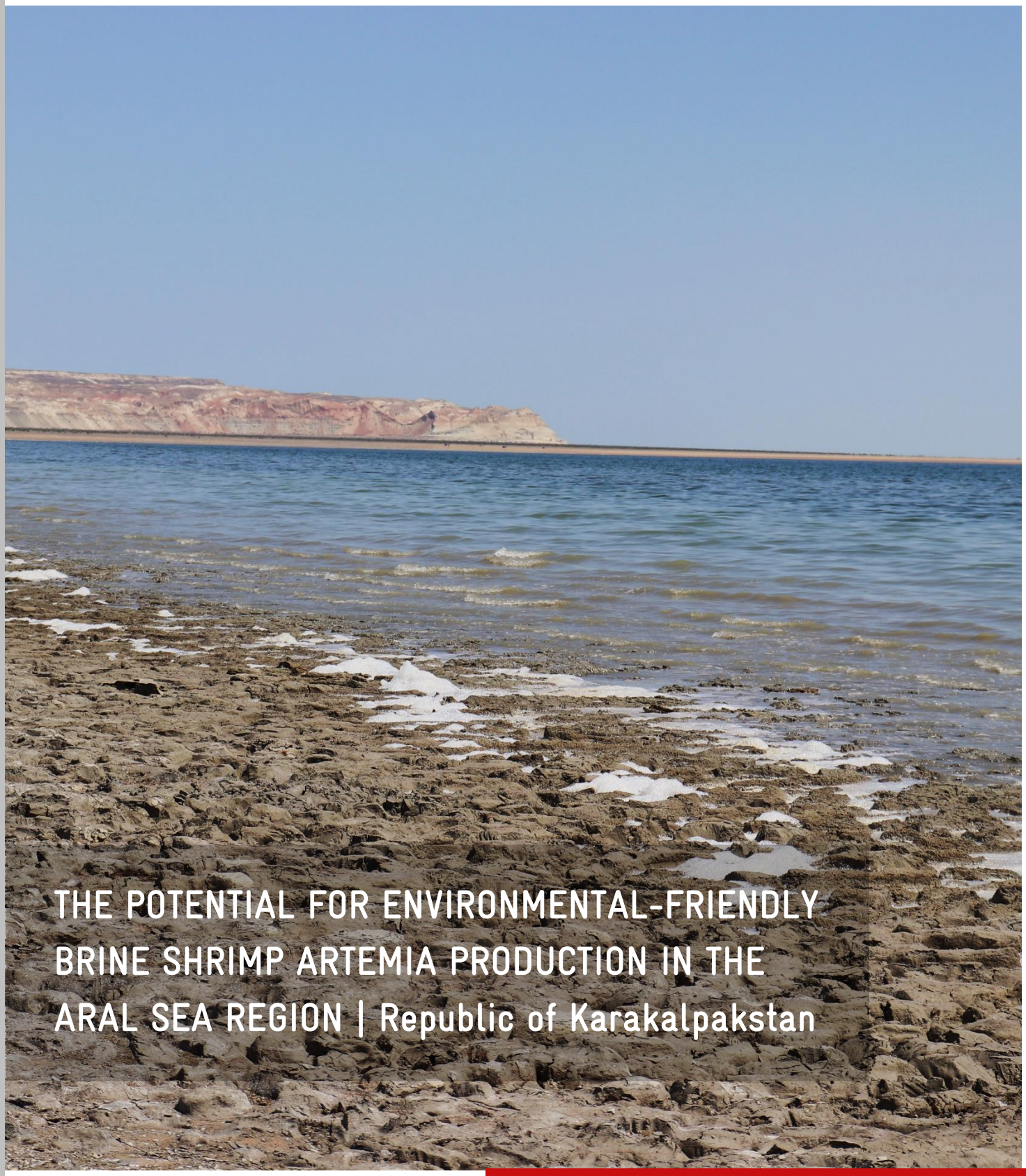

THE POTENTIAL FOR ENVIRONMENTAL-FRIENDLY BRINE SHRIMP ARTEMIA PRODUCTION IN THE ARAL SEA REGION | Republic of Karakalpakstan

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

GHENT UNIVERSITY

ECOLOGICALLY ORIENTED REGIONAL DEVELOPMENT IN THE ARAL SEA REGION

The potential for environmental-friendly brine shrimp Artemia production in the Aral Sea region | Republic of Karakalpakstan

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On behalf of
German Federal Ministry for Economic Cooperation and Development (BMZ)

Uzbekistan, 2021

CONTENTS

1. INTRODUCTION

Brine shrimp Artemia, a 1 cm crustacean species living in salt lakes and solar saltworks is playing a key role in the production of over 10 million tons of high-value aquatic species (Sorgeloos and Roubach, 2021). Artemia produces cysts (encapsulated and inactivated embryos) that are collected in bulk from salt lakes and shipped dry to aquaculture farms around the world. The cysts can be hatched into 0.5 mm Artemia nauplii that are used as a suitable substitute for natural live plankton in the feeding of a wide variety of marine and freshwater crustaceans and fishes. Adult Artemia (called biomass) has a high nutritional value (high protein content with excellent amino acid and lipid profile) can also be used (e.g. as fish meal replacement) in the grow out and maturation diet of different aquaculture species and even terrestrial animals (chicken in China). In Vietnam it is even used in human diets (Artemia omelet) and is considered in other SE Asian countries as partial replacement in shrimp/fish/crab cakes) (Hoa and Sorgeloos, 2020). Global demand for Artemia cysts is on the order of approximately 3500 tons per year (Sorgeloos and Roubach, 2021). The Great Salt Lake (GSL), Utah, USA, is still the main supplier of Artemia cysts on the world market but the unpredictability of these GSL harvests (climate effects) and from the many other salt lakes often not exploited following sustainable practices (Lavens and Sorgeloos, 2000; Sorgeloos and Roubach, 2021) are strong incentives to explore alternative resources.

