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Sustainable ARTEMIA Cultivation in Earth Ponds

INFORMATION PACKAGE

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eco aral
Ecologically Oriented Development in the Aral Sea Region

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Bonn, January 2024

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Abbreviations and acronyms

°C	degrees Celsius
BMZ	Federal Ministry for Economic Cooperation and Development
DW	dry weight
ECO ARAL	Ecologically Oriented Regional Development in the Aral Sea Region
FAO	Food and Agriculture Organization of the United Nations
g	gram
GIS	geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GSL	Great Salt Lake
KAZ	Kazakhstan
kg	kilogram
L	liter
FBD	fluidized bed dryer (for Artemia cysts)
H%	cyst hatching percentage – number of nauplii per 100 cysts
HE	cyst hatching efficiency – g nauplii (DW) per g of cysts
HUFA	Highly Unsaturated Fatty Acids
Øcysts	diameter of the cysts
LED	light-emitting diode
m	meter
MoA	Ministry of Agriculture of the Republic of Uzbekistan
MENR	Ministry of Ecology and Natural Resources of the Republic of Kazakhstan
MIFT	Ministry of Investments and Foreign Trade of the Republic of Uzbekistan
NATO	North Atlantic Treaty Organization
pH	potential of hydrogen
SFB	San Francisco Bay area
US $	US Dollar
UZB	Uzbekistan
WW	wet weight

FACTS & FIGURES

Although the drying up of the Aral Sea and the salinization of a lot of agricultural lands in different regions in Uzbekistan (UZB) and Kazakhstan (KAZ) have major negative consequences, there is a **high potential to develop a new profitable industry and create new job opportunities in this region**: the environmental-friendly and sustainable **pond farming of brine shrimp Artemia,** a well-known source of food in the farming of fish and crustacean species around the world.

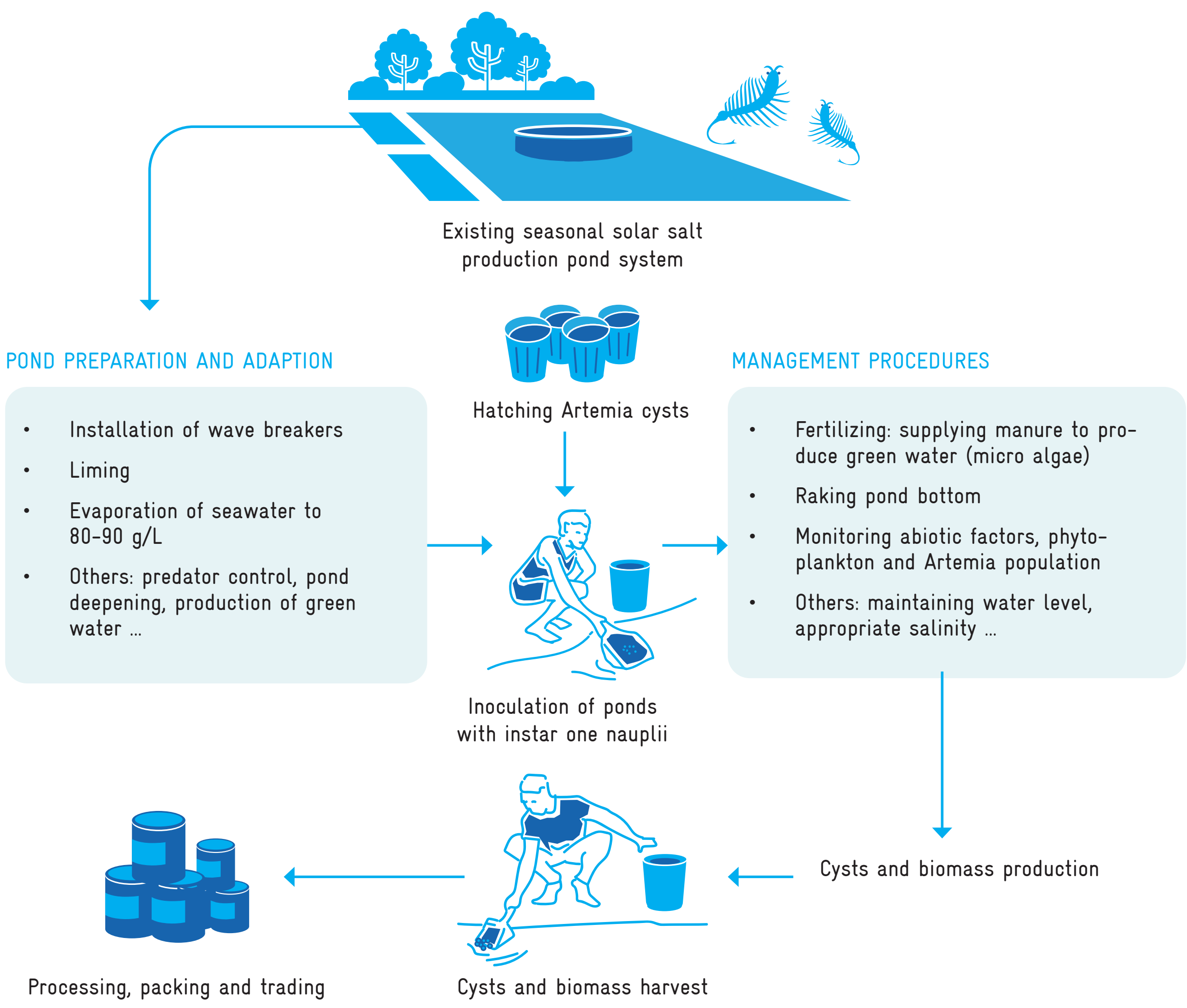
Availability of **high-quality Artemia products** in UZB and KAZ could catalyze further aquaculture developments in the region: the pond farming in the summer season of different species of fish and crustacean species, either integrated in organic rice farming or in brackish water / saline pond systems. The GIZ regional project ECO ARAL has therefore implemented an Artemia pilot project to showcase the feasibility of a sustainable Artemia cultivation in environmentally friendly earth ponds. The GIZ ECO ARAL project is commissioned by the Federal Ministry for Economic Cooperation and Development (BMZ) and works in partnership withthe Ministry of Agriculture of the Republic of Uzbekistan (MoA) and the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan (MENR) as main political partners.

Artemia farming requires warm and salty waters, which are found in the **Aral Sea** region. Composted waste from various agricultural industries can be used to feed Artemia. It can be produced from spring to autumn and can be used for local fish farming and/or for export in various forms to meet the high demand in the world of fish and crustacean aquaculture.

EXECUTIVE SUMMARY

GIZ ECO ARAL in cooperation with project partners aims to setup a new ***Artemia* farming industry in UZB and KAZ** in salt-affected areas where classical agriculture had to be given up. It could result in a **new and sustainable aquaculture industry** with existing and new species (for local markets and for export), resulting in increased **food security** in these countries, r**evitalizing lost agriculture lands**, and ultimately c**reating more job opportunities**, both permanently and seasonally. Not least as an alternative source of income for many - seasonal - artemia harvesters on the shores of the Aral Sea whose jobs are threatened by the further desiccation of the Aral Sea.

