži	0.59	0

The main practical challenge is a fast and sizeable harvesting of seaweed – since humid atmospheric air causes quick biodegradation of algae with accompanied loss of their valuable properties. Besides, algae picked up from sandy beach usually contains considerable amount of sand decreasing thus possibilities to utilize this material as a feedstock. These issues should be brought into mind when considering seaweed utilization for industrial purposes.

Literature review and evaluation of technologies used

Seaweed gathering by hands

Picking up by hands is the simplest, the most ancient and still widespread seaweed harvesting technology – it has been used both in least developed countries like Zanzibar in Africa and developed countries like Scotland. Hand gathering has been chosen since some communities lack advanced algae-harvesting equipment, other ones cannot apply sophisticated technologies because of unfavourable coastal relief and stony beaches.

Fig 2.Algae harvesting in Zanzibar (Tanzania) [6]

Collected macroalgae usually have been piled up and then loaded in vehicles like carts, trailers, etc. According to authors` personal experience algae harvesting productivity is about 1000 kg per hour if using horse-drawn carts for transportation and just 200 kg if bringing algae by hands; productivity heavily depends upon local conditions.

In general, seaweeds pollution with sands could be considered as a moderate. Pollution level depends upon local conditions; as a rule, it is lower when using hand-gathering instead of harvesting by special equipment. Gathering by hands is also more beneficial environmentally: it has minimal environmental impact, including insignificant disturbance to surrounding fauna and flora. Besides, manual harvesting is socially important in least-developed countries since it improves employment situation and provides some income to considerable amount of people.

As regards to developed countries, hand-gathering is still important to ensure beach cleaning from algae waste in e.g. Ventspils city or Sopot (Poland) seashore.

[6] - Ilustrative picture. Viewed in 31.07.2019. Retrieved from https://www.gettyimages.com/detail/photo/pwani-mchangani-woman-collecting-algae-royalty-free-image/541243710?adppopup=true

Mechanized seaweed collection

Another widespread method to harvest piles of seaweed washed ashore is utilization of agricultural or utility machinery, front loaders, grabs, excavators and tractor trailers. Such an equipment has been used most often for macroalgae gathering in Latvia, Poland, Sweden, Australia, New Zealand.

Fig 3.Tractor technology use for algae gathering in France[7]

This technology is easily available and there is no necessity for its specific adjustment. As it has been already mentioned, the main weak point of this method is its comparatively low productivity and considerable sand admixture in the material gathered. Algae collected this way have been used mostly for soil fertilization – certainly, sand admixture is not an issue for such a project.

[7] - "Les algues vertes suspectées d'être la cause de plusieurs décès ces dernières années en Bretagne". Viewed in 31.07.2019. Retrieved from https://france3-regions.francetvinfo.fr/bretagne/rappel-deces-causes-algues-vertes-ces-dernieres-annees-bretagne-1696968.html

Fig 4.Sargasso algae gathering on the Caribbean Sea coast [8]

Specialized beach cleaning machines

Specialized beach cleaning machines have been constructed to separate sand from garbage. Still, their productivity is low: these machines are designed for treatment of small amounts of garbage.

[8] - La Croix "Guadeloupe, la guerre aux sargasses est déclarée", available online https://www.la-croix.com/Sciences-et-ethique/Guadeloupe-guerre-sargasses-declaree-2018-09-29-1200972467; accessed 31.07.2020.

Fig. 5. BeachTech 2800 beach cleaning machine [9]