Since the 1990s multiple international scientific studies have described the Aral sea ecosystem in their transition from a freshwater into a hypersaline water body, including the gradual colonization of the lake by a parthenogenetic (all female) Artemia population. Over the period 2003 to 2007 Ghent University coordinated 2 NATO projects to assess the production potential of this emerging Artemia population in the Aral Sea (Marden et al. 2012). In that period the salinity in both the East and West Aral was over 80 g/L excluding the presence of predators and favoring a monoculture situation for Artemia. However, food conditions for Artemia were not favorable due to unsuitable algal composition and low primary productivity, especially in the much deeper West Aral. It was recommended not to start commercial harvesting but to extend the study to define sustainable harvesting protocols of Aral Artemia cysts based on similar methodologies as developed and implemented for the Great Salt Lake.

Over the last decade further evaporation of the Aral Sea has resulted in a gradual drying out of the East Aral and a further increase of the salinity in the West Aral. Before its complete desiccation several hundreds of tons of Artemia cysts were harvested annually from the East Aral and since a few years commercial cyst harvesting has moved to the West Aral (following unconfirmed reports annual quota amount to over 2000 tons fresh product).

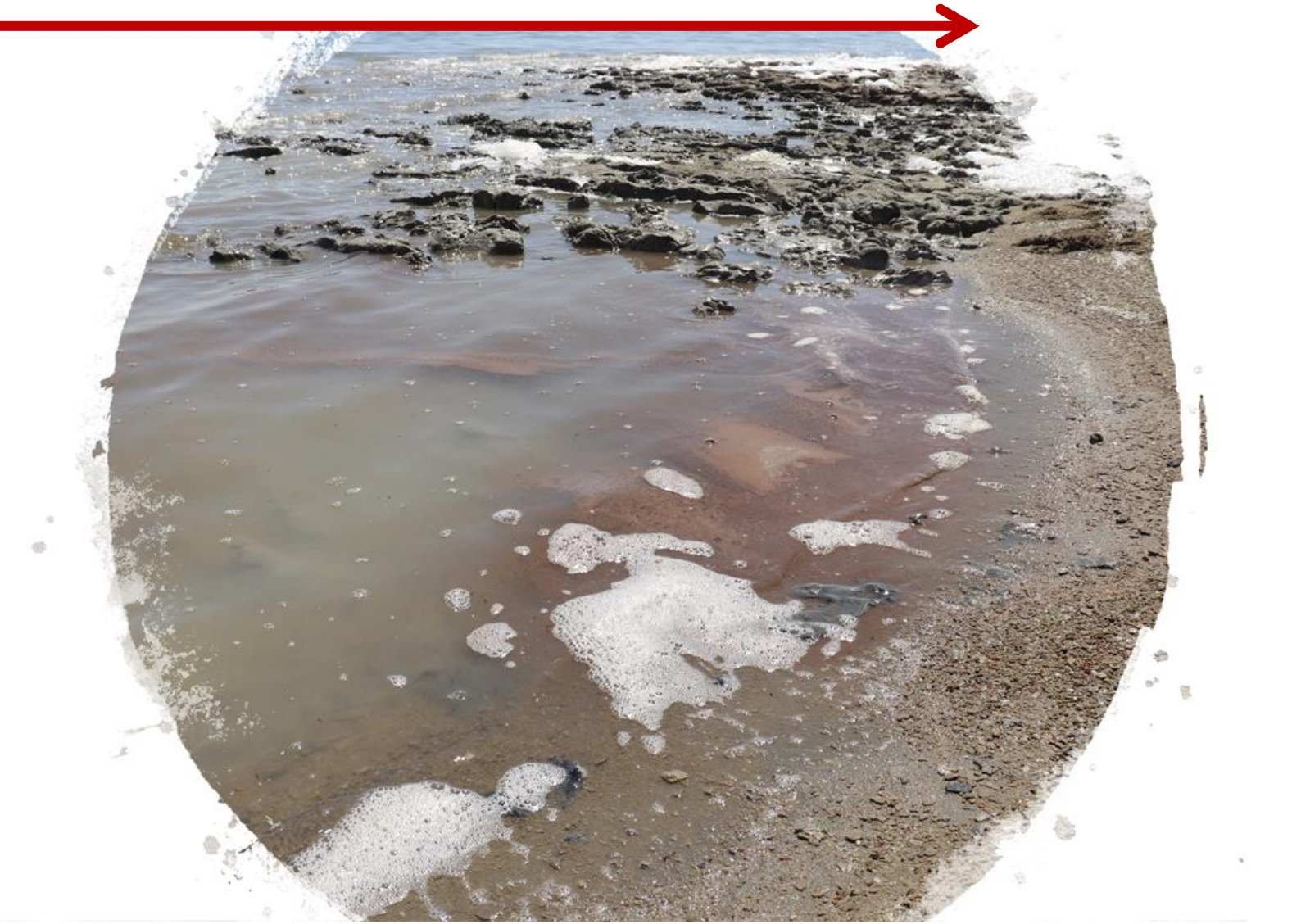
With the present rate of evaporation and consequent increase of salinity the future of the West Aral as a continued source of Artemia is under severe threat and will eventually disappear when salinity levels become too high under food-limited conditions. Since December 2020 several meetings were organized upon initiative of the embassy of Uzbekistan in Brussels with different stakeholders involved in the Aral sea Artemia exploitation. A final consensus was reached that an expert mission should be organized to explore what, if any, opportunities there are for short-term or eventually long-term developments with Artemia in Karakalpakstan.

In the framework of the GIZ regional project "Ecologically oriented regional development in the Aral Sea region" (ECO-ARAL) such Artemia mission was prepared and performed in May 2021 with the specific aims "… in-depth analysis and recommendations to the effectiveness, impact and feasibility of environmentally friendly Artemia (brine shrimp) cultivation and potentially other saltwater aquaculture species in the Aral Sea region".

