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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

1. INDEX

1. INTRODUCTION

Nowadays, intensive (conventional) farming uses significant inputs to maximise production. This can lead to considerable waste releases and to a variety of related environmental problems Consequently, a review of current problems in Farming, Fishery and Aquaculture (FFA) activities, not only in Europe but also at International level, is requested to identify common solutions and to adopt new and more sustainable practices and technologies which reduce to the minimum related impacts.

In this context, AQUAGRIS project ("Environmental management reform for sustainable farming, fisheries and aquaculture") is working to link together current research in European and INCO countries, identifying gaps of knowledge and/or legislations and formulating joint strategies to the future.

During the Aquagris meeting, held in Hamburg in May 2007, 3 different Expert Groups (EG) were selected within WP3:

- EG1: Reducing waste production.
- EG2: Reusing waste.
- EG3: Integrated culture systems.

From the second semester of 2007, the three EGs have been working in parallel, using "e-mail" as the main way of communication. The present document sinthesizes the discussions arisen on each of the three topics.

1st Experts Groups session

On the 9th of June 2008, the First Expert Groups Session was celebrated in Lecce (Italy). After a briefly introduction of the topics adressed by partners by e-mail, the AQUAGRIS Co-ordinator, V. Zonno, chaired an open forum open to all Consortium members.

The following partners participated in this session:

Partner No.	Organisation Name	Participant Name	Country
1	Università del Salento	Vincenzo Zonno Raffaele Acierno	Italy
2	AquabioTech Ltd.	Shane A. Hunter	Malta
3	Tampere University of Technology	Raghida Lepistö Petri Jokela	Finland
4	Centiv GmbH	Patricia Cadaval	Germany
5	Austrian Agency for Health and Food safety	Heide Spiegel	Austria
6	Ben Gurion University of Negev	Sammy Boussiba	Israel
7	STM aquatrade S.r.L.	Brigide Loix	Italy
8	University of Southern Denmark	Marianne Holmer	Denmark
9	Pancham Aquaculture Farms Ltd.	Ajitsinh B. Patil	India

Partner No.	Organisation Name	Participant Name	Country
10	The Suganthi Davadason Marine Research Institute	A. Murugan	India
15	Istituto per lo Studio degli Ecosistemi, Sezione di Firence	Giuseppe Torzillo	Italy
16	National Institute of Oceanography	R.A. Sreepada	India
19	Fundacion AZTI - AZTI Fundazioa	Aintzane Esturo	Spain
21	JTI - Swedish Institute of Agricultural and Environmental Engineering	Lena Rodhe	Sweden
23	Transnational Consulting Partnership	Fred Weirowski Jane Claricoates	Germany UK
24	Universidad de las Palmas de Gran Canaria	Juan Luis Gómez Pinchetti	Spain
26	University of Barcelona	Tania García Sanz	Spain
27	University of Crete	Ioannis Karakassis	Greece
29	University of Haifa	Dror Angel	Israel
31	University of Caen-Basse Normandie	Sebastien Lefebvre	France
32	Cochin University of Science and Technology	B. M. Kurup	India

EXPERT GROUP 1: REDUCING WASTE PRODUCTION

Leader:
UNILE

Other partners involved:
AZTI
SDMRI
TUT
JTI
STM
AGES
CENTIV
NIO
CUSAT
UB
UM
SAMS
UGENT

2. EG 1: REDUCING WASTE PRODUCTION

Fish farming takes place across Europe in a variety of environments and is a big user of either fresh water or sea water. Aquaculture, along with all animal husbandry, produces effluents that contain dissolved and particulate nutrients, which can lead to ecological disturbances in the receiving ecosystem.

The European Union is therefore committed to promoting and encouraging the sustainable use and efficient management of water resources across the continent. Innovative projects that help industry to optimise water use and reduce the impact on the environment are a part of that commitment.

The present document follows the discussion arisen in the Expert Group n. 1 of the AQUAGRIS project, dealing with the proposed strategy for reducing waste in aquaculture effluents. This deliberation concerns, in particular, the analysis of the available technology for solid removal and the final suggestions for improving the system efficiency.

Introduction

Intensive farming uses significant inputs to maximise production. In aquaculture, the accumulated by-products (*e.g.* fish faeces, excretions, uneaten feed) must be removed continuously to maintain optimal growth conditions and the health of the cultivated species. Suspended or settable solids (SS) and dissolved substances (DS) present in the effluents are the major responsible for potential negative impacts on the environment caused by discharging waste water into streams, rivers, lakes, the sea or the soil. The contamination of ground water as a consequence of intensive land-based fish farming activity, can also be considered as becoming increasingly problematic.

The amount of SS and DS in the effluent depends on water quality, fish density, feed quantity and quality, feeding methods, water renewal rate, tank, and site hydrology.

Modern intensive land-based aquaculture systems can be divided in two big classes: open and closed systems. In the first case all the water used to rear fish, collected from natural sources (sea, rivers, artesian wells, etc.), is generally discarded in the environment, with its content of nutrients and pollutants, after its passage through the rearing plant. In closed systems, at least part of the water collected from natural sources is recycled after specific treatments to reduce its solid matter, nutrients and pollutants content, while the rest is discarded “as is” in the environment. In this context, the exigencies of intensive aquaculture consist in efficient, well tested, easy to implement and economically affordable systems to increase the efficiency in water use.

The development and the implementation of innovative methods and technologies for farm waste water treatment, water reuse and by-products recycling permit to reduce the consumption of clean water and the delivery of pollutants in the environment.

In the following paragraph, the available technology for reducing the effluent suspended solid load is described, while in the final paragraph the future trends and conclusions are presented.