How to farm brine shrimp Artemia and the production cycle

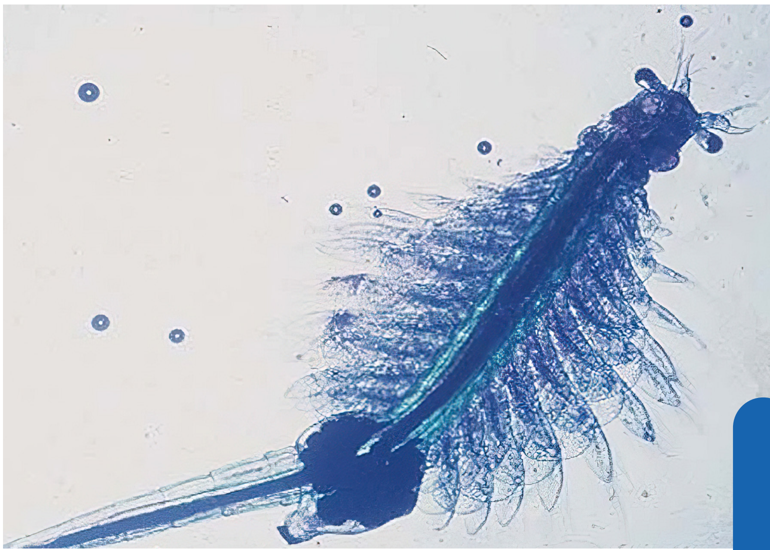


Adapted from: https://firms.fao.org/fi/website/FIRetrieveAction.do?dom=culturespecies&xml=Artemia_spp.xml&lang=en
Cultured Aquatic Species Information Programme
Artemia spp (Leach, 1819)

INTRODUCTION

WHAT IS ARTEMIA?

Artemia are small 1-cm long **brine shrimp** that live in highly saline waters (from 3 to 10 times the salt concentration of seawater) where other aquatic predators or food competitors cannot survive. As a result, many **salt lakes** found on all continents (for example Great Salt Lake (GSL) in North America and the Aral Sea in Central Asia) are **unique habitats** for monocultures of brine shrimp. Depending on the nutrient loads in the salt lake intake waters, micro algae and bacteria develop as food for the brine shrimp and will eventually determine the *Artemia* productivity in the lake (high in GSL, low in the Aral sea). As an adaptation to the harsh winter conditions in these salt lakes *Artemia* mothers can switch their reproduction mode from live babies to encapsulated embryos, called cysts that switch off further development, float at the water surface, accumulate on the beaches, withstand freezing conditions to eventually revive in Spring and result in the development of a new brine shrimp population.



WHAT IS ARTEMIA USED FOR?

Since the 1970s modern aquaculture took off, i.e. closing the life cycle of fish and crustaceans in captivity, producing billions of baby shrimp and fish in commercial hatcheries, with *Artemia* cysts as a most **cost-effective alternative for live plankton**, the natural source of food for baby fish and shrimp. Cysts harvested from salt lakes can be processed and dried, shipped around the world, and within 24-hr incubation of the dry cysts in seawater, 0.4 mm *Artemia* babies are born and used in the hatcheries as a practical and cost-effective **live food**. Over the past decades the successful development of fish and crustacean hatcheries has resulted in an annual world market of over **3000 tons of cysts** valued at over 200 million USD.

IS THERE AN ARTEMIA SHORTAGE?

Most saline lakes have a terminal nature as their **intake waters have been reduced** either because they were diverted for irrigation purposes and/or due to climate change. In some cases new water management rules aim to **maintain suitable conditions** for *Artemia*, as a major source of food for migrating water birds (new water rights at the Great Salt Lake), in other regions, salt lakes are drying up (Urmia Lake in Iran, Aral sea in UZB and KAZ), salinities increase beyond viable conditions for *Artemia*, nutrient intakes decrease, resulting in a significant drop in *Artemia* productivity and eventually a complete wipe out of the population. This is the present situation for the remaining parts of the Aral Sea, making the current business model of manual beach harvesting of the **decreasing densities of cysts less and less cost-effective and approaching soon the end of this business altogether**.

Due to climate change, and increasing use of irrigation waters several Central Asian countries (incl. UZB and KAZ) experience problems with salt-affected soils and saline groundwaters that limit classic agriculture (e.g. due to rice paddy farming or intensive cotton cultivation).

MAN-MANAGED ARTEMIA POND PRODUCTION AS A CURE TO THE SHORTAGE?

Over the past 2 decades, controlled man-managed *Artemia* pond production has become a **successful new aquaculture industry** in different Asian countries with world leaders in Vietnam, Thailand and China for the commercial production of high-quality *Artemia* cysts (fetching a much higher market value as compared to the cysts harvested from wild resources) and *Artemia* biomass, both as high-value food sources for use in local aquaculture farms or for export. As most current *Artemia* cyst stocks are sourced from terminal salt lakes, the FAO recommended at the Global Conference on Aquaculture (Shanghai, China, 22-23 November 2021) that more controlled *Artemia* farming practices should be promoted.

POTENTIAL FOR ENVIRONMENTAL-FRIENDLY ARTEMIA CULTIVATION IN UZBEKISTAN AND KAZAKHSTAN

Over the past years the idea to setup a new *Artemia* **farming industry in UZB and KAZ** in salt-affected areas where classical agriculture is no longer feasible, gained more and more national interest.

To facilitate the launching of this new *Artemia* farming practice, GIZ organized a **multistakeholder study trip** to Thailand for Uzbek and Kazakh participants from government, academia, and aquaculture sector to learn about sustainable *Artemia* cultivation in Thailand and their experiences. Furthermore, the setup of an *Artemia* demonstration farm in Uzbekistan was established: Uzbek professionals were sent to Vietnam to get acquainted with *Artemia* pond farming techniques, including harvesting and processing methods; upon their return the technical feasibility of such a pond cultivation system has been successfully demonstrated in Karakalpakstan, where it makes use of drainage water and salt-affected soil.

WHAT IS THIS INFORMATION PACKAGE ABOUT?

This info package **will (1) show some of the outcomes** but also how to **(2) setup and (3)manage** such an environmental-friendly *Artemia* aquaculture system, present guidelines and recommendations which are important for such a new business sector, do's and don'ts and lessons learned from other countries not to be repeated in the present context but to learn from past mistakes and adapt a context-specific approach that will encourage a new flourishing aquaculture sector in Uzbekistan and Kazakhstan.

ENVIRONMENTAL-FRIENDLY ARTEMIA POND PRODUCTION

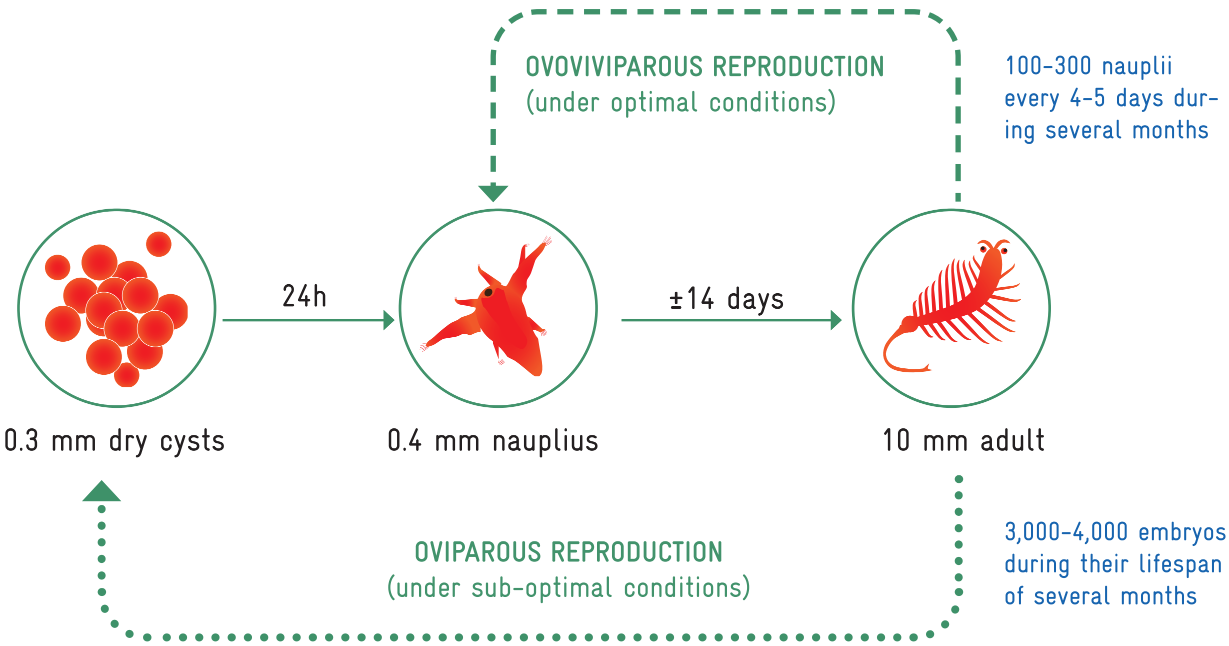
DECLINE IN ARTEMIA HARVESTING FROM THE ARAL SEA