For this mission report the following Terms of Reference were taken into account: 1) consider the economic as well as environmental risks and potentials of Artemia and other aquaculture developments in the region in the natural Aral Sea shores, artificial ponds where leach and drainage water from the fields could potentially be used, and/or irrigation channels near agricultural fields, and 2) prepare an overall plan for short-term and long-term approach for environmental-friendly

aquaculture developments in the Aral Sea basin considering the following aspects:

- adoption of new harvesting protocols for the sustainable exploitation of the present (remaining natural) Artemia resources: including the setting up of more added value techniques as a more economical alternative for the present export of raw material (unprocessed cysts),
- examining the potential for setting up of small-scale Artemia farms (similar to the successful model practiced in seasonal salt pond systems, see Hoa and Sorgeloos, 2020, and Van Stappen et al. 2020) for production of selected (high-value) Artemia cysts or for the production of Artemia biomass,
- examining the potential for setting up cooperative processing centers for Artemia cysts and for Artemia biomass for local use (in aquaculture, in terrestrial animal farming as high-quality animal protein source, in local human diets) and for export (food for aquaculture),
- evaluating the potential for pond production of fish and crustacean species in the salt affected soil systems in the Aral Sea basin,
- assessing the capacity needs, i.e. short term training (e.g. in Artemia production and quality control techniques in e.g. Vietnam, Thailand, Belgium), long term training (MSc in aquaculture, different English programmes in SE Asia, Europe and USA) to prepare future staff with aquaculture expertise for new jobs in policy making, education/training/research and private sector developments.



2. MISSION FINDINGS

2.1 West Aral

Since last visit more than 15 years ago the East Aral basin is no longer under water and commercial Artemia cyst harvesting has been suspended (although there must still be significant accumulations of cysts in the dry lakebed). In the meantime, the West Aral has further evaporated and the deepest parts are now only 30m versus 70m some 15-20 years ago. Water salinity has now reached 175 g/L and increases by 4-5 g/L per year.

Two plans are under consideration to stabilize the salinity in the West-Aral sea and consequently save the Artemia resource. One option is the inflow of freshwater from the North Aral in Kazakhstan (building of new canal). The second option is the completion of the drainage canal from the agriculture fields some 100 km South of the Aral sea: this canal project was initiated with Chinese assistance but the decision to build the last 50 km has been postponed. Upon discussion with several stakeholders it is accepted that both plans are not realistic and most probably not cost-effective (at least for an Artemia exploitation) on a short-term basis.

Due to strong winds it was not possible to enter the lake by boat and plankton samples had to be taken from some 10m away from the coastline: although there were a lot of cysts not a single live Artemia was collected, confirming earlier findings that the Artemia densities are very low + the strong wind might also result in Artemia accumulations in the downwind side of the lake. The reported high water transparencies of up to 6m are a further confirmation of the very low productivity of the lake and thus limited availability of food for sustaining a dense Artemia population (estimated at few animals per m^3, versus per L in more productive Artemia lakes)

The government does not allow cyst harvesting from the water, only from the beach: this can have a negative impact on cyst viability and hatching quality. It is not clear how cyst harvest quota are determined: for last year's harvesting quota were set at 2000 ton fresh product and are increased up to 2500 ton for the next season.

First cyst accumulations on the beach start as of October when the harvesting period starts: up to 5000 persons working for 45 companies are involved in beach harvesting and are paid 2 US $ per kg product. Nonetheless there is a lot of poaching and might result in the harvesting of another 2000 tons of cysts. Over the few km that we traveled along the W Aral beach we noticed several spots where waste was left by poachers.

Cysts harvested in the winter months are washed in lake water, inter-cyst water is removed by centrifuge treatment, wet-dry cysts are packed in sacks and stored at -8°C until they are sold (mainly to Chinese and Russian businessmen). Sometimes significant cyst accumulations happen only after the winter is over, resulting in a main harvesting period in March: these cysts are suspended in 220 g/L brine in plastic pools for 24 hrs, followed by the same centrifuge treatment (+ following steps) as described above. This 220 g/L dehydration treatment might not be enough for Aral sea Artemia parthenogenetica that are out of diapause (to be studied): awaiting further data on quality behavior (shelf life) upon storage (both for the winter and the spring harvests) it is recommendable to always dehydrate the cysts in saturated brine (300 g/L sea salts)

Wet-dry cysts are sold at 14 US$ per kg. Cost of cyst harvesting, treatment and packaging are estimated at 7 US $ per kg.

It is difficult to predict for how long and what amounts of cysts will be available in future years: the increased salinity is becoming very critical for Artemia as at a certain point the salinity will be too high as food will become too limited to fuel the osmoregulation capacity of the Artemia (need for more salt excretion to maintain the body fluids at a salinity of 15 g/L)

2.2 Artemia aquaculture as valuable farming alternative for the salinization problems of local/traditional agriculture

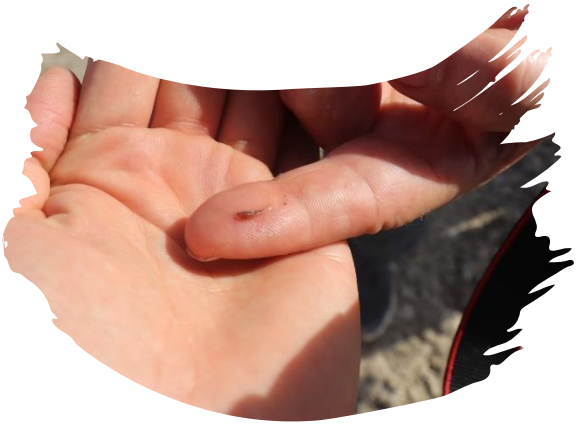
The agriculture activities in the wide area around Nukus suffer from acute salinization problems as a result of which extended areas of salt-affected soils cannot be used for classical agriculture and drainage waters from the agriculture fields are too salty for further irrigation use. Pond farming of brine shrimp Artemia could be a valuable alternative for this region in view of the following suitable conditions.

Land

Availability of good clay soils, suitable to build ponds allowing water depths of 1 – 1.5m, in proximity of suitable water source (see further) and in a region where local labor is available (job opportunities in populated areas, if successful this new aquaculture activity could later be considered for new developments in the Moinak area, attracting people to move into this region.

