UTILIZATION OF GEOTHERMAL SOURCE IN A CLOSED CYCLE AQUACULTURE SYSTEM IN ITALY: PRELIMINARY RESULTS

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ABSTRACT

Geothermal fluids, unsuitable for elecmcal energy production, are used for heating of water to supply a fish farm at Castelnuovo V.C. (Pisa, Italy) with recycled water. The geothermal heat, available as steam at 110 °C is used via plate heat exchangers in order to maintain a temperature of 25±1 °C in the water. Freshwater species, in particular elvers, are weaned in a total holding volume of 350 m^3 to attain a theoretical total annual production of 20 tonnes.
The treatment units of the recycle system include gravitational and mechanical filters and trickling filters, partly operated in a bypass. The system is largely managed by a process controller. Preliminary data on system performance immediately after the start-up phase are presented when the system was stocked with sturgeon, carp, eel and tilapia.

1. INTRODUCTION

Modern aquaculture (the technology of rearing aquatic organisms at high density) has advanced substantially over the past two decades (Liao & Mayo, 1972; Meade, 1973; Rennert, 1992; Rosenthal, 1993). Intensification has aimed at maximizing output per unit investment and this implies high stocking density while at the same time reducing grow-out time to commercial size, improving food conversion and feed adeaquacy for healthy growth, minimal waste output and finally improved system performance.
Annual production levels have passed from a few kg per m^3 to over one hundred kg per unit volume (in some cases). At the same time competition has increased among farmers with profit margins constantly declining. In developed countries, where land and man-power are expensive, the profitability of an aquaculture enterprise is frequently based on some particular aspect that allows a greater margin of earning, reducing part of the production costs or improving the efficiency of the system.
Temperature is one of the more important environmental factors that plays a determinant role in the life of aquatic organisms: in fact they are poikilotherm, that is they do not have a system to maintain their own body temperature, but they assume the same temperature of the water where they are living, and that therefore controls their whole life. The temperature, in fact, controls the rate of all biochemical reactions that are at the basis of life. In accordance with different temperature levels, it can be lethal at upper and lower extreme values, or suitable for the life of the organisms: in this range increasing the temperature increases the rate of growth, up to a maximum value; conversly increasing the temperature will decrease growth.
Every species has a determined value of temperature at which its rate of growth is maximum, and another little lower, where maximum is the food conversion efficiency.
The availability of water with temperatures suitable for the maximum growth of the species reared could therefore allow them to reach commercial size in shorter time and with lower costs.
Surface waters normally do not have these suitable temperatures for long periods, conditioned by seasonal fluctuations during the year. Warming artificially the required water supplies is not economically feasible, due to the great quantity of energy required, and to the waste of this energy, lost with the water discharged in current "passing-through" systems.
In these cases only warmed water residual of other indusmal process can be utilized, as in the case of water discharged by power stations, or when the energy is available without costs, as in the case of geothermal fluids.

1.1. HISTORY

Hot geothermal fluids have been used in fish farming in the geothermal area of Tuscany since ancient times: in the sixth century B.C., the **Greek** poet Licofrone wrote that the water of the River Linceo, identifiable as the River Cornia which flows across the geothermal area of Tuscany, was hot and rich in fish. The Etruscans and the Romans knew about the marshlands at the estuary of the River Cornia in which various species of fish lived in a particular environment made up of a mixture of geothermal, fresh and salt waters characterized by a higher than average temperature. The area was not only fished but ditches and dikes were maintained. The Romans who lived in the city of Cosa in southern Tuscany, near to the present day town of Ansedonia, had a large thermoassisted fish farm fed by geothermal fluids. Even today these waters are used for the same scope.
In 1490 the Republic of Siena dammed the course of the effluent of the Lake of Accesa in order to supply fresh fish to the city. This "peschiera" (fish reservoir) was fed by a geothermal hot spring to increase the temperature of the water so favouring the breeding of fish.
Frequently, nevertheless, the chemical quality of the geothermal fluids is not good for their direct use in rearing animals, and, likewise, in these areas other surface sources of good quality water are not available in great quantity.
A possible solution is then the use of the geothermal fluid as an indirect source of energy, utilized to maintain the temperature of a closed cycle system, where mechanical and biological filters allow the continuous reutilization of the same water, with only a small percentage of renewal per day.
In the Larderello area (Tuscany, central Italy), at the end of the 1980's, it was decided to construct a closed cycle fish farm to wean elvers exploiting the geothermal fluids, not suitable for the production of elecmcal energy, coming from shallow wells near the town of Castelnuovo V.C. (Pisa)

2. DESCRIPTION OF THE INSTALLATION

The Castelnuovo Val di Cecina plant of the Co.Svi.G (Consomum for the development of geothermal sources) was realized in collaboration with Enel S.p.A. and a German consultant, and research was carried out to optimize the utilization of a geothermal fluid coming from wells not connected to power plants. A few of these wells were used for the heating of dwellings.