Technology for solid removal

There are particular engineering challenges inherent in the high flows combined with low pollutant concentrations of aquaculture effluents. Particularly low pollutant concentrations are found in flow through farms. Effluent from recirculation farms tend to have higher concentrations but all fish farms have concentrations significantly lower than found in treatment systems for domestic waste water. There are two methods for reducing suspended solids in fish farm effluent, each of which removes suspended solids from suspension:

- sedimentation – uses gravitational settlement systems of differing complexity
- mechanical filtration – uses energy and filtration meshes dimensioned to trap solids.

Outside influences will impact on the choice of method used to remove suspended solids. Differences in site-specific situations, including farm location and water quality, bank interest rate, and the cost of energy, cement, labour and land in different countries, will lead to a range of optimal solutions being chosen.

Before considering gravitational sedimentation methods, it is important to understand the main principle driving the settlement of a solid in water. Gravitational sedimentation uses the force of gravity to extract particles from a fluid. Differences in density between the particles and the fluid cause the particles to travel downward in a quiescent or slowly moving liquid. The specific gravity of fish faeces is close to that of water and therefore the rate of their sedimentation is low. In contrast, minerals such as sand have a high specific gravity and therefore settle more quickly. Sedimentation rate depends on the characteristics of the material being settled (including their size), and on the velocity and turbulence of the water in which the particles are suspended. Sedimentation rate is measured in centimetres per second (cm/s). In aquaculture, a favourable settlement speed is considered to be 1 cm/s. Most unused feed and faeces are separable by sedimentation.

Sedimentation of suspended solids is made more difficult by degradation of the feed or faeces 'pellet' as it travels from the fish through the fish-holding area to the sedimentation basin. Water turbulence, created by the speed of water flow and the swimming action of the fish, causes the faeces to be held in suspension and to be progressively abraded and broken down into smaller particle sizes. Very small particles become 'non-settling solids'. This degradation of faeces into smaller particles, when combined with time exposure in the water, leads to a portion of the nutrients contained in the solids becoming dissolved. Fish farm design should therefore aim to trap and remove suspended solids as early as possible after being deposited by the fish, to reduce this degradation process.

Sedimentation is critically linked to the flow rate of water through the sedimentation area. Sedimentation can be achieved by the following methods and structures:

- Simple sedimentation using a large area – ponds or basins
- Channels, with or without physical barriers
- Quiescent zones and trapping of solids within a raceway
- Lamellar settlement tanks
- Centrifugal concentrators - hydroclones or cones

Simple sedimentation is achieved by structures, variously called sedimentation, or settling, ponds and basins, that make use of the settlement characteristics of the solids. The method relies on a large area to slow the speed of flow, thus allowing time for the solids to settle. These areas should be designed to achieve laminar flow of the effluent across the area, and to avoid the water taking the shortest, and fastest, route between the inlet and outlet. It is generally agreed that the residence time should be a minimum of one hour. For example: with a flow of 500l/s (1800m^3/h) a minimum pond of 1800m^2 with a depth of 1m is needed to provide a residence time of one hour.

The requirement for a large surface area of water is the main reason that simple sedimentation is used less often where large water flow rates are involved.

When designing a sedimentation area, arrangements should always be made for later removal of the trapped solids. Channels, with or without physical barriers, are often designed with frequent changes of water flow direction in order to reduce the energy of the solids and accumulate the waste at specific points. The channels can be built in concrete to facilitate cleaning. An improved design using a smaller land area consists of channels with internal barriers which partially obstruct the channel section. The internal barriers decrease the energy of the particles and assist sedimentation.

Alternatively, where space is available, channels can be excavated in water meadows providing sufficient transit time for the solids to settle. Such channels must be designed to allow removal of the settled solids. This is best achieved by having twin channels, so that all the flow can be passed through one channel while the other is being cleaned.

Quiescent zones and in-raceway solids collection (cones) Sections of raceways, usually located before the outlet, can be screened to exclude the fish, thus providing an area with reduced turbulence where solids can settle. A further improvement on this is the installation of collection cones within the floor of the raceway. These cones have a valve system for periodic flushing of the sediment.

Lamellar settlement tanks achieve settlement of solids in a restricted land area, by more sophisticated parallel and inclined barriers. They are complicated, expensive to construct and difficult to clean. They are rarely used for fish farm effluent treatment.

Centrifugal concentrators (hydroclones) make use of centrifugal force to separate solids from water. Incoming water is directed tangentially at the top of the cylindrical (uppermost) part of the hydroclone vessel and the velocity of the inflow water is converted to rotary motion, thus creating centrifugal force. Heavy solids are thrown outwards and settle into the lower, conical, part of the vessel for subsequent removal. Hydroclone tanks are effective for high-density solids such as sand and mud but are difficult to use with large flows or with solids having a specific gravity close to that of water, such as fish faeces. The turbulence associated with higher water velocity also contributes to the degradation of the faeces. These limitations restrict the use of hydroclones in aquaculture to specialist situations.

Mechanical filters remove solids from water using physical barriers through which the solids particles cannot pass. This is usually achieved with a packed medium such as sand or with a mesh. Mechanical filters will remove both settling solids and those that will not settle due to their small particle size or low density. Before selecting or designing mechanical filters, it is important to know:

- *Type of solids to be filtered*, in terms of their average particle size, range of particle sizes and nature of the material. These can all be site-specific, and depend on the water source as well as the farm construction and management. The characteristics of the solids will influence the material best suited to their filtration, and the filter cleaning process to be adopted.
- *Concentration of solids within the effluent.* This, with the flow rate, defines the loading of material to be filtered and is usually measured in milligrams per litre (mg/l). The combination of type of solids and loading determines the specification of the filter that will be needed to achieve a satisfactory result without continual clogging.
- *Mesh or filter-media size* sets the performance of the filter. Choice of filter is always a compromise, requiring knowledge of the desired degree of solids' removal, the rate of flow of effluent, the suspended solids' loading and the capital investment that the business can afford. Mesh size is measured in microns (µ m).
- *Flow capacity* of a filter describes the maximum water flow that the filter can accept according to type of solid, loading, particle size and backwashing frequency, for a given mesh size. It is measured in litres per second (l/s). The precise flow capacity is a designed feature of any filter and is declared by the filter manufacturer.
- *Energy requirements to operate filter*. Head loss represents the energy required for a desired water flow to pass through the filter. It is normally calculated based on the flow when the maximum acceptable level of clogging is reached and is measured in metres (m).