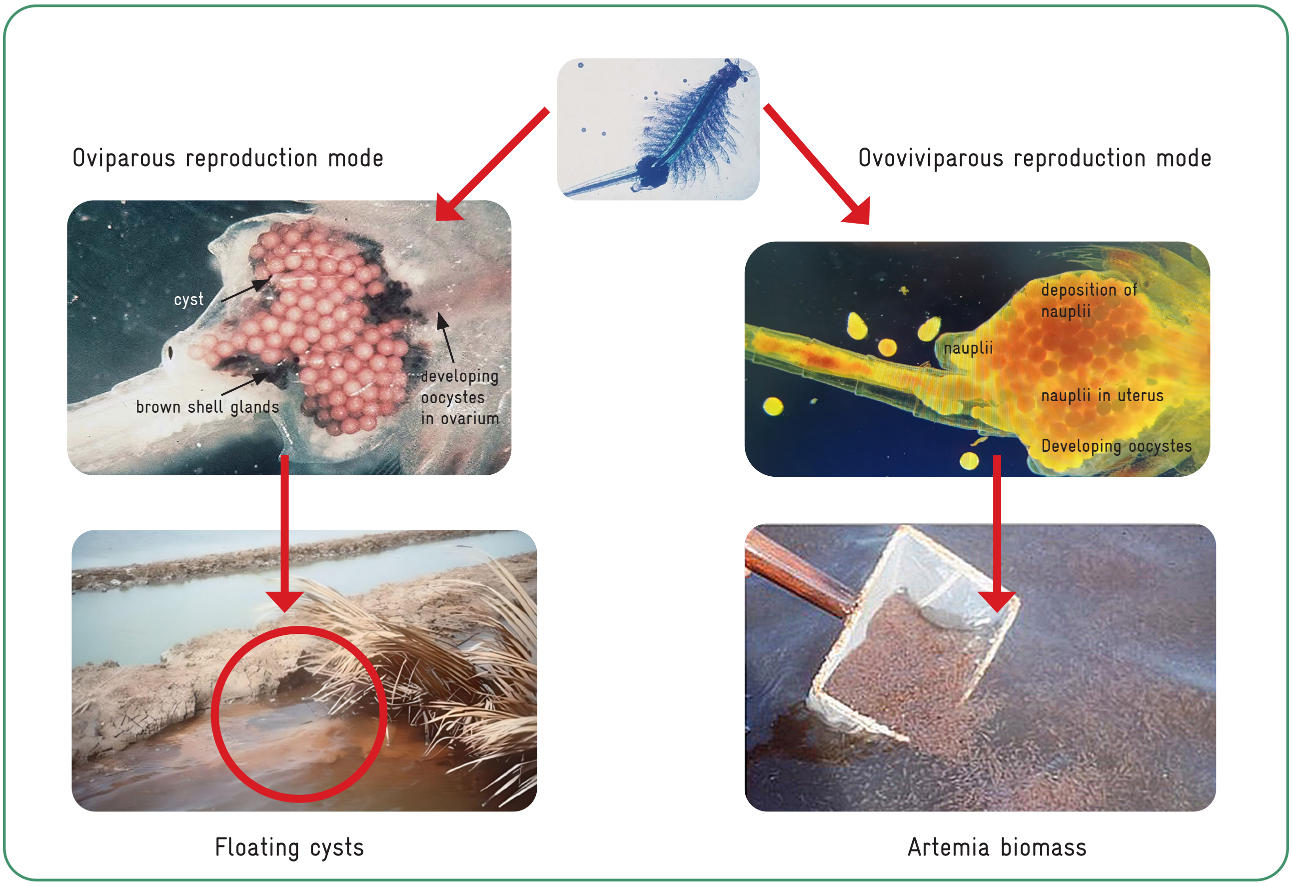
The **Aral Sea** (especially the big East Aral) was a viable and commercially successful *Artemia* cyst resource in the first decade of this century (NATO Science for Peace projects with Uzbekistan). However, the gradual dry out of the East Aral and the continuous increase in salinity (now over 170 g/L) in the West Aral, resulted in very low nutrient levels (water transparencies of several meters), and extremely low *Artemia* densities with female broodsacs carrying few cysts. In recent years, the **commercial future** of this very labor-intensive beach harvesting (in fact a non-sustainable fisheries practice) is **becoming very limited** and will eventually be abandoned (for details see GIZ trip ECO ARAL project report 2021).

MAN-MANAGED ARTEMIA POND CULTIVATION

Basic research on the *Artemia* biology and ecology by different international institutions (under the co-ordination of the *Artemia* Reference Center, based at Ghent University in Belgium) has **resulted in a better understanding of the life cycle** of *Artemia* and all the biotic and abiotic parameters that control/influence the production of either live offspring or cysts. Baby *Artemia* produced under optimal conditions ensure a fast expansion of the population as they quickly develop into adult brine shrimp. **Cysts formed under so-called stressful conditions are released in the brine waters** (with high density), float at the water surface and by wind are blown onto the lake's shore.

Life cycle of brine shrimp ARTEMIA





Although the trials to set up controlled, man managed *Artemia* pond culture date back to the late seventies (in the Philippines and Thailand), it was only in the past 2 decades that commercial *Artemia* pond culture became a **successful undertaking in Thailand, China and Vietnam.** Ever since, new projects were set up in India, Sri Lanka, Kenya, Ecuador, Cambodia, Myanmar, Bangladesh and the United Arab Emirates.

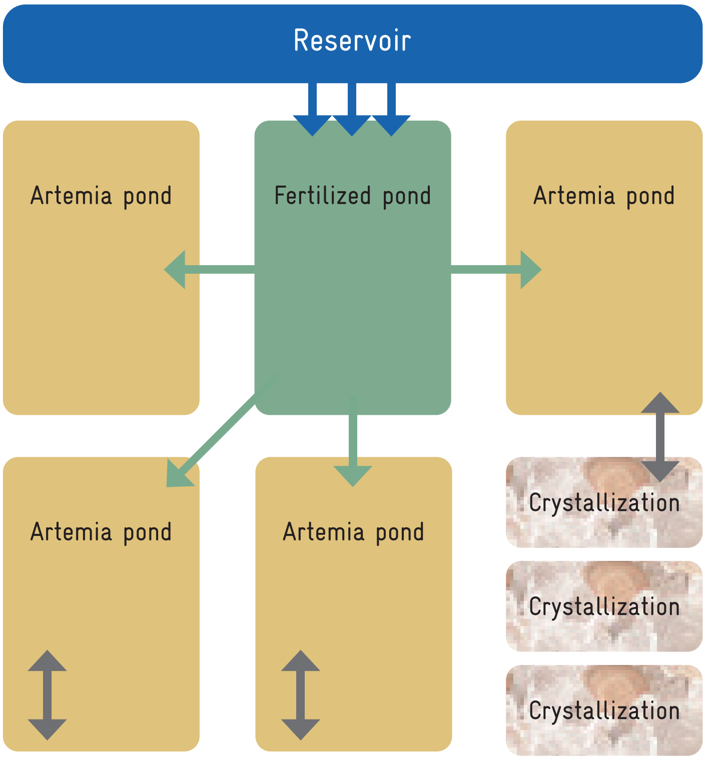
The main factors that determine a successful *Artemia* pond production are the nauplii inoculation conditions (introduction of the baby *Artemia* hatched from a selected species and strain), the **management of the pond conditions** (food, salinity, oxygen levels) to first ensure live reproduction (to boost a quick expansion of the population) geared either towards biomass harvesting and/or cyst production.