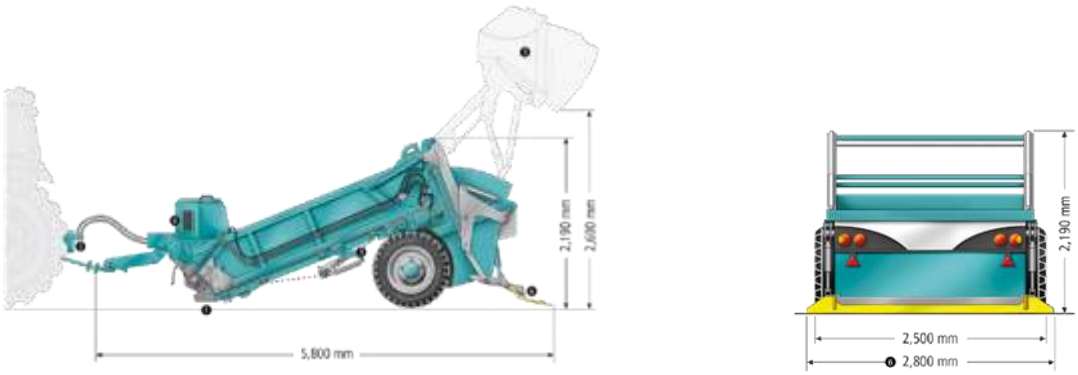

Fig. 6. Dimensions of BeachTech 2800 beach cleaning machine[10]

BeachTech 2800 (Fig. 5. & 6.) represents itself an example of such a cleaning machine. Its technical description reveals that volume of its garbage collection container comprises 2.8 m^3. Such a volume is insufficient for serious algae harvesting projects since small size container must be unstuffed too often – and it would mean frequent switch from algae gathering to unstuffing and back; accordingly, machine`s productivity and usability for seaweed gathering will be relatively low. Still, it is important to analyse structure of this particular machine in order to acquire basic ideas behind the construction of seaweed gathering equipment.

[9] "BeachTech Strandreiniger. Wegweisende Technik für saubere Strände". Viewed in 31.07.2019. Retrieved from https://www.beach-tech.com/fileadmin/content_beachtech/modul_8_download/Dateien/online-version-beachtech_broschuere-deutsch.pdf

[10] "BeachTech Strandreiniger. Wegweisende Technik für saubere Strände". Viewed in 31.07.2019. Retrieved from https://www.beach-tech.com/fileadmin/content_beachtech/modul_8_download/Dateien/online-version-beachtech_broschuere-deutsch.pdf

BeachTech type of machines has the following unit for garbage pick-up: rotatory, flexible steel "fingers" which lift up garbage pieces from the sand and put them on the moving belt which serves also as a sieve for sand separation.

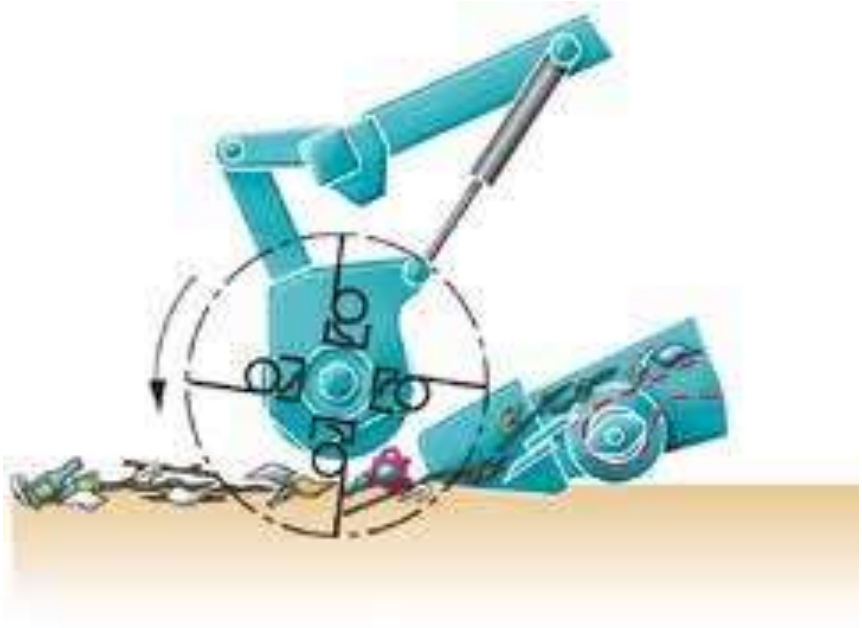

Fig. 7. Rotatory steel "fingers" for garbage gathering[11]

Apart from the garbage itself, rotatory device picks-up also considerable amount of sand. If sand is dry, it falls through the sieve, and "clean" garbage then moves to container. If, on the contrary, the sand is wet, it moves together with the garbage.