Filters are also categorised according to whether they use pumped pressure or gravity with low head loss. Examples of each category are considered next.

Pressure filters are supplied by a pump or by a head of water. Such filters are totally enclosed in order to maintain water pressure across the filtration medium. Head loss through pressure filters varies from 0.5 - 5 bars (1 bar is equivalent to 10 m water head). These filters can be automatically or manually backwashed. Cartridges and bags used as filtration media are not cleaned but have to be exchanged.

Examples of pressure filters are: cartridge, bag and sand filters.

- *Cartridge filters* are the most commonly used filters for very fine filtration, down to 1 µm, when the water flow is low (maximum 1 - 2 l/s). This method is expensive because backwashing the cartridge is not possible. The cartridges are designed to be disposable and are thrown away after use.

Bag filters are theoretically suitable for much higher water flows >100 l/s and can, like cartridge filters, achieve filtration down to 1 µm. The filter is constructed either with a single chamber or with a number of chambers which house the filter bags. Bags are made of various materials, including plastic and stainless steel 316. Bag filters are used in aquaculture for flows up to 15 l/s. Filtering higher flows by this method is uneconomic for aquaculture and is generally only suitable for filtering high value materials in industrial processes.

- *Sand filters* are the pressure filters most widely used in aquaculture. The largest sand filters currently available are 3 m diameter and 3 m high. These can filter up to 50 l/s with a filtration down to 50 µm and an inflow containing <10 mg/l of suspended solids. Sand filters are economical because:
  - sand is cheap and widely available;
  - filter vessels are now made of glass re-enforced plastic, which is less costly than stainless steel.
  - maintenance is simple.

Sand pressure filters, in common with all pressure filters, have high operating costs due to the

energy used for pumping.
Pressure filters are frequently used for filtering seawater at the inlet of a hatchery. They are normally installed in series in order to avoid fast clogging of the finest mesh. When water is to be filtered down to 5 µm, a series of three filters of 100, 50 and 10 µm, respectively, should be installed upstream of the 5 µm filter. The system will work better and the total cost for filtration mesh will be reduced. Cost of filter mesh material increases as mesh size is reduced. It is economic to remove larger particles using larger mesh size.
Gravity filters These include drum filters, disc filters and belt filters, known collectively as microsieves, and use less energy than pressure filters. They pass water through the filter using the gravity, or water head, available at the site. They operate with a low head and water is usually delivered to the filter through an open channel. Such filters are frequently used when large flows, from 5 - 1500 l/s, or even more using a battery of filters, have to be filtered. Microsieves can handle significant quantities of suspended solids and can remove particles down to 20 µm in size. They are more usually fitted with 60- or 90-µm mesh filters.
Gravity filters typically have a large filter-mesh surface area and a low head loss. They are generally equipped with an automatic periodic cleaning system which is used to avoid the filter clogging with solids.

- *Drum filters* are the most efficient and most widely used filters for aquaculture. Water passes axially into a stainless steel drum, the inner wall of which is made of plastic or metal mesh, through which the water passes by gravity, leaving suspended solids' particles caught on the inside of the mesh. The filter is either in constant movement or its rotation is activated by sensors that detect an increasing difference of water height between that before and after the filter mesh. The backwash cycle is actuated by a timer. Drum filters are suitable for both fresh- and saltwater. Where disposal of solids retrieved from saltwater farms requires low salt levels in the sludge, freshwater can be used for the backwashing.
- *Disc filters* are a variation of the drum filter (microsieve) offering a large filter surface area within a relatively small space. Disc filters are more expensive than drum filters for a given water flow, and are recommended in aquaculture only when the available space is limited.
- *Belt filters* are a third possible configuration for gravity filtration. Water passes through a moving belt which provides the filtration element. The belt is inclined at a shallow angle away from the direction in which the water flow approaches. As the water passes through the belt, any suspended solids that are greater in size than the filter mesh are lifted gently from the flow and are then washed off by intermittent water jets into a collecting trough. Belt filters have proved effective for low flows heavily loaded with suspended solids.

The efficiency of microsieves at removing solids will depend on the condition in which the solids arrive at the filter. In particular, the degree to which the faeces have been degraded in travelling from the fish to the filter will be critical to filter performance

Future trends and conclusions

As the world population and economy grows, water becomes an increasingly scarce commodity.

Fish farming takes place across Europe in a variety of environments and is a big user of either fresh water or sea water. Aquaculture, along with all animal husbandry, produces effluents that contain dissolved and particulate nutrients, which can lead to ecological disturbances in the receiving ecosystem.

The European Union is therefore committed to promoting and encouraging the sustainable use and efficient management of water resources across the continent. Innovative projects that help industry to optimise water use and reduce the impact on the environment are a part of that commitment.

There are three strategies at farm level to improve water quality and to reduce effluent nutrient load: improved farm management, effluent treatment and water reuse.
The application of each strategy, either individually or in combination, can significantly reduce effluent concentrations.

The provision of optimal rearing conditions for fish, to reduce stress and to promote optimal growth, is the first management strategy to limit the nutrient discharge.
New feed formulations for improving the physical removal of particulate wastes are needed; the application of binders in fish diets is a highly promising approach.