Fig. 1 - General view of the plant

The total covered area of the plant is of 1800 m^2, and is divided into a quarantine zone, where the first weaning section will be realized, a service area (laboratory, food storage room, technical areas) and two identical sections of reanng tanks, each of them wlth their own mechanical and biological filters
The plant is arranged in modules. Each section has 8 rectangular tanks (plastic foil, hooked to a frame) of about 20m^2 water volume (water supply = 20 l/s; exchange rate 10 tlmes per day; outlets connected to sediment traps). Water is then passed through a mechanical drum filter which rotates periodically its fme-meshed screen (Drum Filter, HYDROTECH Ltd., mesh size **40** pm).

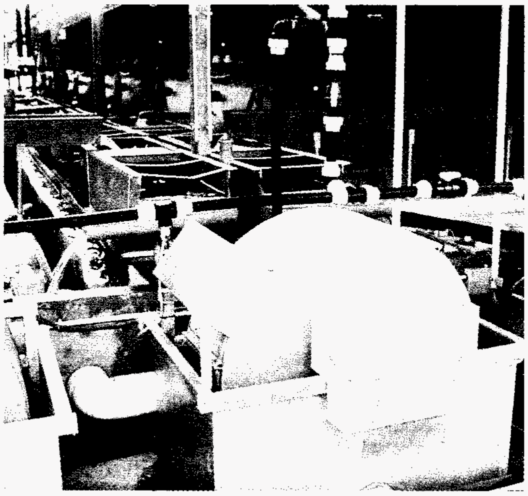

Fig. 2 - Drum filters

Most of the suspended solid load is removed here. After passing through the drums the water is collected in a sump from which pumps recirculate the water to either the fish tanks or the various biological and physico-chemical treatment units (e.g. ozonation).

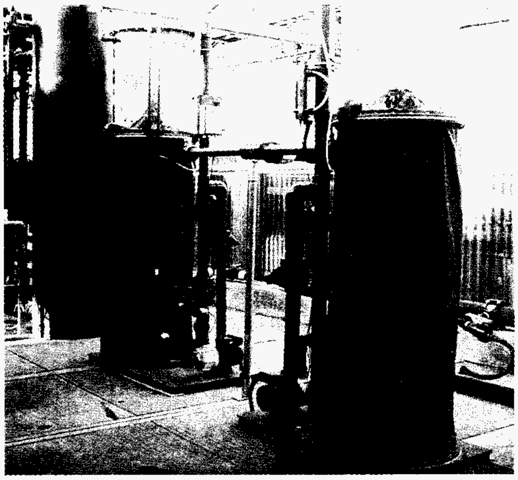

Fig. 3 - Ozonation system

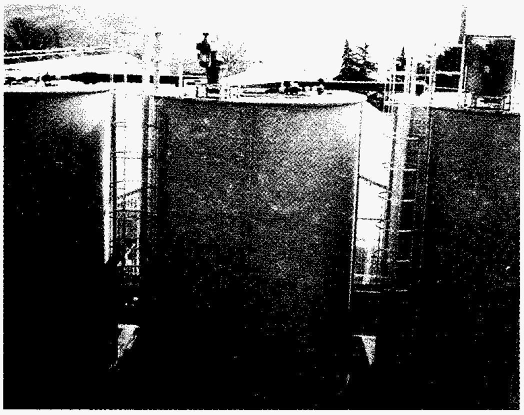

Fig. 4 - Trickling filters

The pumps supplying water to the biofilters are separate so that flows through the fish tanks and through the biofilters can be managed independently.
Flow-rates through the trickling filters can be varied but have presently been kept at 15 1/s. Surplus sludge produced in the trickling filters is collected in sediment traps before the water is returned to the general sump of the recirculation system.
Thus, the entire recirculation represents a multi-loop system (presently three loops) that can be operated independently and thereby allow to manage any drastic changes in water **quality** due to changes in metabolic activity of fish or due to changes in load by adjusting operational procedures to meet the carrying and working capacity of each unit.
The management options are manifold and allow to respond effectively and quickly to any drastic and sudden, unexpected or pursued changes in loads.