STEPS IN SETTING UP A SUCCESSFUL ENVIRONMENTAL-FRIENDLY ARTEMIA POND PRODUCTION SYSTEM:

1. Site selection in function of:

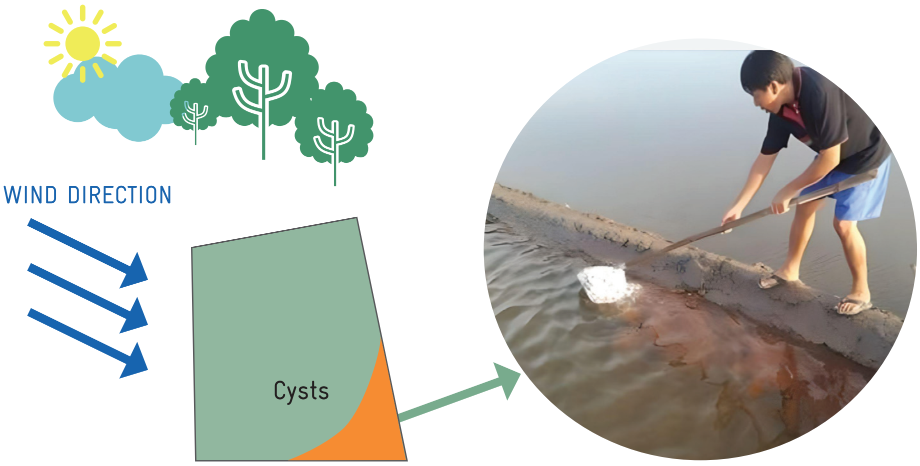
- climatic conditions: minimum 4 months of water temperatures higher than 25 °C and positive ratio evaporation/precipitation;
- soil conditions: high content of clay, high water retention, limited infiltration;
- water availability: brackish water, seawater, brine of different salinities (eventually from wells or desalinization plants);
- nutrient availability in intake waters to promote algae blooms as food for *Artemia*;
- local availability of labor/man-power.
- Geographic Information Systems (GIS) could be applied to narrow down possible sites of salt-affected soils;

2. **layout and construction of pond system for food production** (algae, bio-flocs*, in salinity range 30-60 g/L) **and for *Artemia* farming** (minimum salinity of 80 g/L) with water depths of minimum 50 cm and pond configuration taking into consideration the wind directions to facilitate cyst harvesting in the corner of the ponds. See schematic outline of *Artemia* pond system integrated in operational salt farm in Vietnam:
3. **proper selection** of ***Artemia* species/strain:** suitable for local farming conditions and for final commercial use: cysts or biomass with specific characteristics (especially size and nutritional value) for local use and/or for export.
4. **method to reach sufficient salinity level for *Artemia* inoculation:** 80 g/L (beyond the limit of local predators and food competitors): use of brine waters from canals or wells, eventually reaching higher sa-



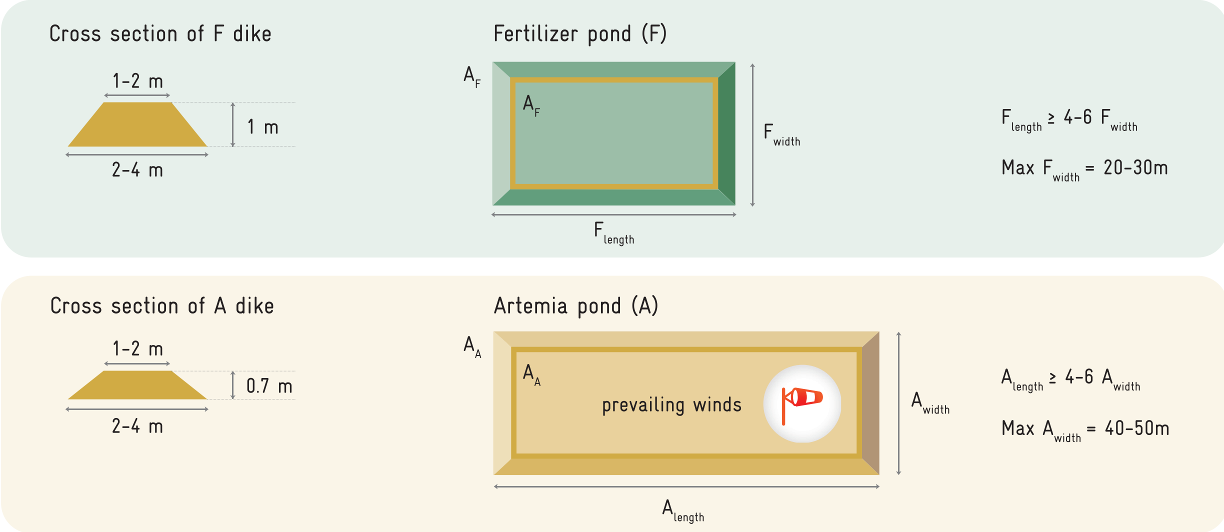
An ideal design for Artemia mono culture (in which 20-30% area is for fertilizer (F) pond, the rest is reserved / split up into Artemia (A) ponds. Supplying and draining canals require insignificant area in the same plot

Design of culture pond coincides to local wind direction to facilitate for cyst collecting

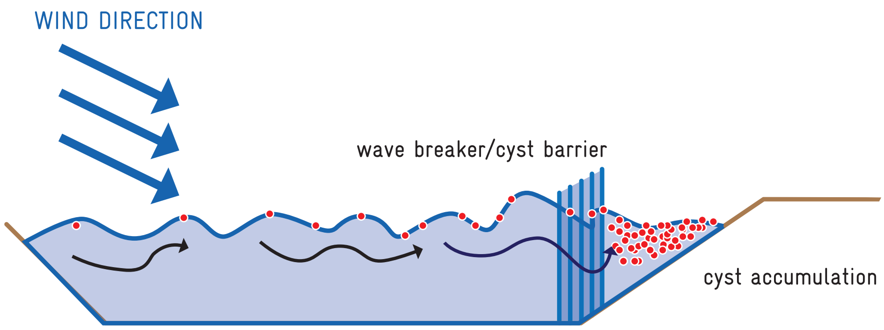


* Bio-floc technology: the use of aggregates of bacteria, algae, or protozoa, held together in a matrix along with particulate organic matter for the purpose of improving water quality, waste treatment and disease prevention in intensive aquaculture systems

Basic layouts and cross section for fertilizer pond and Artemia pond:



Use of wave breaker / cyst barrier systems to prevent loss of cysts by very strong winds:



linity levels through evaporation, use of brine stored from last season.

5. **inoculation procedure:** hatching of selected cysts, harvest of freshly hatched nauplii (all in instar I stage, very crucial to ensure their survival upon direct transfer from low to high salinity) for transfer to the *Artemia* ponds - either direct inoculation in close proximity (availability of suitable conditions for cyst hatching, electticity for aeration of the incubated cysts) or properly packed nauplii for transport to the inoculation site.
6. **pond management for food production*:** use of agriculture byproducts (dried animal manure, for example from chicken and camels; rice bran; composting waste/byproducts from food processing with high carbohydrate content, for example licorice).
7. **pond management for *Artemia* production:** inoculation density (100 or more instar 1st stage nauplii per liter), daily food intake based on water turbidity levels (not less than 30 cm measured with Secchi disc), weekly observation of population composition and animal conditions, regular raking of pond bottom to resuspend settled food/bio-flocs.
8. **harvesting protocols:** either regular culling of *Artemia* biomass for live/frozen use/sales, versus daily harvesting of cysts, cleaning, and primary processing by storage in saturated brine, before transfer to centralized cyst processing/packaging facility for final cleaning, washing and drying.