Mechanical filtration of effluent treatment is established practice in both flow through and recirculation farms. Further development is needed to improve filter efficiency and the processing of the micro-screen backwash water (wet sludge). Greater mechanical dewatering and more effective and economic use of coagulation/flocculation chemicals can be developed. Research trials with polymers of natural origin which do not chemically alter the sludge or the clarified water will pay dividends.

The economic aspects of most treatment methods have not been well documented until now, an area where reliable data are imperative for farmers to make decisions over investment.

The treatment of effluent water from aquaculture poses different challenges to other better understood fields of water treatment. The aquaculture industry is still young and serious aquacultural engineering is even younger as a field of study. The rate of progress has been high and with further investment in suitable research projects, that progress rate can be maintained and enhanced.

The significant reductions sought for the environmental impact of aquaculture can only be delivered on the back of improved technology. This is an area where investment of public funds will deliver results in the form of environmentally friendly and sustainable aquaculture.

EXPERT GROUP 2: REUSING WASTE
Leader:
NIO/UNILE

Partners involved:
CENTIV
IGZ
CUSAT
ISE-CNR
JTI
UMB
TNC
AQUABT

EG2: REUSING WASTE

Fish farming takes place across Europe in a variety of environments and is a big user of either fresh water or sea water. Aquaculture, along with all animal husbandry, produces effluents that contain dissolved and particulate nutrients, which can lead to ecological disturbances in the receiving ecosystem.

The European Union is therefore committed to promoting and encouraging the sustainable use and efficient management of water resources across the continent. Innovative projects that help industry to optimise water use and reduce the impact on the environment are a part of that commitment.

The present chapter follows the discussion arisen in the Expert Group n. 2 of the AQUAGRIS project, dealing with the opportunity to reuse the solid waste extracted from marine aquaculture effluents. This deliberation concerns, in particular, the analysis of marine sludge physico-chemical characteristics, recommendation for its reuse in agriculture and suggestions for future research topics.

INTRODUCTION

Sludge comprises uneaten fish pellets, faecal material, soluble metabolite products and also any particles that enter the tanks/raceways with the water inflow. Fish sludge may be described as the 'solids' part of the waste stream in a fish farm. The water content of sludge depends on the system used to separate the solid and liquid fractions.

Farmed fish are fed pelleted feed to provide a balanced diet for optimum growth rates. Feeds contain nutrients such as nitrogen (N) and phosphorus (P) as well as trace elements. Since fish typically utilise only 30% of the ingested N and P, the remainder is voided. Most of the voided N is dissolved and lost through the gills, whereas for P, the majority is associated with the solid material and is excreted in the faeces.

Fish farm effluents containing P and N have been reported to have caused eutrophication of receiving waters. Sludge can be removed from effluent water by mechanical filters or by settlement, with or without the use of flocculating agents. Sludge is removed to comply with legislation governing the quality of water discharged to the water catchment. It may also be removed from recycled water to maintain healthy conditions for fish growth. Under certain environmental conditions, P and N can be released from nutrient-rich sludges and may stimulate algal growth.

Fish sludge contains nutrients and organic matter which have potential for spreading on agricultural land to reduce the amount of inorganic fertiliser required. Furthermore, such reuse of nutrients may offer a low cost 'disposal' option.

However, fish sludge can contain harmful substances, such as heavy metals and pathogens which would limit its suitability for use as fertiliser. Sludge from saltwater fish farms can also contain significant quantities of sodium (Na) which may adversely affect soil structure.

In order to optimise the use of fish sludge on land and to minimise negative environmental impact, it is essential to know the nutrient content and plant availability, as well as the content of any heavy metals, Na and viable pathogens (see later).

PHYSICO-CHEMICAL CHARACTERISTICS OF FISH SLUDGE

The chemical composition of fish sludge can be expected to vary due to differences in management practice, species, size of fish, feed, aquatic environment (freshwater or saltwater), water flow dynamics and dewatering efficiency. Due to the different efficiencies of dewatering systems it is best to compare nutrient contents on a dry weight basis.

Nutrient contents

It has been shown that the nutrient content of Rainbow Trout (*Oncorhynchus mykiss)* sludge was in the range of that measured in different animal manures (Table 1). This would suggest that freshwater fish sludge could be utilised in a similar way to livestock manures. Marine sludge has similar values to freshwater (See Table 2), but may also have high levels of sodium.

Dry weight g/kg	**Freshwater Fish**	**Dairy cattle**	**Poultry**	**Pig**
Total Nitrogen (N)	0.20 – 0.39	0.01 – 1.01	0.13 – 1.50	0.06 - 1.00
Phosphorus (P)	0.06 – 0.47	<0.01 – 0.25	0.01 – 0.40	0.04 – 0.65
Potassium (K)	<0.01 – 0.02	0.01 – 0.65	0.06 – 0.54	0.05 – 0.63

Table 1: A comparison of the nutrient content of Rainbow Trout (*Oncorhynchus mykiss)* sludge with different livestock manures.

Freshwater fish sludge contains relatively small quantities of total N and most of this (*ca*. 80%) is in its organic form. The majority of the N not utilised by fish is voided in a dissolved form in the water. Fish excrete the majority of their nitrogenous wastes across the gills as ammonia ($NH_{3\,(aq)}$).

Heavy metal contents

Heavy metal content of fish sludge can pose problems if applied to acidic soils where the availability of the heavy metals could result in plant uptake and transport into sensitive ecosystems.

Studies in Chile and in Canada found levels of heavy metals to be low in both freshwater and marine sludges. Levels of individual heavy metals will reflect their presence, in the feed, the farm water supply and native sediment under cages.

Pathogens

No literature was found regarding the impacts of fish sludge applications on pathogen transfers to agricultural land. The risk of pathogen transmission from aquaculture to humans and domestic livestock remains a possibility via this route.