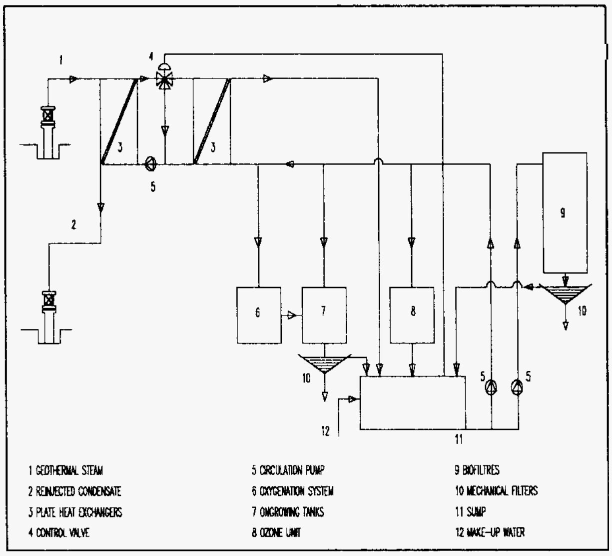

Fig. *5* - Lay-out of the aquaculture thermal closed cycle

2.1. TEMPERATURE CONTROL SYSTEM

The temperature of the water is maintained constant at 25+/-1 °C by means of heat exchangers which transfer the thermal energy from the geothermal fluid to the water supply.
The system consists of a network of pipelines including separators at the well heads and valves which conduct the fluid to a thermal plant, comprising of two heat exchangers, a waste separator and an open expansion tank connected to the secondary circuit. The thermal load is determined by heat loss throughout the plant, prevalently due to evaporation in the open areas of water in the tanks in the recycling system, to the thermal transmission between the bottom of the tanks and the ground, and through the cylindrical walls of the biofilters.
The maximum thermal load is 290 kw while the annual thermal requirement is about *3.3* TJ per year.
The physical characteristics of the fluid supplied from the wells are as follows:

Name of well	Pressure (bar)	Temperature (°C)	Flow rate (kg/h)	Percentage (%)
Ex-Belga	1.15	103.6	510	0.73
S.Marzio	1.03	100.4	734	0.84
Ignoto	1.09	102.2	188	0.63
Baldi	1.54	113.2	530	0.43

All the devices of the plant, as well as all chemical and physical characteristics of the water are monitored continuously by means of a WinLab program on Macintosh (National Instruments) that controls by means of feed-back the status of the devices and of the pumps. The program collects more than 50 analogical values and more than 150 digital signals; the scanner time is about 8s. The program interacts automatically not only in the maintenance of optional values of chemical and physical parameters but also in the optimization of rotation time of all electrical motors in order to optimize the life of the machines.

3. GROWTH RATE AND FEED CONVERSION

Species	G.R. (g/day)	F.C.R.
Acipenser naccarii	9.2-12.0	2.2-3.3
Acipenser baeri	8.9-12.1	3.2-4.2
Huso huso **X** A.gueldenstaedti	9.2-19.1	2.8-3.2
Tilapia spp.	0.8 - 1.7	1.2-2.2
Anguilla anguilla	-----	1.2-1.8
Cyprinus carpio	8.5 - 12.0	2.5

G R.= (final weight-initial weight)/days
F.C.R.=Food fed/ Live weight gain

Growth rate of carp and sturgeon over a period of **320** days can be seen in Fig. 6 - 7.

