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KALANTUTKIMUSOSASTO

MONISTETTUJA JULKAISUJA

74
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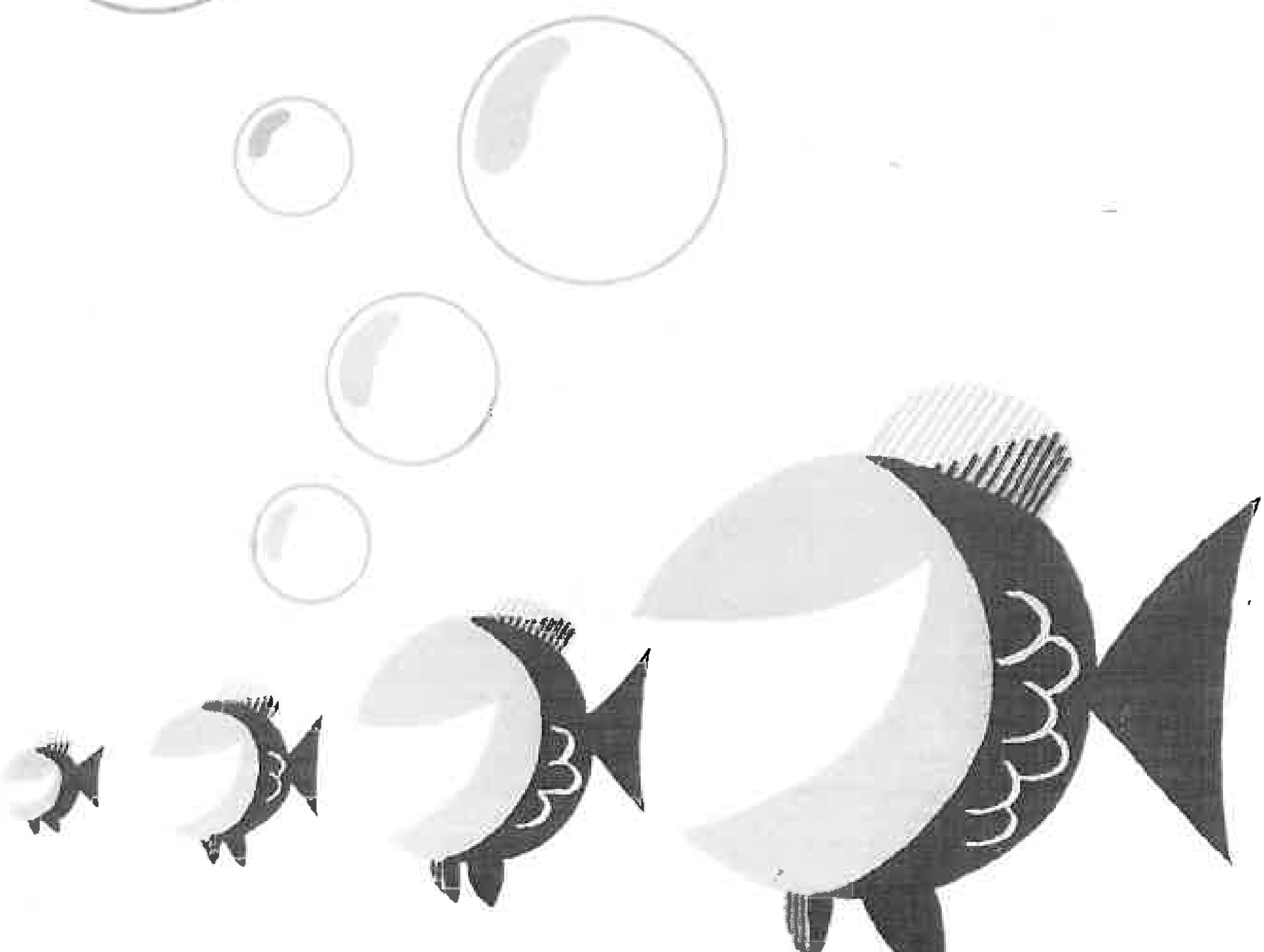

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MONISTETTUJA JULKAISUJA

No 74 1988

NATIONAL CONTRIBUTIONS ON SUSPENDED SOLIDS FROM LAND-BASED FISH FARMS

PAPERS PRESENTED AT THE FIRST SESSION OF THE EIFAC
WORKING PARTY ON FISH FARM EFFLUENTS
THE HAGUE, NETHERLANDS, 29-30 MAY AND 1 JUNE 1987

EDITED BY
MARKKU PURSIAINEN

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PREFACE

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1. ABOUT EIFAC WORKING PARTY ON FISH-FARM EFFLUENTS

During the Eleventh Session of EIFAC (European Inland Fisheries Advirory Commission) in Stavanger, Norway, in 1980, the following recommendation was given by the Sub-Commission II (Fish Culture and Diseases): " The effects of effluents from intensive aquaculture facilities on natural fish populations should be studied. Such water quality aspects should be taken into consideration by EIFAC Sub-Commission III - Fish and Polluted Water."