Sludge type	**3. Selected Chemical Components** (Mean values)						
	Dry Matter	Total N	NH4-N	Total P	Total K	Total Na	pH

	%[1]	kg/m³	%[1]	kg/m³	kg/m³	kg/m³	
Trout (*Oncorhynchus mykiss*)	1.3	1.37	58	0.38	0.01	0.09	5.9
(range)	*(0.5-2.4)*	*(0.83-2.10)*	*(35-78)*	*(0.14-0.90)*	*(0-0.02)*	*(0.07-0.11)*	*(5.3-6.4)*
Turbot (*Psetta maxima*)	4.3	0.64	39	0.36	0.33	7.61	7.2
(range)	*(3.3-6.1)*	*(0.4-0.83)*	*(18-60)*	*(0.11-0.79)*	*(0.260.38)*	*(5.94-9.19)*	*(6.8-7.3)*
Sea Bass (*Dicentrarchus labrax*)	14.5	3.3	-	0.07	0.75	8.3	7.2
(range)	*(14-15)*					*(4.5-12)*	
Cattle (*Bos taurus cv. Freisian*)	2.2	0.9	52	0.23	1.82	0.13	7.1
(range)	*(0.9-4.5)*	*(0.29-1.90)*	*(37-66)*	*(0.09-0.43)*	*(0.81-3.67)*	*(0.11-0.16*	(6.8-7.3)
1. Calculated as weight / volume %							

Table 2: Chemical components of sludges used in experiments carried out in the AQUAETREAT Project (EU Collective Research COLL -CT-2003-500305).
Data expressed on a fresh weight basis; i.e. as received and used.

SLUDGE CHARACTERISTICS

Sludge characteristics depend on fish species, age, diet and effectiveness of the thickening treatments (including flocculation, filtering, sedimentation). The composition of the sludge and of the supernatant, collected from a turbot fish farm, can be seen in Table 3, together with a typical pig slurry analysis for comparison. The difference in the chemical characteristics of the dry matter in the sludge and in the supernatant is notable. The BOD_5, total N (Kjeldahl), total P and ammonium-N contents of the thicker sludge are much greater than that of the supernatant: thickening up sludge (dewatering) concentrates the nutrients (and microbial populations).

	Dry Matter (%)	pH	BOD_5 (mg/l)	Total N (g/kg)	NO_3-N (g/kg)	NH_4-N (g/kg)	Total P (g/kg)	Total K (g/kg)
Supernatant	4.3	7.2	21	0.09	0.00	0.05	0.02	0.81
Fish Sludge	22.6	6.8	5,615	2.65	0.00	0.45	10.09	0.21
Pig Slurry	6.0	7.0	20,000	8.33	0.00	5.00	2.17	4.17
1. Calculated as weight / volume %								

Table 3: Physico-chemical analyses of the effluent from the settling tank at the Turbot (*Psetta* maxima) **fish farm**. Nutrients expressed on a dry weight basis.

Because of the high P content in the fish sludge in the above example, the value of marine fish sludge as a fertiliser is debatable. The application rate of 100 kgP/ha is an impractical 5 m^3/ha and for this reason this turbot product is likely to be classified as a waste. Under present conditions of escalating world price of phosphorous, its recovery from such sludge must be coming increasingly attractive.

The sodium content of marine sludge may not present a problem, if, during filtration, the sieves are back-washed with freshwater, where it might be expected that most of the sodium would be removed from the resulting sludge. Many plants do need sodium (Na) for maximum yield; together with K, it is involved in osmotic regulation within the plant. Some crops such as Beet (*Beta vulgaris*), turnips (*Brassica rapa*) and carrots (*Daucus carota*) will still respond to sodium when potassium levels are adequate. Cereals (*Triticum, Hordeum and Avena spp.*)**,** some varieties of *Brassica oleracea* (e.g. kale, broccoli, cabbages) and peas (*Pisium sativum*) are only responsive when Potassium is deficient. Sodium is soluble and it therefore leaches easily down through the soil profile; up to 50% of soil sodium may be lost in this way each year.

RECOMMENDATIONS FOR USING FISH SLUDGES ON CROPS AND FUTURE TRENDS

Determine if there are any legal issues relating to the use of the fish sludge

Having established that it is legal to apply the fish sludge in the particular circumstances concerned, the following steps are recommended.

Determine the soil nutrient content. It may have sufficient N, P and K to support much of the crop growth, in which case less sludge is required.

Determine what nutrient input is recommended for the crop to be grown. This will be dependant on the soil nutrient supply. There are guidance texts available for some countries, e.g. the UK[1].

Determine the nutrient content of the fish sludge in the state it will be applied to the land (i.e. after dewatering or flocculation and settling). A sample will need to be sent to a commercial laboratory for analysis. There will be some nutrient loss during storage, mainly as gaseous ammonia; agitation or aeration would increase this loss.

5.When livestock manures are used, it is recommended that they supply 50 - 60% of the total crop requirement, using inorganic fertilisers to supply the remainder. This reduces the potential risk of over-applying nutrients. The same guidelines should apply for fish sludges.

6.Apply the fish sludge at the estimated rate using calibrated spreading equipment to ensure uniform application.

7. Apply inorganic fertiliser to supply the remaining nutrients.

Notwithstanding the above guidelines, farmers should take note of any national/regional/local advice about timing and rates of applications[2], and must comply with EU legislation regarding the application of organic materials and nutrients to land, for example with the European

[1] MAFF (now DEFRA). Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209). 2000. 7th Edition.

Nitrates Directive[3].

Improved sludge thickening, stabilisation, storage and reuse are needed in order to achieve cost effectiveness for this by-product as a soil conditioner or fertiliser in agriculture. The long term effect of disposing marine sludge on the land must be addressed to give confidence in its use.