Water sources

Drainage water from agriculture lands that is lost for classic agriculture practices (via drainage canals, so called "kollektors" or terminal lakes of different salinity) and effluents from deep water-wells too salty for classic agriculture: all these brackish waters could be used as source for Artemia pond culture provided salinity levels can be increased up to 80 g/L through evaporation or addition of salt at the start of the production cycle. As it might take more than a month to build up the salinity level suitable for Artemia farming, one could extend the Artemia production period by increasing the salinity of the brackish water intake with sea salts. Karakalpakstan has 2 salt mines: one near Kirrkyz (about 10 km²) and a large one (>1000 km²), the Barsakelmes deposit, 90 km NW from Kungrad city (see locations in attachment 8). Based on inputs from the salt company (see attachment 13) the NaCl purity varies from 85 to 99% and the ionic composition reveals ocean water origin. This means that using the lowest NaCl purity (contamination with other salts, most probably also their cheapest product, or maybe even not meeting the QC standard for their commercial products) it is very likely that a suitable ionic composition can be reached for Artemia. The same brackish waters could be used during the culture period to compensate for evaporation and keep the salinity within the optimal range for Artemia biomass/cyst production (80 – 120 g/L). In function of the upper tolerance limit of local Artemia predators/competitors it might be possible to operate the Artemia ponds at lower salinities.



The drainage canals and their terminal lakes (not the deep water-wells) might be contaminated with pesticides and herbicides used in agriculture: this requires further study in view of possible bio-accumulation in Artemia biomass and/or cysts (critical QC factor). Levels are not toxic for Artemia as adult stages of Artemia parthenogenetica (same strain as in the Aral sea - to be verified by DNA genetic analysis) in good condition are present in some high-salinity terminal lakes (see sample collected from lake East of Nukus, picture in attachment 8).

Feed

Different sources of locally available agriculture byproducts could be tested as possible feed for Artemia: rice bran, carbohydrate rich waste products (maybe the licorice root), etc. In a first year of demonstration classical N/P/K fertilizers could be used to stimulate algae growth and cheap sugar-rich wastes (f ex molasses) to stimulate biofloc formation, the suitable feeds for Artemia. In parallel studies should be started to select and test by-

products (wastes) of locally available agriculture products.

Production season

Climatic conditions appear to be suitable for Artemia production in the period April to October when water temperatures are above 20 °C. Selected Artemia strains perform well up to 35°C and even tolerate short term exposures (in afternoon hours) to temperatures up to 40 °C. .

Production yields and estimated costs

Based on commercial pond production experiences under similar conditions in Vietnam and Thailand, see Hoa and Sorgeloos (2015), Van Stappen et al. (2020), Hoa et al. (2020) and references listed in these papers (see Literature of interest under item 6.3 of this report)

- Artemia cysts: 150 to 200 kg wet weight per hectare per cycle of 3 months (2 crops per year?) at an estimated production cost of 15-20 US $ per kg (land cost not included)
- Artemia biomass: minimum 3 tons per ha per month at a production cost of less than 1 US $ per kg

Very likely that production figures can be higher (at lower costs) as it will be possible to work in deeper ponds (1m and deeper versus 0.5m in Vietnam).

Use of Artemia products

Cysts: different strains/qualities (especially cyst size and lipid composition) for local market (use in freshwater/brackish water fish/crustacean hatcheries) and especially for export (specialty cysts of small size and nutritional value)
Biomass:
- live and frozen (use in aquaculture, local and export)
- high quality protein ingredient in animal feeds (terrestrial/aquatic), replacement for fishmeal
- ingredient in food recipes for mankind (see Artemia omelet as consumed in Vietnam, Hoa and Sorgeloos, 2020)

Important QC item: possible contamination of Artemia cysts and/or biomass with waste chemicals from agriculture drainage canals will need to be verified

2.3 Artemia as catalyzer for other aquaculture activities

The local availability of Artemia products will facilitate the further development of ongoing aquaculture activities, making the production more profitable (i.e. availability of cheap Artemia) and more successful (i.e. better performance - improved stress resistance and survival) and will open opportunities for new aquaculture activities: f. ex. giant freshwater prawn Macrobrachium rosenbergii (potential integration in organic rice farming, see new developments in several Asian countries; or in polyculture with freshwater fish species such as silver carp) or maybe Penaeid shrimp in brackish water ponds (see further for proposed verification actions)

2.4 Critical needs for capacity building

Since aquaculture expertise is limited in Uzbekistan there is an urgent need to gain aquaculture knowledge through academic training (BSc, MSc in aquaculture in universities in SE Asia, eventually through credit exchange agreements) and vocational training (in Artemia techniques, brackish water spp farming, etc.). This is crucial to prepare future staff with aquaculture expertise for new jobs in policy making, education/training/research, and private sector developments. Such approach better guarantees future ownership for all stakeholders

2.5 Environmental risk assessment

Since it was not possible to meet with the authorities of the State Committee on Ecology responsible for ecological issues, a meeting should be planned to ask

their permission in pursuing this plan for setting up controlled Artemia farming in salt-affected agriculture lands. It is important to explain the unique environmental (hypersaline) conditions under which monocultures of Artemia can be set up.

Extensive experience in many countries (in Asia, Africa and Latin America) with different species/strains of Artemia (available from commercial sources or from Artemia cyst banks) for use in the seasonal farm production has revealed no environmental risks: as Artemia is only farmed at high salinities it does not interfere with local ecosystems and at the start of a new season (in April) a new population needs to be inoculated. It is possible that high-salinity terminal lakes of drainage canals (as visited in the Nukus area, see attachment 8) might be colonized with Artemia species from neighboring Artemia farms and eventually outcompete the locally occurring Artemia parthenogenetica. That's why before the start of this project enough cyst material of the Aral sea Artemia (and of other hypersaline habitats in the region; same or different species/strain) should be collected and preserved in recognized Artemia cyst banks.