*As it might take some time to select and develop protocols for use of local waste products as more sustainable source of Artemia food, it might be advisable to enhance algae production in the first experimental trials with locally available agricultural fertilizers

POTENTIAL PRODUCTION YIELDS AS OBTAINED IN DIFFERENT ARTEMIA-PRODUCING COUNTRIES:

In Vietnam the technique of integrated salt-Artemia production is practiced: part of the salt evaporation ponds is stocked with Artemia, and the pond effluent eventually reaches the crystallizer ponds where the salt is harvested (see the scheme on page 11). Cyst yields in these integrated salt-*Artemia* production in shallow 30 cm deep ponds vary from 15 to 50 kg wet weight (WW) per hectare per month, or the equivalent of 7 to 25 kg dry weight cysts (in Vietnam recovery rate from wet to dry weight following processing is about 50%). Higher yields (at least double this amount) are possible when operating deeper ponds (1 to 2m).

In Vietnam the cyst harvesting period can last 2 to 3 months per season.

Biomass production yields vary from 1 metric ton WW (data for Vietnam in shallow ponds) to 4 metric ton per hectare per month (in 2 m deep ponds in Thailand). Biomass production in Vietnam can last 4 to 5 months while in Thailand it can be year-round.

Artemia biomass soon to become a cost-effective alternative for fish meal?

Maybe the most successful Artemia biomass farm in the world, already in production for more than 15 years, is operated by the Penaeus monodon shrimp farmer Mr Banchong Nissagavanich in the Chachoengsao Province, nearly 60 km east of Bangkok. Two ponds are in operation on a year-round basis, they have a surface area of about 6500 m² and a depth of 2m, as to be able to drain the freshwater upon heavy rainfall during the rainy season: 110 g/L salinity at the start of the rainy season to still have 70 to 80 g/L at the end of the rainy season. Different wastes of plant and fruit processing, cow dung and even kitchen waste are used as organic fertilizers and added daily. Every other day the pond bottom is raked with a heavy metal chain dragged by boat over the pond bottom. Harvesting of the Artemia biomass that accumulates at the water surface in the morning hours when low oxygen levels prevail is pushed into a harvesting net by a paddle wheel (see pictures). Harvest yields range from 100 to 120 kg WW Artemia biomass per pond per day or expressed in kg per hectare per month approximate 4.5 metric tons! *Artemia franciscana* strain (which was introduced in Thailand over 30 years ago) no longer produces cysts but is adapted to the local conditions.

Live biomass proofs to be much more nutritious than frozen Artemia and is used for feeding brood stock as well as nursery stages of different species of marine as well as freshwater fish and crustaceans. Farming the Artemia at these high salinities apparently assures high biosecurity, biomass free from shrimp pathogens as over all these years of feeding live biomass to his Penaeus monodon broodstock Mr Banchong has never experienced a disease outbreak.

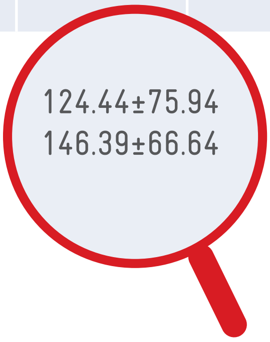
Harvesting the Artemia pond: The slowly turning paddlewheel and bamboo guides direct Artemia into the shallow-set net fixed in position behind, where it can be easily removed

CASE STUDY: VIETNAM'S ARTEMIA SUCCESS STORY

Comparison of productivity and yield of Artemia production versus integrated Artemia-salt production in Mekong Delta salt farms in 2014

Description	Soc Trang (n=40)		Bac Lieu (n=30)		Medium (n=70)	
	Artemia (n=22)*	Artemia-salt (n=18)	Artemia (n=15)	Artemia-salt (n=15)	Artemia (n=37)	Artemia-salt (n=33)
1. Productivity Artemia (kg) Salt (Ton)	57.34±20.27	60.12±33.11 69.11±25.33	34.49±21.86	41.4±41.69 50.85±23.26	28.07±23.55	51.35±36.42 60.81±25.74
2. Yield Artemia (kg) Salt (Ton)	100.32±42.06	124.44±75.94 146.39±66.64	59.93±30.49	74.27±73.38 138.13±75.57	83.95±42.39	101.63±77.87 142.64±69.82

*n = number of samples common way when referring to standard deviation (+- 33.11 = based on 18 samples)
**productivity of artemia and artemia and salt per farm per 3-month season
***yield of artemia and artemia and salt per ha per 3-month season



Hong Thi Hai Yen et al., 2014

The *Artemia* cysts produced in Vietnam originate from an inoculum of the *Artemia franciscana* species, that formally occurred in the artificial ponds of the Leslie Salt company in the bay of the city of San Francisco (California-USA). Many fundamental studies had revealed that this "SFB *Artemia*" is a superior strain to other *franciscana* strains (f ex Great Salt Lake *Artemia franciscana*, in Utah-USA). This so-called SFB strain was inoculated in the artisanal Vinh Chau salt works in the Mekong delta in the late 1980s. The Vietnam cysts, known as Vinh Chau cysts that resulted from his SFB inoculum, have an **excellent quality and reputation**, and are superior even to the SFB cysts (no longer commercially available since the restauration of the salt ponds into the natural estuarine ecosystem in the bay of San Francisco). The Vinh Chau cysts are smaller in size than any of the commercial natural sources, have **excellent hatching characteristics** and contain **very high contents of the fatty acid EPA**, essential in the larval nutrition of most marine fish and many crustacean species. As a result, the demand for these cysts is far beyond the limited offer (40 tons WW annually) and in the world market they fetch more than double the price of other commercial sources (around 210 US $ per kg DW versus 50 to 70 US $ for good hatching quality cysts commercially available from GSL and other salt lakes in Central Asia and China).

The Vinh Chau cysts have been successfully used as inoculation material in other experimental projects in the SE Asia region, China, Africa and the Persian gulf, always resulting in **cyst quality characteristics** similar to the Vietnam inoculation material.

The *Artemia* pond production business is very profitable in Vietnam, Thailand and China:

- biomass is sold at prices varying from less than 1 to 3 US $ per kg WW. It is estimated that production cost is less than 0.5 US $ per kg WW.
- Studies in Vietnam revealed that cyst production costs range from 15 to 20 US $ per kg WW.

Salt farmers in Vietnam who integrate their salt production with *Artemia* farming double to triple their income over a production period (in the dry season) of 4 months only.

Income, profit and profit ratio

Unit: Million VND*/ha/crop

Description	Soc Trang (n=40)		Bac Lieu (n=30)		Medium (n=70)	
	Artemia (n=22)	Artemia-salt (n=18)	Artemia (n=15)	Artemia-salt (n=15)	Artemia (n=37)	Artemia-salt (n=33)
Income	68.61±35.56	119.73±43.06	29.98±16.21	93.51±45.34	39.75±16.56	107.81±45.39
Profit	41.48±34.31	84.85±48.14	7.73±20.2	68.61±39.94	15.52±17.54	77.47±2.97
Profit ratio	1.67±1.28	3.17±2.55	1.3±3.38	2.74±1.35	1.08±2.17	2.97±2.72

*1 US$ = app. 22,000 Vietnamese Dong (VND)
Hong Thi Hai Yen et al., 2014

POTENTIAL FOR ENVIRONMENTAL-FRIENDLY ARTEMIA CULTIVATION IN UZBEKISTAN AND KAZAKHSTAN:

In 2021 and 2022 GIZ organized **regional missions** (site visits, supported with GIS data) in Uzbekistan and Kazakhstan to search for potential sites for *Artemia* production. Several potential sites were identified in the Nukus and Chimbay region in Karakalpakstan in the neighborhood of either saline water wells or brackish water drainage canals (so called collectors).

In the North Aral Sea region in Kazakhstan several brine wells were visited that could be used as intake waters for *Artemia* pond production.