[11] "BeachTech Strandreiniger. Wegweisende Technik für saubere Strände" Viewed in 31.07.2019. Retrieved from https://www.beach-tech.com/fileadmin/content_beachtech/modul_8_download/Dateien/online-version-beachtech_broschuere-deutsch.pdf

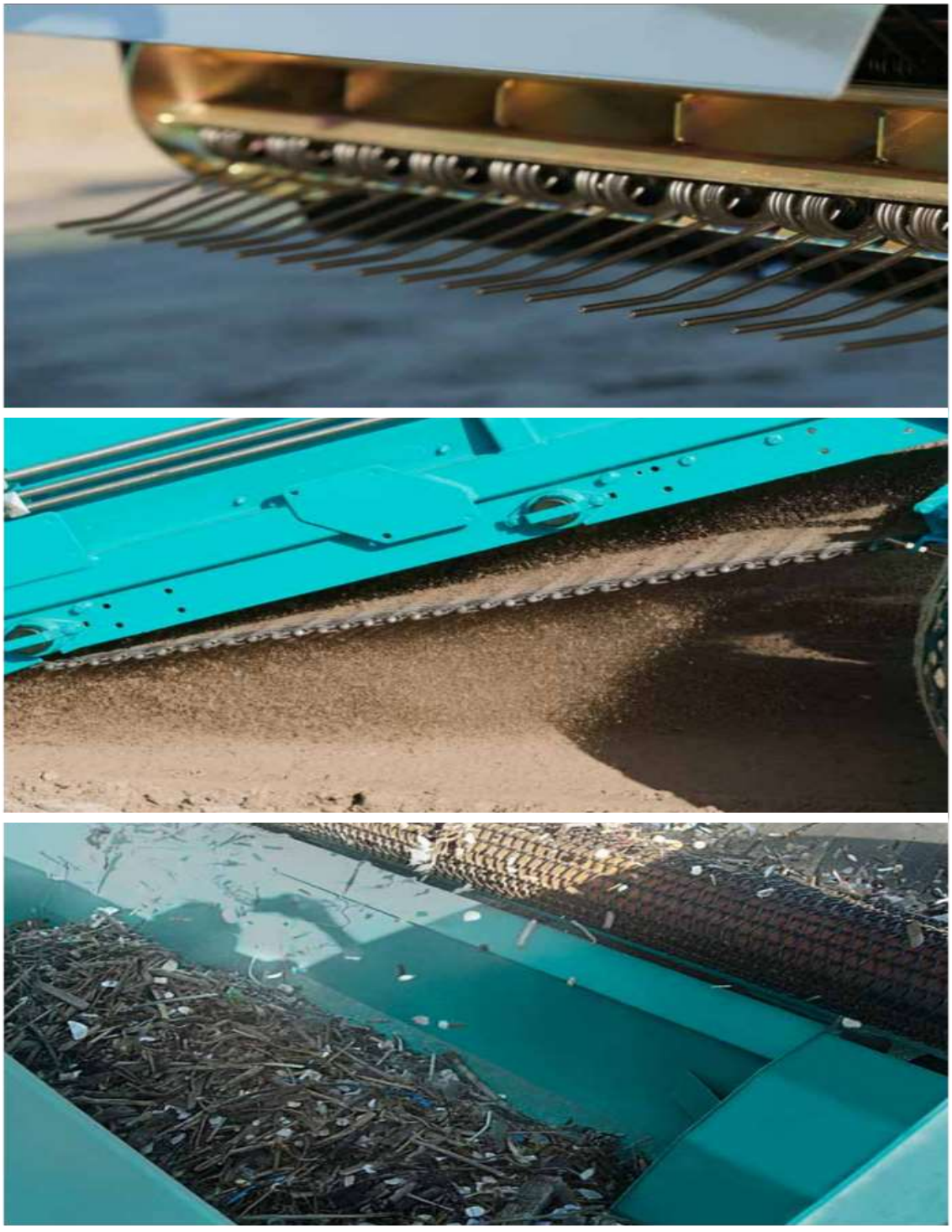

Fig. 8. Garbage collection, transporting and storage devices [12]

[12] - "BeachTech Strandreiniger. Wegweisende Technik für saubere Strände" Viewed in 31.07.2019. Retrieved from https://www.beach-tech.com/fileadmin/content_beachtech/modul_8_download/Dateien/online-version-beachtech_broschuere-deutsch.pdf

In order to ensure highly efficient sand removal from seaweed / garbage material additional appropriate active or passive elements should be attached to the transporter belt – they would interact with material gathered separating thus sand admixture.