For the Artemia farming in Karakalpakstan a new Artemia production system needs to be designed to minimize the needs for salt, only to be used at the start of the first production season. It should be possible to recycle the pond culture waters and thus prevent/minimize the discharge of high-salinity waters once or more during the production season through the use of a deep (brine) storage pond (per farm) allowing the temporal drainage and (bottom soil) treatment of the Artemia ponds. The storage pond could also be used to further evaporate pond effluents and create an optimal environment for the monoculture of Dunaliella salina as most suitable food for Artemia. This will be an important component of the development plan for the setting up of an Artemia demonstration farm. Next to the setting up of recirculation systems for Artemia farming one might also consider the economic potential of using Artemia pond effluents to produce high-quality sea salt in solar salt farms (as practiced in SE Asian countries).

The idea to do seasonal Macrobrachium rosenbergii farming in rice paddies or in polyculture with different fish species should also be discussed with the authorities of the Ecology Department in the Ministry of Agriculture. This giant freshwater prawn species is a tropical species that cannot survive through Uzbek winter conditions. The plan would be to maintain brood stock and perform hatchery production during winter to prepare post larvae kept for on growing in indoor tank systems until they can be stocked in ponds for on growing once the water temperatures are optimal.

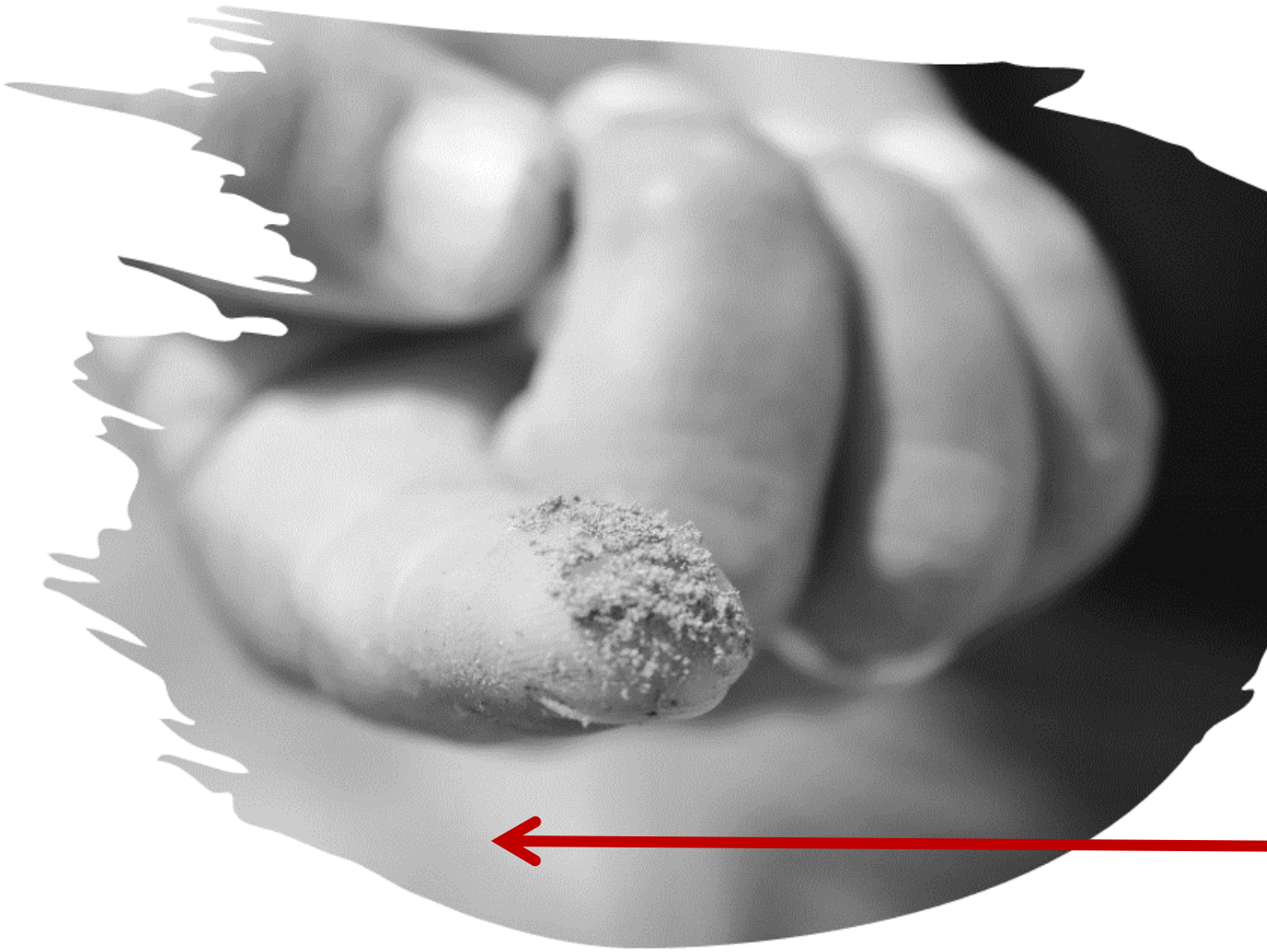
Same discussion needs to be considered for the possible farming of tropical Penaeid shrimp in brackish water ponds during the summer months (annual import and stocking of disease-free post larvae).

2.6 Need for regulation

As Artemia farming could be more lucrative than some traditional agriculture practices the risk exists that some farmers might convert their farmland into Artemia ponds. It will be important for the government authorities to develop appropriate rules and regulations, to eventually identify restricted areas for Artemia pond developments or set up strict permit requirements.

3. CONCLUSIONS

Whereas the NATO projects on the Aral Sea Artemia (2001-7) were optimistic about a long-term Artemia future for the East Aral and to some extent also the West Aral, today there appear to be no realistic prospects to save the natural Artemia resources in the West Aral as salinities continue to increase and are reaching levels that might be too high for Artemia as food limitation will interfere with its needs for increased osmoregulation. However, there are excellent prospects for the Karakalpakstan region (North of Nukus) to set up a new farming industry: the controlled pond production of brine shrimp Artemia biomass and cysts as successfully practiced in many countries in SE Asia. Several thousand hectares of salt affected soils, unsuitable for classic agriculture, could be converted into Artemia ponds. The unused salty waters from the many deep water-wells and from the agriculture drainage canals (kollektors) could be a suitable source of water for Artemia production after its salinity is increased to suitable levels for Artemia using the lowest quality salts (in terms of NaCl content) from the large Barsa Kelmes open salt mines NW of Nukus. Waste products from local agriculture could become suitable food sources for Artemia. As seen in other countries local availability of cheap Artemia biomass and cysts becomes a catalyzer for new aquaculture developments in the region (for local consumption and for export). Finally, the high nutritional value of Artemia biomass offers opportunities for use as protein ingredient in animal feeds and even in food recipes for man.