Alternatives for sludge reuse, including composting, heat production through combustion or pyrolysis, for methane or phosphorous recovery, as a fibre source or as a growth medium for worm culture, are possible but not yet sufficiently understood to be commercially exploited.

The economic aspects have not been well documented until now; an area where reliable data are imperative for farmers to make decisions over investment.

[2] For example, MAFF (now DEFRA). Code of Good Agricultural Practice for Protection of Water. October 1998, has been developed for conditions in the UK.

[3] Council Directive 75/440/EEC.

EXPERT GROUP 3: INTEGRATED SYSTEMS

Leader:
UCBN

Partners involved:
ULPGC
PAFL
SDRMI
CUSAT
UH
SDU
AQUABT
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4. EG3: INTEGRATED SYSTEMS

Integrated System may be defined as the association of two or more normally separate farming systems which become part of the whole farming system. The major features of this system include:

- ♦ Recycling of waste or by-product in which the waste of one system becomes the input of other system.
- ♦ ú Efficient utilisation of farm space for multiple production.

The intensive development of the FFA industries has been accompanied by an increase in environmental impacts. The production process generates substantial amounts of pollutants outputs; discharges from aquaculture into the aquatic environment contain nutrients, various organic and inorganic compounds such as ammonium, phosphorus, dissolved organic carbon and organic matter; nutrients dragging from agriculture and cattle farming activities, lead to environmental deterioration of the receiving water bodies. In addition, the drained water may increase the occurrence of pathogenic microorganisms and introduce invading pathogen species.

Different methods have been tried to minimize the effects of nutrient loading. Integrated systems and other sustainable practices as recirculation systems are ones of the most feasible methods to reduce the environmental impacts of by-products from FFA industries.

The possibilities of systems integrations are very wide, from the combination of different fish production systems to the integration of agriculture and/or livestock by-products into aquaculture farms.

The integrated livestock/fish farming systems safeguard the environment because the livestock manure is used as organic fertilizer for the fishponds, which also function as waste stabilization ponds. The most popular systems are fish/poultry culture, fish/pig culture and mixed culture (fish, pig, poultry). Effluent from freshwater culture can be used to irrigate terrestrial crops, the nutrients of which will supplement the crop fertilization and significantly reduce fertilizer requirements. This will greatly help in reducing the discharge of effluents into the ecosystem.

CURRENT INTEGRATED SYSTEMS

Nowadays, multiple variations are possible in the domain of systems integration. Residues from one culture are utilize to feed the following culture of the system, in order to minimize as much as possible the socio-economical and environmental impacts related to FFA industries.

The following figure ilustrates an example of how an integrated farming system could looks like :

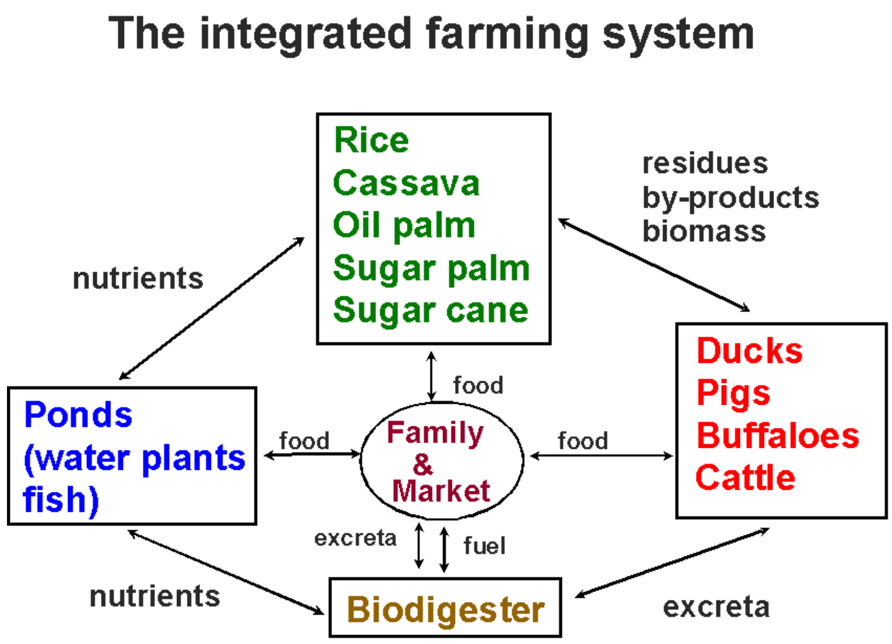

Fig 1 : *Livestock Production from Local Resources in an Integrated Farming System, by Thomas R Preston from the University of Tropical Agriculture Foundation and Royal University of Agriculture, Phnom Penh, Cambodia*

Bivalves and seaweeds can be used as biomechanical filters. It has been shown that integrated seabream-seaweed culture can help negate the pollution problem. Integrated seabream-shellfish-seaweed farm has been proposed with higher output. Integrated freshwater fish-vegetable farms and fish-algae-shellfish/abalone integrated mariculture farms are in operation today.

Shrimp culture assumed greater significance all over the world and simultaneously, environmental concerns have also been raised. Therefore, integrated culture with suitable species which can efficiently utilize the excess organic and inorganic inputs, would be a viable option to sustain the industry.

In shrimp culture, edible seaweed such as *Gracilaria* sp. can be used as a nutrient scrubber to remove dissolved nutrients from effluent. The water containing organic and inorganic inputs can be discharged into a settling pond holding seaweeds. The photoautotrophic plants counteract the environmental effects of the heterotrophic fed fish and shrimp and restore water quality by using solar energy to turn nutrient-rich effluents into profitable resources. Also, fish species such as tilapia, milkfish, and mullet may be stocked in settlement ponds, providing an additional income.