Nevertheless, previously described technology could ensure clean algae output only if the sand is completely dry – and it is not possible if algae have been washed ashore not long ago.

Fig. 9. "Cherrington" company`s garbage collection machine`s set-up[13]

In comparison with garbage gathering process that was described Fig. 9 demonstrates "Cherrington" company`s garbage collection machine which functions differently: steel forks lift up garbage and put it on immobile sieves Conveyor blades move near these sieves and shift garbage material along the surface of sieves, cleaning it from the sand. It looks like this garbage collection

[13] - Online Brochure Main Cherrington Model 5450 Booklet. Viewed in 31.07.2019. Retrieved from https://literature.puertoricosupplier.com/089/DW88630.pdf

technology is more efficient and more suitable for seaweed gathering – however, more research is necessary to get full confidence.

Free-floating algae harvesting

Seaweed sites where algae have been gathered directly from water (including seaweed aquaculture) require floating equipment with relevant algae catching and storage devices. Certainly, such an equipment could be used only if chosen marine sites are physically accessible (coastal relief).

Fig. 10. Chinese company`s "Julong" algae gathering machine[14]

[14] - Product description "Hot sell Aquatic weed harvester/ water lawn mower machinery/ Garbage salvage boat". Viewed in 31.07.2019. Retrieved from https://dredgerchina.en.made-in-china.com/product/pSAnLPCTmgUQ/China-Hot-Sell-Aquatic-Weed-Harvester-Water-Lawn-Mower-Machinery-Garbage-Salvage-Boat.html

Fig. 11. Floating algae collecting machine in France[15]

Unfortunately, these machines are not applicable everywhere on Baltic Sea coast since beach waters could be too shallow (especially in Eastern Baltic). The most appropriate depth for floating machine is at least 2 m.

Choice of particular algae gathering technology also depends upon economic considerations. It would not be gainful for small users to have specialized seaweed gathering technology because of its high price and owners` inability to make full use of the machine (the latter would be necessary for recoupment).

Seaweed processors need clean and fresh macroalgae feedstock – consequently, heavy-duty highly productive clean-working seaweed gathering machines are necessary. Such a technology is available, however it is very expensive – it costs starting from hundred thousand euros. For example, Canadian company Aquamarine (https://www.aquamarine.ca/) offers heavy-duty specialized machines Custom Beach Harvester.

[15] - Product descriptio "Aquatic Weed Harvester". Viewed in 31.07.2019. Retrieved from https://weedersdigest.com/eco-harvester-aquatic-weed-harvester/

Specialized seaweeds gathering technology

Specialized seaweeds gathering technology usually has been constructed on the basis of rebuilt undercarriage of different combines – like cereals, corn and sugar cane harvesting ones.

Undercarriage rebuilding is related first of all to material gathering components, e.g., heder replacement by a smaller size rotor pick-up mechanism. Conveyor construction has been modified as well – to strengthen purification and dewatering functions. Container size, construction and unstuffing mechanisms can be also altered, e.g. through changeable container modules integration.

Fig. 12. Macroalgae collecting machine for seashore works[16]

[16] - "Les algues vertes suspectées d'être la cause de plusieurs décès ces dernières années en Bretagne". Viewed in 31.07.2019. Retrieved from https://france3-regions.francetvinfo.fr/bretagne/rappel-deces-causes-algues-vertes-ces-dernieres-annees-bretagne-1696968.html

Fig. 13. Highly productive seaweed gathering machine [17]

Fig. 14. Sargasso algae gathering on the beach using heavy-duty specialized machine[18]