4. RECOMMENDATIONS

4.1 Artemia exploitation from West-Aral

The hatching quality (and as a result the commercial value) of the harvested cyst product could be significantly increased by setting up one or more central processing units for the West Aral sea cysts where they could be cleaned from heavy and light debris (floatation techniques) and following centrifuge dewatering be dried in fluidized bed dryers: techniques for processing and for quality control are described in the FAO Fisheries Technical Paper 361 (Lavens and Sorgeloos, 1996) and the more recent manuals for the Artemia projects in Vietnam (Hoa and Hong Van, 2019) and Bangladesh (Rahman et al., 2020)

The nutritional quality of Aral Artemia cysts for use in commercial fish and crustacean hatcheries is not documented: representative samples of Aral cysts should be tested at a recognized lab for quality evaluation: cyst characteristics (diameter, diapause characteristics, hatching quality) and nutritional composition of the hatched nauplii (especially fatty acid profile)

In order to be able to judge cyst qualities and issue quality certificates a National Quality Control Artemia laboratory should be set up (in Nukus?) and perform an intercalibration exercise with a recognized Artemia lab (in Belgium, China or Vietnam).

4.2 Environmental Impact Assessment

Since it was not possible to meet with the authorities of the State Committee on Ecology responsible for ecological issues, a meeting should be planned (eventually with national/international expert assistance) to ask their permission in pursuing this plan for setting up controlled Artemia farming in salt-affected agriculture lands, and to engage in a preliminary EIA study involving local and international experts.

4.3 Artemia demonstration farms

Pending a positive outcome of the EIA, study plans should be made to select 3 sites for the setting up of Artemia demonstration farms. Prior to an expert identification mission data need to be collected with regard to

- regions and sites in highly salt-affected agriculture regions (GIS assisted analyses)
- suitability (with regard to ionic composition) of local salt qualities to make up 80 g/L culture medium for Artemia: first test as hatching medium for Artemia, if positive then as culture medium for a lab scale culture test up to adult stage
- temperature regimes in operational fish ponds of different depths
- possible chemical contamination of adult Artemia (and if possible cysts) present in the high-salinity terminal lakes of the drainage canals (Artemia found E of Nukus)

4.4 Demonstration of Macrobrachium farming in rice farm

Testing of batch of prawn post-larvae imported from Thailand or Vietnam for stocking in rice paddy or freshwater pond to evaluate growth potential over summer period in 2021

4.5 Demonstration of Penaeid shrimp farming in brackish water ponds

Testing of shrimp viability and short-term nursery grow out tests with typical water samples from drainage canals and water wells at lab in Belgium or Vietnam, or at Nukus institute following import of small batch of post-larvae of Penaeus vannamei over the summer period in 2021

5. IMPLEMENTATION ROADMAP

Tentative outline, based on earlier experiences with similar Artemia projects

5.1 Preliminary EIA study

Facilitate dialogue among local and international experts with the responsible Ecology Department of the Ministry of Agriculture to approve the plan for setting up Artemia farming in the region

5.2 Capacity building – academic training

- Since academic training programs start in September very urgent action is required not to lose one and a half years
- Selection of 10 motivated students: very urgent
- BSc (1 year credit exchange) and MSc (2 years) in basic aquaculture at different institutions: Can Tho University (Vietnam), University of Malaysia Terengganu, Asian Institute of Technology (Thailand), Ghent University (Belgium)
- Registration deadline probably before July (need to check)
- English language proficiency is critical: English crash course to fulfill IELTS score, need to check. Urgent action needed
- Important to ensure future job commitment:
  1) in government (future legislation, permits, quota, etc.)
  2) in academia (education, research and extension)
  3) in the private sector (future head of new aquaculture farm association)
- Commitment of returning students to stay in the job for a minimum period of x years
- Funding provided by government with facilitation (selection of students, language training, …) by GIZ?

5.3 Identification mission for setting up of 3 demonstration farms

- Site selection (near Kungrat, Taxtako'pir and Bes-tobe?)
- Detailed plan for pond construction, purchase of materials, …
- Detailed plan for production cycle, minimizing the needs for salt, recycling of pond culture waters (minimize discharge of high-salinity waters)
- Tentative timing: 2 weeks in the period August-September 2021
- Two senior Artemia specialists in Artemia pond production (minimum 25 years of practical experience in different countries/environments)
- GIZ funding with facilitation by government?

5.4 Visit Uzbekistan delegation to Thailand and Vietnam

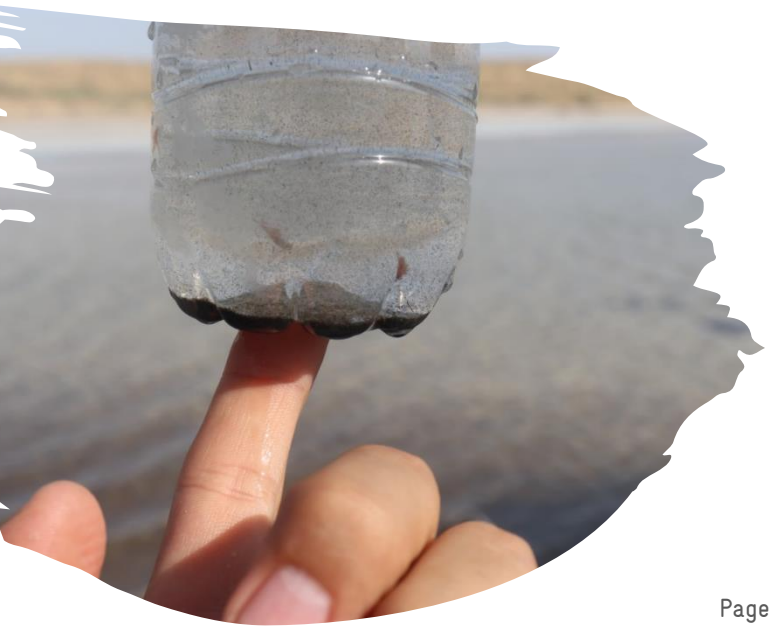
- representatives of government, academia and private sector
- one-week study visit in February 2022
- accompanied by Artemia specialist and translator
- visit farms, universities, meet with government authorities, farm associations
- GIZ funding with facilitation by government?
- private sector participants pay for their international travel