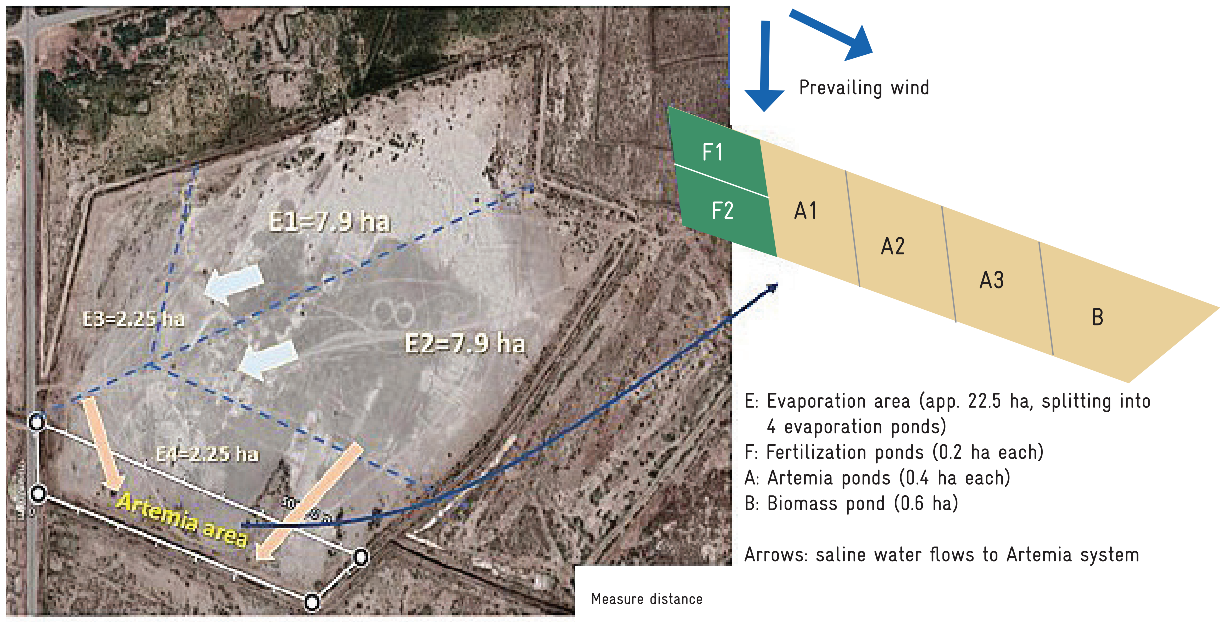
Here under one site in Uzbekistan (Nukus region) with brackish water drainage canal (collector) and salt-affected soil area formerly used for rice farming:

The following site in KAZ (N Aral region) is near a brine well and extended flat area where brine waters eventually dry up in salt lake:

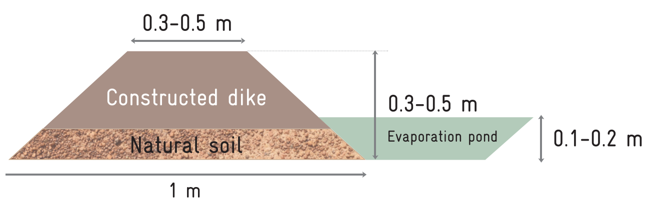
TECHNICAL DEMONSTRATION OF ARTEMIA POND PRODUCTION IN UZBEKISTAN:

A first selection of suitable sites in Karakalpakstan were further evaluated regarding their soil characteristics, water and salt availability, site accessibility, acceptance by local population, and support from local authorities. **Using Google Map's data**, pond layouts for algae production and for *Artemia* farming were prepared (see one example hereunder) and proposed for further confirmation and follow up by the local authorities.

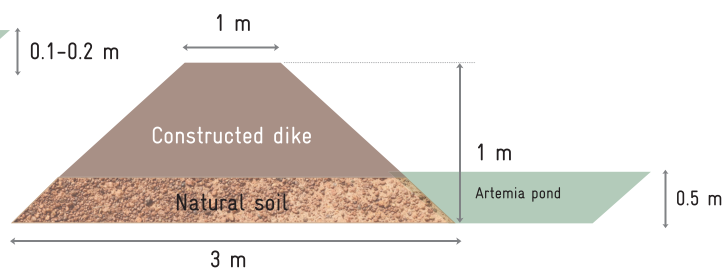
Pond layout for setting up the demonstration farm (area for water evaporation and area for fertilization and Artemia ponds):



Layout for pond dike construction:

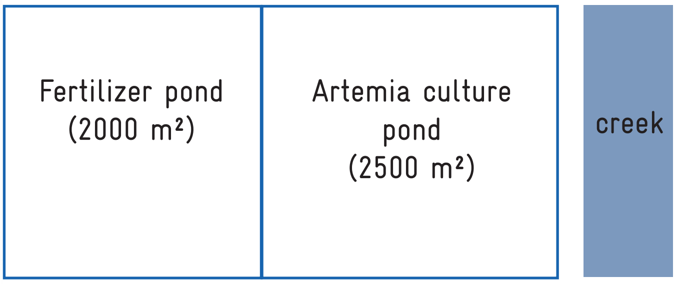


Evaporation pond



Artemia/fertilization pond

located in TAG JAP APJ, Chimbay (GPS: 42°56'01.2"N 59°49'09.5"E).



CAPACITY BUILDING – THE INS AND OUTS OF ARTEMIA CULTIVATION

From several candidates proposed by the Nukus authorities, four technical staff were selected in consensus with GIZ for a **6-week training in *Artemia* pond production and processing for use in aquaculture,** at Can Tho University in Vietnam (at the main campus in Can Tho and at their *Artemia* field station in Vinh Chau).

Upon return of the trainees from Vietnam, local authorities had chosen a new site for the demonstration unit near Chimbay. A new plan for pond construction, water and salt source was finalized and construction work initiated. One *Artemia* expert from Can Tho University joined the *Artemia* expert team in the first inoculation and pond production of Vinh Chau *Artemia* in Karakalpakstan.

Although conditions were not ideal (low water temperatures as the demonstration was set up too late in the season, nonetheless algae production in the fertilizer pond and *Artemia* production were successful and the technical feasibility of producing *Artemia* biomass and cysts was **successfully demonstrated** before the temperature dropped to suboptimal levels and production was stopped.

As this testing period was too short not enough production data could be collected to draw a conclusion on the commercial feasibility but considering the successful approach in commercial *Artemia* pond farming in Vietnam and Thailand it should be possible to develop a successful new aquaculture industry in UZB and in KAZ, initially starting with commercial *Artemia* pond production. Knowing that it was possible to show the technical feasibility for *Artemia* cultivation under suboptimal conditions shows the **true potential** of such business model for the two countries.

POLICY ADVICE: SUGGESTED GUIDELINES FOR THE DEVELOPMENT OF AN ARTEMIA FARMING SECTOR IN UZBEKISTAN AND KAZAKHSTAN

1. For the **selection of suitable sites** for environmental-friendly *Artemia* production in pond systems, initially GIS should be applied to narrow down possible sites (flat lands, former agricultural lands especially rice paddies, salt-affected soils, neighborhood of water resources, local settlements to ensure availability of manpower).
   To further narrow down choices, soil tests should be conducted to ensure high clay content to minimize water leaching in the *Artemia* ponds.
   In the absence of such sites (conflict with agriculture activities on good clay soils) the use of bentonite could be considered to seal the bottom of less suitable soils.
   Local water resources need to be analyzed regarding ionic composition, possible contamination (chemicals used in local agriculture) and flow rates.
   In relation to the surrounding area of putative sites it is critical to check for any possible harm to local flora and fauna, and possible measures be analyzed that can decrease or curb such negative effects.
   Water salinities might have to be increased through evaporation, as to be suitable for *Artemia* farming.
   Instead of a restriction to areas where electricity is available, more remote places could be considered when using solar energy for water pumping activities.