Heavy-duty specialized algae collecting machines have been constructed to ensure quick algae harvesting from beach sites. Gathering mechanisms are not efficient enough to provide cleanness of algae biomass, though: collected algae still contain considerable ratio of sand admixture. Besides, beach cleaning efficiency is insufficient as well – accordingly, repeated drives or even combining of different machines is necessary. Nevertheless, these machines are highly productive

[17] - Ilustrations of special machines from Axinor S.A.R.L. realized project. Viewed in 31.07.2019. Retrieved from http://www.axinor.fr/real.htm

[18] - Ilustrations of special machines from Axinor S.A.R.L. realized project. Viewed in 31.07.2019. Retrieved from http://www.emavitrine.com/68102-axinor/home-EN.htm

– and it means substantial time-savings for cleaning works. Still, collected algae need additional washing prior to use them for processing.

Unlike algae used for fertilization, seaweeds for industrial processing have been collected in coastal waters where additional rinsing is possible, and, accordingly, disturbing sand admixture could be easily removed.

Algae to be processed should be collected as fast as possible in order to avoid decaying caused by contact with atmospheric oxygen. Heavy-duty machines have been developed to ensure such seaweed gathering. These machines are adapted for working in coastal waters. They have been additionally supplied with caterpillar tracks in order to decrease pressure on ground with simultaneous increase in traffic ability and mitigation of environmental impact. Conveyer of algae gathering mechanism is long enough to ensure full dewatering of seaweed biomass – consequently, collected algae material is comparatively dry when it reaches the container.

Loading container is comparatively large (25-30 m^3) in order to avoid algae collection process to be interrupted too often and thus assuring an increase in machine`s productivity.

Fig. 15. Algae collecting in coastal waters, France[19]

Comparison of technologies: SWOT analysis

SWOT analysis has been performed to sum up information about discussed technologies and to reveal their strength and weakness in order to make justified choice of technological solution (see Table 2).

[19] - "Les algues vertes suspectées d'être la cause de plusieurs décès ces dernières années en Bretagne". Viewed in 31.07.2019. Retrieved from https://france3-regions.francetvinfo.fr/bretagne/rappel-deces-causes-algues-vertes-ces-dernieres-annees-bretagne-1696968.html

Table 2. Compared algae gathering technologies – strength and weakness summarization

Technology	Strength	Weakness
Seaweed gathering by hands	The most widespread and the most long-standing technology Can be used in hard-to-reach sites Moderate algae pollution with sand Additional income for people in the least developed countries Low environmental impact	Low productivity
Mechanized seaweed collection	Widely accessible technics has been used No special adjustment necessary Comparatively low mean relative costs	Relatively low productivity Considerable sand admixture
Specialized beach cleaning machines	Rotatory, flexible steel "fingers" as one of machine`s components: allow to collect considerably clean algae	Low productivity Designed for gathering of small amounts of garbage Often switch from algae collecting to unloading and vice versa
Free-floating algae harvesting	Particularly high cleanness of material gathered	Technology could be used not everywhere on Baltic Sea coast Expensive technology

Technology	Strength	Weakness
		Comparatively high mean relative costs
Specialized seaweed gathering technology	Undercarriage of different combains could be used for construction	Collected algae contain high level of sand admixture Additional washing is necessary to make algae useful for processing

According to available information, Baltic Sea countries utilize the following technologies for algae gathering:

Table 3. Comparison of algae gathering technologies used in Baltic Sea countries

State	Technology	Collection site
Estonia	Pumping from lagoon or agricultural technics	Lagoon or coast
Latvia	Front loader or hand work	Coast
Lithuania	Front loader	Coast
Poland	Grab loader or hand work	Coast
Germany	Front loader	Coast
Denmark	Front loader	Coast
Sweden	Front loader	Coast

As regards to Finland, there are no available data on gathering technologies used.

Comparison of technologies utilization clearly demonstrate domination of front loader use; as a rule, algae have been collected on coast. Besides, front loader could be useful also for algae gathering in lagoons.

Algae storage

In seaweed gathering sites where algae processing is not implemented, seaweeds are utilized for agricultural fertilization and delivered to field just after the harvesting.