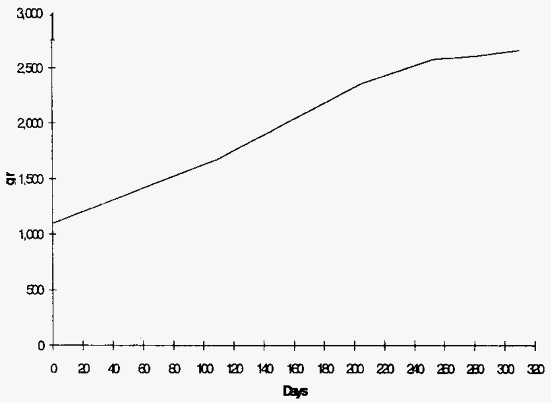

Fig. 6 - Growth rate of Cyprinus carpio

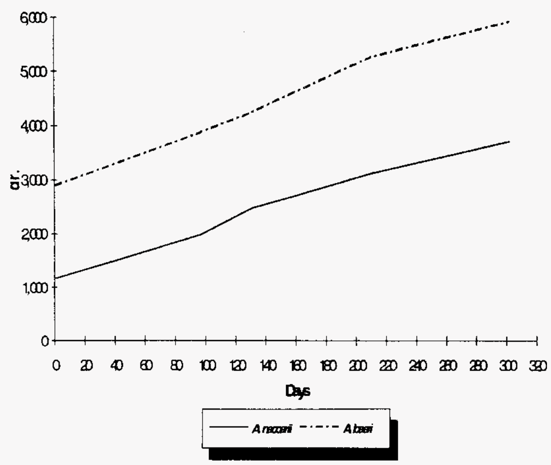

Fig. 7 - Growth rate of sturgeon

4. WATER QUALITY CONSIDERATIONS

During the course of the experimental start-up phase, water quality criteria were followed to evaluate system performance and to use the data obtained in system management and improvement. Water quality data determined included total ammonia, un-ionized ammonia (calculated), nitrite, dissolved oxygen, pH-value, suspended solids and occasionally several other parameters.
The overall performance can be briefly described by the above mentioned parameters.
After the initial start-up phase with the usual elevation in nitrogen compounds in the system water, the treatment units performed very well, showing an effective degradation capacity for BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) and for the nitrogen compounds nitrite and total ammonia. Unionized ammonia never reached toxic levels, despite the relatively **high** pH values of the system which are due to the specific situation of the bicarbonate system in this facility. Nitrite levels often were negligible. The pH-value declined in the fish tanks, depending on respiration rate and stocking density. Some examples of the water quality data observed during the first operational period of the system are shown in the following table

Total ammonia	0.5-0.8 mg/l
Nitrite	0.1-0.3 mg/l
Nitrate	16-40 mg/l
pH	6.8-7.5
Dissolved Oxygen	6.5-7.5 mg/l
Suspended solids	
Efficiency ammonia oxidation(*)	70-95 %
Efficiency nitrite oxidation(*)	40-60 %

(*) in the biofilters system

Trends of total ammonia and nimte over an operational period are depicted in Fig. 8 - 9

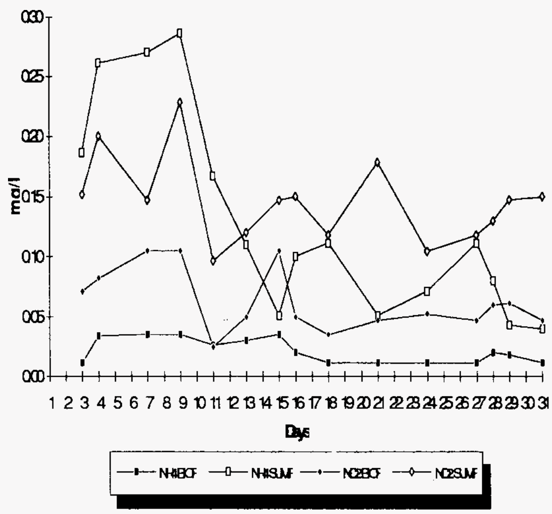

Fig. 8 - Trend of total ammonia and nitrite during March 1994

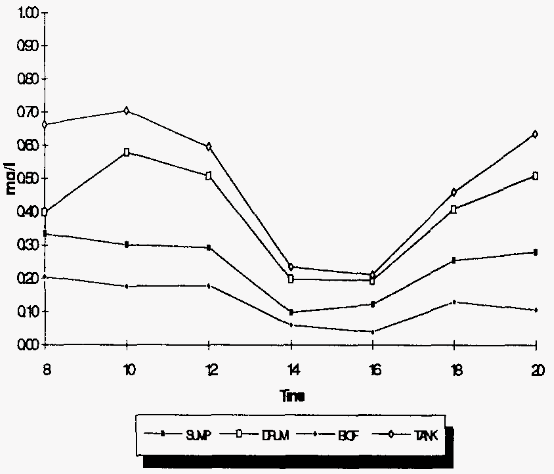

Fig. 9 - Trend of total ammonia on a daily cycle.

5. CONCLUSION AND OUTLOOK

From the initial operational period it seems obvious that the water treatment capacity is sufficient to support the dnticipated production. Water quality can be maintained at high quality. The oxygenation back-up system is particularly useful to assist in times of peak demand. Growth and feed conversion can still be improved and will certainly be optimized once the appropriate feeding schedules have been **worked** out.
The total expected production is of 20 tonnes per year of weaned elvers of about 15-20 g *in* 3-4 cycles, for a value of about $ 550.000; the saving through use of geothermal fluid to maintain the temperature compared to an oil-fired system is of about $ 80.000 per year.
A commercial plant of this production capacity is expected to cost about 1.5 million dollars.

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