5.5 Vocational training of 3 technicians in Artemia farm production

- 6 weeks in the period February – March 2022
- at the Artemia field station of Can Tho University in Vinh Chau
- accompanied by translator
- upon their return they will be the operators of the demonstration farms
- GIZ funding with facilitation by government?

5.6 Setting up of 3 demonstration farms

- start April 2022
- operated by returning technicians from training in Artemia production in Vietnam
- assisted during the first 2 months by Artemia technician from CTU
- inspection mission in September 2022 by 2 Artemia experts from Ghent University (Belgium) and Can Tho University (Vietnam) to review results and develop further planning (extension of demo farms, setting up of central processing facility for Artemia cysts and biomass, etc.)
- GIZ funding with facilitation by government?



5.7 Demonstration of Macrobrachium farming in rice farm

Pending positive outcome of testing of batch of prawn post-larvae imported from Thailand or Vietnam for stocking in rice paddy or freshwater pond to evaluate growth potential over summer period in 2021:

- vocational training in hatchery production of Macrobrachium rosenbergii in Malaysia, Thailand or Vietnam: 2 technicians with translator for period of 3 weeks (winter 2021-22)
- shipment of post-larvae from SE Asian country in April 2022 (when water temperature in ponds are minimum 25 °C)
- upon their return these technicians set up brood stock facility for Macrobrachium (before end of Summer)
- maintenance of brood stock and hatchery production during winter to prepare postlarvae kept for on growing in indoor tank systems until they can be stocked in ponds for on growing once the water temperatures are optimal

5.8 Demonstration of Penaeid shrimp farming in brackish water ponds

Might be considered pending positive outcome of shrimp viability and short-term nursery grow out tests with typical water samples from drainage canals and water wells.

6. ANNEXES

6.1 Timetable of activities and observations

May 21 – meetings in Nukus

Meeting with staff of government, institutes and universities involved in Artemia (see list and affiliations in attachment 5): powerpoint presentation "Present status and future perspectives of Artemia aquaculture - production and use" (see attachment 6) followed by discussion (all day accompanied by GIZ staff Julian Felten and Rakhat Ganiev, and translator Derrick).

Round-table discussion with officials of institutions and universities involved in Artemia (see list and affiliations in attachment 5): powerpoint presentation "Status of Aquaculture: historical aspects, future challenges & opportunities" (see attachment 7) including review of earlier NATO Artemia projects, present status of Aral Sea Artemia and discussion about possible mission outcomes; information about possible options to lower salinity and increase fertility of W-Aral, availability of drainage waters from agriculture (too salty for further use in agriculture) via canals to terminal (salt) lakes that eventually dry up, availability of large amounts of licorice root and its waste.

Meeting with Mr Murat Kallibekovich Kamalov, Chairman of the Jokargi Kenes (Parliament) of the Republic of Karakalpakstan and his Deputy: impressions on the limited future potential of Artemia exploitation from the W-Aral sea but the potential to develop a new Artemia farming industry on the salt affected soils South of the Aral sea basin in Karakalpakstan. Strong support of Mr Murat for developing plan that could result in new industrial activities with Artemia farming and aquaculture applications: creating new jobs and resulting in new sustainable developments for Karakalpakstan

May 22 – visit West Aral

Travel from Nukus to West Aral sea via KS7 accompanied by Mr. Alibek Kamalov, Mr Musaev Ablatdin (who studied Artemia since the NATO SfP project), Mr Atabik Ismailov (Artemia business man), 2 staff from fishery and sericulture department of the Tashkent State Agrarian University Nukus branch (Ms Kaliknazarova Almagul Kurbanazarovna and Ms Nurabullaeva Gulshexra Kuanishbaevna), GIZ staff Rakhat and translator Derrick.

Visit drainage canal (Kollektor GLK) near Karakalpak cemetery: slightly salty but still populated by fish (several fishermen active): flows further N and eventually ends S of Moinak. Passing along big open salt mine (Qara-Umbet) located between Kunkhodja and Kirkkiz (estimate few km^2): what is the chemical composition of this salt? What is it used for?

Meetings at camp site at W Aral with former and present Hakim of Moinak, 2 representatives of the Committee on Environmental Protection and Ecology of the republic of Karakalpakstan, another Artemia businessman (sorry no name) harvesting Artemia from W Aral.

May 23 – visits in Nukus area

In view of observations and conclusions of previous days, change of original agenda and planning with Mr Alibek Kamalov for site visits in the wide Nukus area to different drainage canals and their terminal lakes, meeting with local Hakim, visit deep water wells, and licorice processing plant accompanied by Mr Alibek Kamalov, GIZ staff Rakhat, translator Derrick and student from Nukus branch of Tashkent State Agrarian University. See pictures in attachment 8.

Deep water wells (more than 150 in the region) with very high flow rate but slightly salty taste (below the detection limit of the refractometer used, thus probably below 5 g/L) and not suitable for irrigation of agriculture fields end up in drainage canals and

finally in terminal lakes (more than 25 in the region, draining 2.2 million ha of agriculture lands – among which rice fields - with lake areas varying from 25 ha to 2500 ha); at one point of time these deep water-wells were used for the production of freshwater (desalination project funded by German development cooperation?) but the project was discontinued; with new and more energy-efficient techniques for desalinization this option could be reconsidered and the brine effluent from the desalinization plants could be used as water input for the Artemia farms (as practiced in other countries, f ex China and Egypt)

Terminal lakes of drainage canals vary in salinity from brackish water (several fishermen active) to high salinity with local parthenogenetic Artemia, to saturated brines with salt crust at bottom, to dry salt flats: presence of Artemia is good proof that ionic composition of the drainage waters and deep water-wells are suitable for Artemia.