Seaweeds harvested on Kurzeme coast in the 1960s-80s used to be dried on nets in the open field and then transported to kolkhoz "Nākotne" where they have been processed into carrageenan. Similarly, seaweeds are stored in Estonian factory "Est - Agar". (http://estagar.ee/) which is algae processing site nearest to Kurzeme coast.

Trelleborg (Sweden) municipality owns *Detox Biogas AB* which has commissioned study on testing of macroalgae collection and storage methods (Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality[20]).

Algae storage has been studied in relation to the following technologies:

1. Using ensiling towers (designed for appropriate storage of different bulk materials – like forage, grains, salt, woodchips, etc.),
2. Making silage in bunkers (trenches),
3. Using wrapping (in film) for silage.

In all the cases lactic acid bacteria development takes place and, accordingly, preservative environment has been created to ensure long-term algae storage.

Table 4. Comparison of algae storage technologies

Algae storage technology	Advantages / Disadvantages
Using ensiling towers	Few manual work / not widely available
Making silage in bunkers (trenches)	Widely available, relatively cheap / product decay related risk factors
Using wrapping (in film) for silage	Agricultural machinery can be used

Silage through seaweed wrapping should be considered as a the most beneficial method for users since it represents itself widespread, well-known technology.

[20] - Study "Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality". Viewed in 31.07.2019. Retrieved from http://wabproject.pl/files/Technological%20solutions%20for%20the%20collection%20and%20removal%20of%20algae%20from%20the%20beach,%20sea%20and%20coastal%20strip%20in%20Trelleborg%20Municipality%20%20ENGLISH.pdf

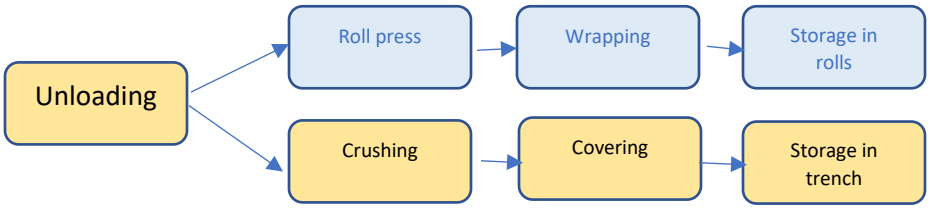

Fig. 16. Seaweed preparation for storage: recommendable technological charts

Still, storage technology should be subordinated to algae processing technology. If algae with low pH and high lactic acid contents could be used for biogas production, proposed storage method will not be always useful for extraction.

Different gathering machines` suitability for diverse coastal environments has been compared in Trelleborg tests as well.

Table 5. Coastal type suitability for different macroalgae gathering technologies[21].

Savākšanas tehnika	Coastal type	Coastal suitability
Grid bucket	Sandy coast (beach & water)	**70%**
Pontoon machines	Harbour	**5%**
Beach cleaners	Sandy coast, water	**35%**
Dry pumping	Sandy coast Pebble coast	**45%**
Water pumping	Sandy coast	**45%**
Deep-water pumping	Pebble coast	**45%**

[21] - "Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality". Viewed in 31.07.2019. Retrieved from http://wabproject.pl/files/Technological%20solutions%20for%20the%20collection%20and%20removal%20of%20algae%20from%20the%20beach,%20sea%20and%20coastal%20strip%20in%20Trelleborg%20Municipality%20%20ENGLISH.pdf

Trelleborg research data has been summed up in the following comparative results table.

Table 6. Comparison of macroalgae gathering technologies[22].

Gathering technology	Productivity (m^3/h)	Costs (EUR/h)	Mean relative costs (EUR/ m^3/h)	Suitability
Grid bucket	80	96.18 -144.27	1.50	Beach and water
Pontoon machines	4 - 12	144.27-192.36	10.52	Harbour
Beach cleaners	2 - 10	144.27-192.36	28.07	Beach
Dry pumping	2 - 7	192.36 – 288.54	48.09	Beach
Water pumping	2-12	192.36 – 288.54	34.36	Beach
Deep-water pumping	10 - 40	96.18 -144.27	4.80	5-10 m depth

Test results demonstrated that the most efficient algae gathering method is front loader with grid bucket use for beach seaweed piles. Research also reveals beneficial experience of roll press application thus additionally supporting significant potential of this machine.