2. All these considerations are critical inputs for the local authorities to **develop a government master plan** with appropriate guidelines to make sure that this new sector of *Artemia* farming has clear boundaries so it can thrive and generate income for the local population without any potential harm to the environment.

3. Both governments need to take up the responsibility to **officialize a master plan for regional *Artemia* pond farming** with specific conditions for obtaining farming license (environmental issues regarding water use and disposal, selection of *Artemia* strain), and policies for farmers to join *Artemia* farmer clusters or associations.

4. In both countries new **demonstration farms** (preferentially as public private partnerships) should be set up timely as to operate over a complete summer season and to collect sufficient data to estimate production potential and perform detailed cost/benefit analyses

5. Once the demonstration farms are in successful operation (month 2 and later) it is advisable to organize **training sessions for interested farmers** who are convinced seeing the results at the demonstration farms and who already want to start their first trials before the end of the summer/autumn production season.

6. In the course of the *Artemia* production season a **demonstration unit** should be set up for **cyst and biomass processing** as template for later adoption by farmer clusters or associations. Priority should be given to **biomass processing** that require minimal investment in sieves and deep freezers. This would generate an immediate product that could quickly be commercialized: live and frozen food for local fish farms in the country, for the aquarium pet market (national, international), and for export as shrimp maturation feed (to the main shrimp farms in the region, e.g. Saudi Arabia, UAE, even Europe).

IN VIETNAM AND BANGLADESH ARTEMIA BIOMASS (FRESH AND FROZEN) IS EVEN USED AS HUMAN FOOD (ARTEMIA OMELET IN VIETNAM, ARTEMIA KEBAB IN BANGLADESH)

First tests could also be considered to dry *Artemia* biomass (use of sun-driers as developed in Vietnam) and explore its commercial value as fishmeal substitute, especially for countries that are highly dependent on fishmeal imports as vital ingredient in the manufacturing of fish feeds.

In parallel a small **cyst processing facility** could be set up that requires an investment of roughly 20,000 USD to buy cleaning, drying, sieving and packaging equipment. The small facility could process the first year's cyst production (roughly hundreds of kg WW) and produce samples for quality analyses including nutritional composition and feeding trials in fish and crustacean hatcheries. The samples can also be used for market testing with major *Artemia* cyst distributors to negotiate sale contracts for bigger productions in future years.

Before cyst productions reach significant quantities, harvested cysts can be easily processed and conditioned in saturated brine and stored for up to one year without loss of quality. This period allows to perform detailed quality analysis of the cysts (size, hatching characteristics, nutritional value) and already test and use these cysts in local fish hatcheries, awaiting a more responsible decision to invest in cyst drying and packaging equipment.

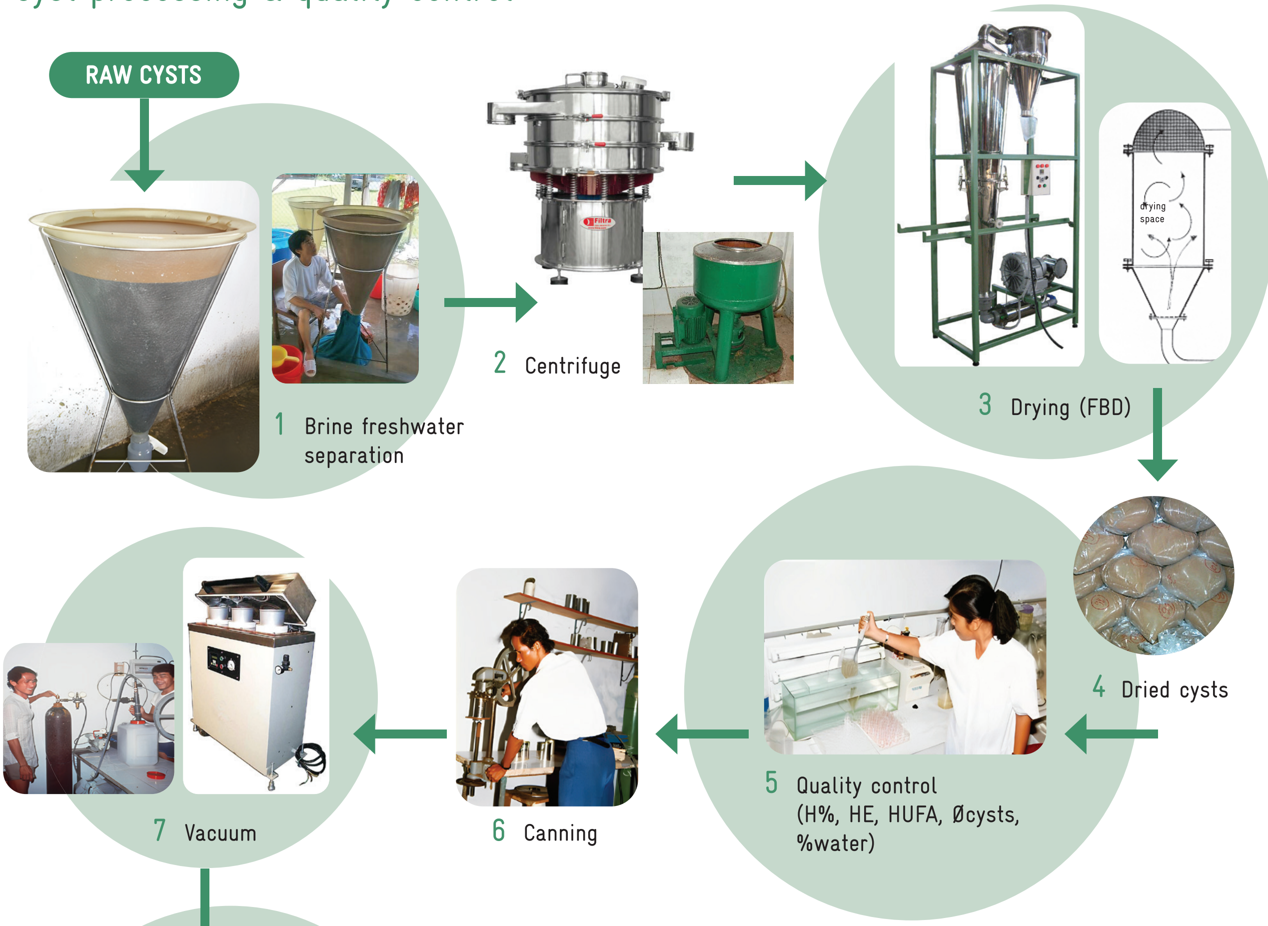
7. To decrease future production costs a research programme needs to be set up to explore the possibility of using waste/by products of local agriculture (carbohydrate rich byproducts e.g. from the licorice extraction, from rice processing, other crops) and animal production (manures) as sustainable and cheap source of nutrients in the *Artemia* production.

8. As discharge of high-salinity waters needs to be prevented (unless the site is connected to a salt farm), it is important to study the possibility at the demonstration site to recirculate *Artemia* pond waters via a biological treatment system (deep pond with long retention time, acting as microbial biofilter) resulting in the natural development of the microalgae *Dunaliella salina*, a suitable natural diet for *Artemia*.

9. It is desirable to set up an **independent reference lab for quality control** to evaluate and certify the new *Artemia* products following international standards. For example, following an intercalibration audit by an FAO recognized authority such as the *Artemia* Reference Centers in Europe and in Asia.

10. As was the case in different countries in Asia, the availability of locally produced *Artemia* (cysts and biomass) in UZB and KAZ can act as catalyst for commercial activities with other aquaculture species: aside from its use in existing domestic aquaculture the availability of *Artemia* can play a key role in pond farming of high-priced brackish water and marine tropical species during the summer season, using the *Artemia* cysts and biomass during the winter period for indoor hatchery/nursery production of the fish juveniles/shrimp/prawn postlarvae ready for one-cycle pond production when climatic conditions become suitable for these tropical species.