Visit licorice processing plant: licorice root available in large quantities allover Karakalpakstan. After chemical extraction (2 steps in acid medium in 3-m high towers) the end product is dried in the son and exported to China (for use in pharmaceutical and cosmetic products, also use as a flavoring in candies). The final waste (rich in fibers and still tasting sweet, still containing carbohydrates) is dumped on the fields (see picture in attachment 8). Either the waste product or even the root itself (upon fine grinding, and maybe short-term fermentation at the farm site) could be tested as a potential feed source for the Artemia pond culture

May 24 – meetings in Nukus

Meeting with Vice-Rector for International Cooperation, Dr Abduaziz Abduvasikov and Dept Director for Innovation and Research, Dr Berdiyar Jollibekov of Tashkent Agrarian University Nukus branch (soon to be recognized as Karakalpakstan Agriculture & Agriculture Technology Institute): highly interested in small scale fish farming techniques (GIZ support for small scale fish hatchery activities), brief summary of outcome of visits so far and discussion of suggested plan for setting up Artemia farms in Nukus region on salt-affected agriculture land with effluents from drainage canals and deep water-wells; opportunity for new aquaculture training programs at local university and need to invest in capacity building in exchange with universities in SE Asia that have developed successful programmes in aquaculture education (BSc, MSc and PhD level), eventually through credit exchange agreement with selected universities in SE Asia. For curriculum Bachelor program Zootechnics (Fishery) at Nukus branch of Tashkent State Agrarian University: see attachment 9.

Presentation for staff and over 50 students from both universities (Tashkent Agrarian University Nukus branch and Karakalpak State University) "The potential for environmental-friendly brine shrimp Artemia production in the Aral Sea region, Karakalpakstan – Uzbekistan" (see attachment 10)

May 25 – meetings in Tashkent

First debriefing with GIZ staff Paul Schumacher, Zlatko Tadic and Julian Felten.

Presentation for staff (and for students via videoconferencing) of Tashkent State Agrarian University on "The potential for environmental-friendly brine shrimp Artemia production in the Aral Sea region, Karakalpakstan – Uzbekistan" (see attachment 11)

Round-table discussion on "Sustainable Artemia production in the Aral sea region" with officials from the university, different ministries and institutes chaired by Mr Ramin Gasanov, Chief of Department 'Grants and Technical Assistance', Ministry of Agriculture (on behalf of Mr Alisher Shukurov, Vice Minister) - see group picture in attachment 8: some of the university professors illustrated how the availability of local Artemia could boost the local aquaculture industry: cysts in the hatcheries of different carp species and African catfish, and biomass in nursery and growout feed formulations

May 26 – meetings in Tashkent

Discussion of mission outcome with GIZ staff Paul Schumacher, Zlatko Tadic, Said Khasanov and USAID staff Mr Umidjon Sayfudinov

Reporting meeting with Paul Schumacher and Zlatko Tadic: discussion of powerpoint (attachment 12): suggestions for updating report with extra information

6.2 Attachments[1]

1. NATO Collaborative Linkage Grant "Artemia colonization of the Aral sea: hope for a dying ecosystem" 2003-2004: project report
2. NATO Science for Peace Project "Economic and ecological benefits from sustainable use of the Aral Sea" 2004-2007: project outline
3. Paper by Marden et al. (2012) "Assessment of the production potential of an emerging Artemia population in the Aral Sea, Uzbekistan"
4. List of participants in VC meetings with staff in Nukus, Tashkent and Embassy in Brussels over the period December 2020 – March 2022
5. Nukus, May 21: List of participants in meetings with representatives of local government, institutions and universities involved in Artemia
6. Nukus, May 21: powerpoint presentation "Present status and future perspectives of Artemia aquaculture"
7. Nukus, May 21: powerpoint presentation "Status of aquaculture: historical aspects, future challenges and opportunities"
8. Mission pictures
9. Curriculum Bachelor program Zootechnics (Fishery) at Nukus branch of Tashkent State Agrarian University
10. Nukus, May 24: powerpoint presentation "The potential for environmental-friendly brine shrimp Artemia production in the Aral Sea region, Karakalpakstan – Uzbekistan"
11. Tashkent, May 25: powerpoint presentation "The potential for environmental-friendly brine shrimp Artemia production in the Aral Sea region, Karakalpakstan – Uzbekistan"
12. Powerpoint de-briefing for GIZ staff in Tashkent
13. Information about the salt deposit "Barsakelmes"

6.3 Documents / Literature of interest

1. Manual on the production and use of live food for aquaculture: Lavens and Sorgeloos, 1996
2. Integrated salt and brine shrimp Artemia production in artisanal salt works in the Mekong delta in Vietnam: a socio-economic success story as model for other regions in the world: Hoa and Sorgeloos, 2015
3. Principles of Artemia culture in solar saltworks: Hoa and Hong Van, 2019
4. State of the art of brine shrimp Artemia production in artisanal saltworks in the Mekong delta, Vietnam: Hoa et al. 2020
5. Brine shrimp Artemia as a direct human food: Hoa and Sorgeloos, 2020
6. Guidelines for Artemia production in artisanal solar salt farms in Cox's Bazar, Bangladesh: Rahman et al. 2020
7. Review on integrated production of the brine shrimp Artemia in solar salt ponds: Van Stappen et al. 2020
8. Past, present and future scenarios for SDG-aligned brine shrimp Artemia aquaculture: Sorgeloos and Roubach, 2021

[1] Attachments and documents/literature of interest. Available from: http://users.ugent.be/~psorgelo/GIZreportMissionUzbekistanMay2021/