These algae gathering technologies have been implemented also in Liepaja – relevant data are reflected in Table 7 (data source – statistical information offered by Liepaja Communal management Authority and Tranzīts L Ltd).

Table 7. Comparison of macroalgae gathering technologies in Liepaja City

Gathering technology	Productivity (m^3/h)	Costs (EUR/h)	Mean relative costs (EUR/ m^3/h)	Suitability
Front loader	60	50 - 60	0.92	Coastal
Pontoon machines	-	-	-	-

[22] - "Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality". Viewed in 31.07.2019. Retrieved from http://wabproject.pl/files/Technological%20solutions%20for%20the%20collection%20and%20removal%20of%20algae%20from%20the%20beach,%20sea%20and%20coastal%20strip%20in%20Trelleborg%20Municipality%20%20ENGLISH.pdf

Gathering technology	Productivity (m^3/h)	Costs (EUR/h)	Mean relative costs (EUR/ m^3/h)	Suitability
Beach cleaners	4	30	7.5	Coastal
Dry pumping	-	-	-	-
Water pumping	-	-	-	-
Deep-water pumping	-	-	-	-

Front loader with grid bucket appeared to be the most efficient seaweed gathering technology (lowest mean relative costs) both according to Trelleborg study and Liepaja city experience. Despite algae collection with beach cleaners is more advantageous on Liepaja coast than in Trelleborg case it is still not efficient enough both from economic and technical point of view (i.e. low collection productivity).

The most appropriate algae collection and storage technologies for Kurzeme region

The following considerations must be taken into account when collecting algae on Kurzeme coast:

1.coast is predominantly sandy in all the territories where seaweed is washed ashore;

2.algae are located on land or shallow waters where depth does not exceed 0.6 m;

3.there is a limited time for algae to be removed from seashore (in accordance with management agreement);

4. agricultural or utility technics could be used for algae collecting.

As demonstrated in Table 7 front loader appeared to be the most efficient seaweed gathering technology (lowest mean relative costs) in Liepaja city. Algae collecting with beach cleaner is not efficient enough both from economic and technical point of view (i.e. low collection productivity). Still, if front loader used instead of grid bucket, sand admixture would increase. Pumping and pontoon machines are not used because they are not available; buying them would not be cost-effective. Deep-water pumping is not possible in Latvia because of ecological considerations.

As it was mentioned above, if algae have been used as a fertilizer or considered to be a biological waste, their cleanness is of no importance and, accordingly, seaweeds could be collected using any technology available – like front loader and tractor traction machine which are comparatively productive technologies. If, on the contrary, collected algae are intended for processing, they have to be clean and fresh. Such a high-quality material could be obtained only in coastal waters through using heavy-duty specialized algae collecting machines.

Seaweeds intended for processing could be gathered also by farmer-owned technologies – however, algae have to be washed before utilization. Farmers can use hay-gathering equipment, both original or modified – like rotatory rake, hay press, lift fork, tractor traction machine: they all could be useful for algae collection. Storage – through drying algae on horizontal nets.

Still, field tests have to be carried out in order to get full confidence about suitability of this technology and to get to know technical improvements necessary. Therefore, relevant field tests will be implemented in the framework of present study: algae gathering with lattice front loader and roll press will be tried out in autumn 2020.

If users are planning to modify construction of the machine appropriate legal harmonization is necessary; it has to be based on:

Commission Delegated Regulation (EU) No 1322/2014 of 19 September 2014[23] supplementing and amending Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to vehicle construction and general requirements for the approval of agricultural and forestry vehicles.

Since there is no intention to change all the construction of the machine, testing will be focused only on selected elements / modules to be modified; in addition, methods of comparative evaluation will be used.

Planned field tests are aimed to determine agricultural machinery suitability for seaweed collection. In particular, hay roll press suitability for algae gathering will be tested.

Testing methods will include:

1. Hay press running and detection of collected amount at different movement speeds;
2. Hay press running and collected amount detection at different locations of collecting device;
3. Hay press running and collected amount detection at different algae layer thickness;
4. Sand admixture amount will be detected in all the test regimes.