Cyst processing & quality control



Vietnam is an excellent example of the successful approach of working with Artemia farmer associations (3 in the Vinh Chau – Bac Lieu area, each with 100 to 200 members, salt/Artemia farmers): through their membership they receive a fixed price per kg raw product, share in the profit of the cyst sales, receive inoculation material and fertilizer/manure for the next production season, receive updates on innovations in the production system. These associations have been in existence for more than 15 years: they ensure better quality control (and certification), more negotiation power and faster adoption of new practices. Before the setup of the first association individual farmers competed among each other, delivered varying cyst qualities, and eventually lost confidence of foreign buyers.

These options should be thoroughly considered by the UZB and KAZ authorities to develop a long-term National Aquaculture Master Plan, including an important component for aquaculture capacity building (i.e. sending young staff for training in countries with an established aquaculture industry) to serve this new aquaculture industry (at the level of education and training of future farmers, policy making and implementation, extension services, as well as research for new developments).

PHOTO: ZLATKO TADIC/GIZ

CHECKLIST

LIST OF EQUIPMENT FOR ARTEMIA OPERATION (EXCLUDING THE POND CONSTRUCTION WORKS)

Mandatory equipment:

- ◯ Mobile water pumps (preferentially electric pumps using solar power);
- ◯ Nets and sieves of different mesh sizes (i.e. 200, 500 and 1000 µm) to filter out small zooplankton from intake waters, harvest Artemia of different sizes;
- ◯ Setup for production of inoculation material: cyst hatching equipment (plastic/ fiberglass cones, LED illumination, air blower, plastic tubing, air stones, salinity meter, pH meter, oxygen meter); blue ice packs for transport of nauplii in cool box;
- ◯ On-site brine (salt-saturated) water tanks to store harvested cysts;
- ◯ Dissection microscope and operating equipment to prepare samples for observation (petri dishes, glass slides and cover glasses, tweezers, etc.
- ◯ Regular compound microscope for observations at higher magnification
- ◯ Refrigerator and deep freezer for storage of Artemia products

Optional equipment

- ◯ Camera for microscope
- ◯ Spectrophotometer for more detailed water quality analysis (Nitrogen and Phosphorus components)
- ◯ Cyst processing equipment: 100-L plastic/fiberglass cones, centrifuge, fluidized bed dryer, sieving machine for final dry cyst cleaning, canning equipment, equipment for Nitrogen flushing or vacuum packing of cyst cans

CONCLUSIONS AND RECOMMENDATIONS

- Uzbekistan and Kazakhstan have suitable conditions to develop a new aquaculture industry starting with the production of brine shrimp Artemia biomass and cysts on salt affected soils that are not suitable anymore for classical agriculture.

- Upon suitable site selection, especially in regard to soil characteristics with high clay soils in alluvial regions, demonstration farms for Artemia biomass and cyst production, processing and packaging should be set up. These should serve as demonstration and training centers for interested farmers to engage in this new farming sector.

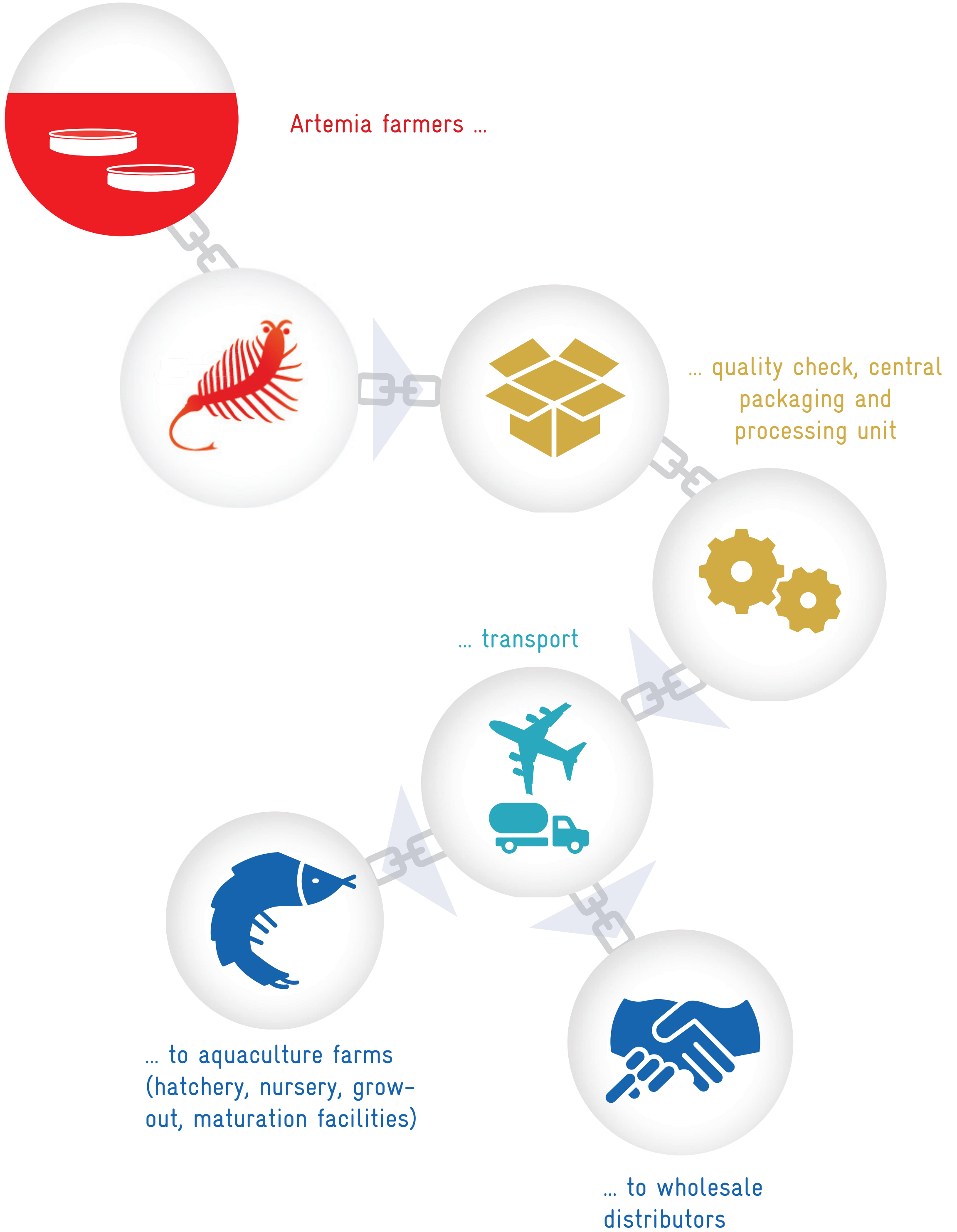
- Artemia product quality needs to be evaluated and certified at a dedicated independent laboratory that follows internationally recognized protocols for quality control.

- Locally available Artemia can trigger new aquaculture developments in both countries (integrated rice + prawn farming in Kazakhstan; in both countries pond farming of brackish water/marine fish/crustacean species in regions with salt-affected soils).

- Priority now is to set up demonstration farms of suitable size to estimate production costs and produce sufficient product for initial market testing.

- Government commitments are needed to 1) develop and implement a Master Plan for a new aquaculture industry with priority for Artemia farming on salt-affected soils, 2) set up Artemia demo farms (eventually as public private partnerships), 3) organize training programs for Artemia farmers, 4) set up demonstration unit for processing of Artemia biomass and cysts, 5) organize Artemia quality certification body, 6) promote further studies to economize Artemia farming (e.g. recycling of organic waste, improved quality products) and 7) organize next steps for farming of new species of fish and crustaceans taking advantage of local availability of high-quality and cheap Artemia sources.

TYPICAL ARTEMIA SUPPLY CHAIN



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Webinar dealing with pond production of *Artemia* and other interesting *Artemia* information at the website of the "International *Artemia* Aquaculture Consortium" https://artemia.info/news/?id=29

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