Inland Shrimp culture can be also combined with Olive production. Effluent from low salinity inland prawn farms can be used for irrigation of salt tolerant crops such as sorghum, cotton, wheat and olives[4].

In addition, there is a successful case about the integrated aquaculture of sea cucumbers and

[4] McIntosh and Fitzsimmons, 2003.

shrimp in Australia - both yield high valued aquatic products. Sea cucumbers, as well as sea-urchins and abalone, seems to be excellent candidates for integrated aquaculture from both, technically possible and economically interesting, points of view. It appears that actual supply of these organisms (easily cultivable) for human consumption is not enough for the market. In the case of sea cucumbers, natural populations (i.e. Peru's coasts) are decreasing very fast due to over-exploitation. Integration of shrimp/fish with sea cucumbers/sea urchins, abalone and seaweeds (non-processed feed for abalones and sea urchins) might be a good organisms combination in an integrated on-land system.

Another type of system integration is tested in the University of Gran Canaria (Spain) where fish, abalone and green and red macroalgae are combined in the integrated system, in order to feed the abalones with the algae produced.

Integrated livestock-fish, poultry-fish, and rice-fish farming and crop rotation in fish ponds have been well developed and practised in countries like China, Hungary, Germany and Malaysia. Indian freshwater aquaculture has been largely organic-based, with inputs derived from activities of agriculture and animal husbandry with plants and animal residues forming the major component of feeds and fertilizers in carp polyculture. For centuries, small-scale farmers have sustained themselves by practising different kinds of crop diversification.

Many other culture integrations are tried and addopted in European and INCO countries and new ideas have been explored.

Advantages of integrated fish farming systems

Integrated fish farming systems utilise the waste of live stock, poultry and agriculture byproducts for fish production. **About 40-50 kg of organic manure can produce 1 kg of fish**. Fish farms having an integration with mulberry cultivation, sericulture and silk extraction from cocoons allow the pupae to be utilised fish feed and the worm faeces and wastewater from the processing factory to be used as pond fertilisers. Pond silt can be used as fertiliser for fodder crops which in turn can be used to raise live-stock and poultry or as fish feed. Thus a recycling of waste is done in integrated fish farming system. The scope of integration in a fish farm is considerably wide. Ducks and geese may be raised on the pond, pond dykes may be used for fruit plants and mulberry cultivation or for raising pigs, cattle, and dyke slopes for fodder production. From integrated fish farming systems not only fish but meat, milk, eggs, fruits, vegetables, mushrooms etc. can be obtained. This system fully utilizes the water body, the water surface, the land, and the pond silt to increase food production for human consumption. The integrated fish farming system holds great promise and potential for augmenting production, betterment or rural economy and generation of employment. In India this has a special significance, as it can play an important role in improving the socio-economic status of a sizeable section of weaker rural community, especially the tribals.

Aquaculture for wastewater treatment

Development and pollution are two interrelated processes that have been causing great concern to the planners. With worlwide increasing population, in many countries the quantities of wastewaters generated have been increasing beyond treatment capacities, apart from a host of industrial effluents in the recent years and solid wastes. Several processes of treatment include the conventional activated sludge and trickling filter methods, oxidation/waste stabilisation ponds, aerated lagoons and variations of anaerobic treatment systems, the latest one being the Upflow Anaerobic Sludge Blanket (UASB) process.

It is increasingly being recognised that sewage is just not a pollutant but also a nutrient resource, as evidenced by about 90 t of nitrogen, 32 t of phosphorous and 55 t of potassium that could be recovered from the country's domestic sewage daily. Traditional practices of recycling sewage through agriculture, horticulture and aquaculture, they being basically biological processes, have been in vogue in several countries.

Several variations of models of aquaculture for treatment of domestic sewage have been proposed. Employment the biotic components in an aquatic ecosystem that include bacteria, algae, duckweeds, macrophytes and fish/shellfish, the principles of all the models has primarily been dilution, oxidation, reduction of BOD, COD and the suspended solids along with nutrient recovery in terms of biomass. Several food chains operate in these systems, rendering the influent, nutrient-deficient and less harmful to the environments to which they are discharged.

Fish ponds serve as facultative ponds for sewage treatment, also providing oxygen output form to photosynthesising algae and macrophytes. The macrophytes also serve as nutrient pumps, reducing the eutrophication effects that the sewage is likely to cause in the natural waters. It has been demonstrated that the ponding reduces the bacterial loads by 2-3 long units and bacteiophage loads by 3-4 long unit seen at sewage loading of 100 kg COD/ha/day.

With no evidence of build-up on the concentration of excreted micro-organisms in pond water with either an increase in organic loading or time, it has been shown that the faecal coliform concentrations reduced by 4 log units within 24 hours of retention in the ponds. Studies have also shown that about 1 MLD of domestic sewage could be treated over an area of one hectare through water hyacinth reducing the BOD and COD by 89 and 71% respectively, along with removal of nitrogen and phosphorous to extents of 89 and 50%.

The sewage-fed fish culture of Munich in Germany and Bheries in Calcutta are world-famous. Emphasis on these practices has been on the recovery of nutrients from the wastewaters. Taking culture from these practices and deriving from the new databases in different disciplines of wastewater management, aquaculture is being proposed and standardised as a tool for treatment of domestic sewage. A successful demonstration in related area pertains to treatment of distillery effluents through fish culture in Madras.

Nevertheless, Public Health concerns are being raised with regard to sustainability of consumption of fish/shellfish from such systems as Aquaculture represents a product-oriented practice. These pertain to the microbial load of the produce, possibilities of harbouring human pathogens, accumulation of pesticides residues, heavy metals etc. Accordingly, the sewage-fed aquaculture models are being modified with incorporation of plant cultivation prior to application of wastewaters in his fish pond, also followed by necessary deprivation measures.