In order to ensure statistical data reliability each test regime will be repeated 10 times.

Possibly, construction of the gathering mechanism will be modified if there will be high probability it will increase machine`s productivity.

[23] - Commission Delegated Regulation (EU) Nr. 1322/2014 (September 19, 2014). https://eur-lex.europa.eu/legal-content/LV/TXT/HTML/?uri=CELEX:32014R1322&from=LV

Conclusions

Globally the most common way for algae gathering is utilization of communal or agricultural technology – front loaders; for transportation – tractor trailers or motor transport. Such a technology is suitable for different users since these machines are broadly available and do not requires special adjustment. This kind of technology is economical and universal (i.e. suitable for different types of algae). It is also productive enough and does not require application of specialized machines.

Algae gathered in this way do not need additional treatment if intended for biogas production or soil fertilization. Whereas, if algae will be used for extraction, they must be preliminary washed in order to get rid of sand and impurities.

Roll press utilization possibility is of particular interest since it would ensure separation of considerable amounts of water obtaining thus easily transportable collected algae material. Still, field tests have to be carried out in order to get full confidence on suitableness of this machine.

References

1. Latvijas lauksaimnieku gadagrāmata "Darbs un Zeme". Jelgava: Zemgale, 1943
2. Pētījums "Jūras aļģu sanesumu izvērtēšanas un apsaimniekošanas plāns Latvijas piekrastē". Biedrība „Baltijas krasti"; 2018
3. "Guadeloupe, la guerre aux sargasses est déclarée"*// La Croix.* 29.09.2018.
4. R. Tuvikene, K. Truus, M. Robal, O. Volobujeva, E. Melikov, T. Pehk, A. Kollist, T. Kailas and M. Vaher. The extraction, structure, and gelling properties of hybrid galactan from the red alga Furcellaria lumbricalis (Baltic Sea, Estonia) *// Journal of Applied Phycology*. 2010
5. Russell. G. The seaweed flora of a young semi-enclosed sea: the Baltic. Salinity as a possible agent of flora divergence*// Helgoländer Meeresuntersuchungen*. 1988. Nr. 42. P. 243–250
6. http://www.emavitrine.com/68102-axinor/home-EN.htm Uzņēmuma Axinor S.A.R.L. speciālo mašīnu realizēta projektu ilustrācijas."; (31.07.2020)
7. https://weedersdigest.com/eco-harvester-aquatic-weed-harvester/ Produkta apraksts "Aquatic Weed Harvester"; (31.07.2020)
8. https://dredgerchina.en.made-in-china.com/product/pSAnLPCTmgUQ/China-Hot-Sell-Aquatic-Weed-Harvester-Water-Lawn-Mower-Machinery-Garbage-Salvage-Boat.html Produkta apraksts "Hot sell Aquatic weed harvester/ water lawn mower machinery/ Garbage salvage boat"; (31.07.2020)
9. https://literature.puertoricosupplier.com/089/DW88630.pdf Online Brochure Main Cherrington Model 5450 Booklet; (31.07.2020)
10. "BeachTech Strandreiniger. Wegweisende Technik für saubere Strände" https://www.beach-tech.com/fileadmin/content_beachtech/modul_8_download/Dateien/online-version-beachtech_broschuere-deutsch.pdf online-version-beachtech_broschuere-deutsch.pdf; (31.07.2020)
11. http://www.codif-recherche-et-nature.com/wp-content/uploads/2016/02/HYDRANOV-FICHE-BOTANIQUE-GB.pdf Botanical Sheet Furcellaria lumbricalis; 31.07.2020.

12. Veillard K. Les algues vertes suspectées d'être la cause de plusieurs décès ces dernières années en Bretagne // https://france3-regions.francetvinfo.fr/bretagne/rappel-deces-causes-algues-vertes-ces-dernieres-annees-bretagne-1696968.html; (09.07.2019)
13. The Research “Technological Solutions for the Collection and Removal of Algae from the Beach, Sea and Coastal Strip in Trelleborg Municipality”.
14. The Research “Training Manual on Gracilaria Culture and Seaweed Processing in China”. Zhanjiang Fisheries College; 1990