Reuse of Aquaculture effluents using halophytes

Some types of halophytes (as Samphire and sea aster) are being grown in aquaculture wastewater as a salad and could be used as fodder and the fruit also produces oil (www.saltygreens.com).This is an intereting possibility as far as the development of the so called "**Biosaline agriculture**" is a promising approach for land regions with desertification problems. Indeed, possible new applications including oil production are being described and new species of halophytes seem to be perfect candidates to be irrigated with wastewaters produced by intensive aquaculture operations.

The International Center of Biosaline Agriculture (ICBA) is an applied research and development center located in Dubai, UAE that is working in the same direction. The need for ICBA arose from the realization that fresh water resources are overexploited in much of the developing world and that other sources of water must be exploited to make agricultural expansion possible.

The ICBA has several running activities to develop sustainable water management to irrigate areas affected by the high content in salt (in soil and water). The use of aquaculture effluents to irrigate halophytes may represent a very good solution for countries were agriculture has to deal with desertification and high salinity levels.

Use of sponges to concentrate aquaculture effluents

Sponges are among the most efficient benthic filter-feeding invertebrates (Reiswig 1974, Riisgard et al. 1993) and are capable of feeding on both living and detrital organic particles (Navarro and Widdows 1997, Ribes et al. 1999), spanning a broad size range, from small bacterioplankton (Fu et al. 2006) to zooplankton (e.g. Watling 2007). A number of workers have proposed to use these feeding characteristics for practical purposes such as removal of particulate organic matter released from marine sewage outfalls and reduction of organic effluents from marine fish farms (Barg and Philips 1998, Ostroumov 2002, 2004, 2005, Stabili et al. 2006). Sponges have been observed to recruit spontaneously and in high abundances on hard substrates around fish farms (Angel et al. 2002, Spanier et al. 2003, Cook et al. 2006, Tsemel et al. 2006, Spanier and Angel 2008) indicating that the fish farm environment is suitable for their growth. In light of overfishing of sponges in many parts of the world, as well as mass mortalities, such as the recent event in the Mediterranean Sea (Pronzato 1999), a number of workers have suggested incorporating sponge farming around net cage fish farms as a way to promote sustainable sponge farming. One of the problems with sponge aquaculture is the difficulty in successfully transplanting and farming many of the sponge species, but some recent successes (e.g. Milanese et al. 2003, Fu et al. 2006) infuse hope in this direction. Moreover, a number of new initiatives on integrated mariculture using sponges (Pronzato et al. 1998, Manconi et al. 1999, Pronzato et al. 1999, Corsi et al. 2004) have generated considerable interest in the aquaculture community (see Annex 1: Reference).

The potential of sponges and microalgae have a potential application in medical technologies, in food and feed ingredients and as biofuels. (read more:)

Future trends and conclusions

Although integrated farming has now been proved to be highly profitable, its practice remains very limited in scale. This is because the relevant scientific and technological information on diversification of methods is unavailable to farmers. To remedy this, there must be a bridge between the information sources and the farmers. A multidisciplinary approach is needed, including technological, economic, social and political aspects which are interrelated. Any approach must, however, be relevant to national economics, social and environmental conditions and to the farmers need.

Thus, most of the current integrated farms in south East Asia are operated in the traditional way without proper planning, modern technology or modern farm management techniques and rely on personal experience.

Marketing is therefore a recurrent problem except in year where demand is sufficient. Fish disease constitute a further major problem with the farmers cannot solve by themselves since they have inadequate experience and knowledge, and such knowledge is not as readily accessible as with other farm animals where feed manufacturers or veterinary supply companies offer services to assist farmers in many cases.

A further problem for farmers is the shortage of credit and working capital, which forces them to contact their produce sales to middlemen, usually at unfavourable prices.

Past research, like in the GENESIS[5] project, for the development of sustainable integrated marine multi-trophic aquaculture systems, identified several **bottlenecks**, like of current approaches:

- Need of water fluxes control (alternatively in coastal zones, known and optimized).
- Need of further development in using multi-trophic combinations.
- Need of a "polyculture" spirit admitted by farmers
- Need of the acceptance of integrated systems by consumers.

AQUAGRIS project meets many experts in FFA industries who are ready to discuss existing technologies, problems, policies and barriers but also potential solutions for more sustainable integrated practices.

First EG3 deliberations conclude that the lack of knowledge is one of the main barriers to move from intensive monoculture to integrated farming. Farmers and stakeholder must be well informed about the possibilities of integrated practices. To adapt monoculture systems to integrated ones, farmers may have to learn a new type of culture production and find to the new organism a place in the market. Another question which may influence farmers' final decision is if the income of the new culture will justify the investment.

On the other hand, consumers are sceptic when it comes to consume products from integrated aquaculture systems, because they are raised with waste from other cultures with the aim of lowering the costs and promoting sustainable development. The lack of information and the competitiveness in global markets of food produced by current farming activities are the main

[5] http://genesis.ocean.org.il/main.htm

barriers to the development of sustainable integrated aquaculture systems. Therefore, considering consumers' increasing awareness of environmental and food safety issues, some farmers and (more often) farmers' associations/consortia have adopted a variety of standards and labels, most of which are specifically intended to allay consumers' concerns about negative environmental consequences. Examples of such labels are the "better management practices", clean production agreements, "principles of responsible aquaculture", and certification and eco-labelling schemes.

The coordination of European and INCO countries efforts by establishing common guidelines for policy-makers, producers and consumers is required. This co-ordination is very important in order to facilitate technology and knowledge transfer, avoid overlaps and double efforts, and to ensure the competitiveness of products from ntegrated systems in global markets.

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