This recommendation was taken into cosideration by the Sub-Commission III, which recommended: " A separate Working Party should be established to analyse the problems arising from the discharge of effluents from fish farms, together with possible remedial measures. To assist the Working Party, a workshop should be organized with the assistance of Sub-Commission II, during the next intersessional period and a report made to the Twelft Session of EIFAC."

These quotations ment actually the beginning of the EIFAC Working Party on Fish-Farm Effluents. In 1981 the recommended Workshop on Fish-farm Effluents was convened by Mr. J.S. Alabaster, the former Convenor of the Working Party, in Silkeborg, Denmark. The report of this Worksop is published as EIFAC Technical Paper No. 41. In 1982 in Budapest, Hungary, during the Twelft Session of EIFAC, Sub-Commission III recommended that the Working Party's terms of reference should be amended as follows:

i) To keep under review potential and actual water pollution problems arising from fish-farming activities:

a) identify important problems
b) formulate quidelines and advise on appropriate methods for their control and
c) report recent developments and identify relevant research needs.

ii) Sub-Commission II should consider directing its attention to the need to improve fish-feed formulations so as to reduce adverse effects on the quality of water from fish-farm activities.

Since its establishment and the Workshop the Working Party have had several ad hoc meetings during the EIFAC Sessions. EIFAC has also given a number of recommendations concerning suspended solids, organic and inorganic phosphorus, and therapeutic agents in fish farm effluents, and spreading of information.

In Bordeaux, France in 1986 in conjunction with the Fourteenth Session of EIFAC the Working Party had an ad hoc meeting. The meeting was informed by the chairman, Mr, R. Lloyd that Mr J.S. Alabaster had resigned just before the Session. In the meeting of the EIFAC Sub-Commission III (Fish and Polluted Water) it was proposed that Mr. M. Pursiainen (Finland) Should be appointed as Convenor of the Working Party. Sub-Commission also recommended: " The newly formed Working Party should be convened as soon as possible by Mr. Pursiainen in order to make arrangements for progressing the future programme."

2. FIRST SESSION OF THE EIFAC WORKING PARTY ON FISH-FARM EFFLUENTS

The first session of the EIFAC Working Party on Fish-Farm Effluents was held in the Hague 29-30 May and 1 June in 1987 at the kind invitation of the Ministry of Agriculture and Fisheries of The Netherlands. The session was attended by 17 participants from 10 EIFAC Member States. The meeting was chaired by the Convenor of the Working Party, Mr M. Pursiainen (Finland). Mr J.F. Solbé (United Kingdom) acted as Rapporteur and Mr. G. Marmulla (FAO) as Technical Secretary. The Report of the First Session of the Working Party will be handled by the Fifteenth Session of EIFAC in Göteborg, Sweden, 31 May - 7 June 1988. The following gives only some information concerning the meeting.

The main item during the Session was suspended solids from land-based fish farms. Reports from 8 EIFAC Member States were presented by the authors and discussed in the Session (Austria, Finland, Federal Republic of Germany, Greece, The Netherlands, Norway, Sweden, United Kingdom). The Report from Yugoslavia was summarized by the Convenor as Mrs L. Debeljak was not present. Some information was also available from Belgium and Spain. After the meeting reports of Czechoslovakia, Hungary, and Italy were received and included to the material. This means that alltogether 12 EIFAC Member states contributed about problems concerning suspended solids in land-based fish farm effluents. These 12 contributions are collected into this publication according to the aggreement of the meeting.

The Session discussed also briefly about suspended solids from net gages. In this the Working Party aggreed that, for its immediate work, this and all other effects of gage rearing should be considered in combination. In this, to avoid duplication, collaboration with the ICES Working Group on Environmental Impact of Mariculture should be encouraged by the exchange of reports and observers.

About other future activities the meeting aggreed immediately to continue in gathering information on suspended solids from land-based fish farms from those member countries which did not contribute, collect national guidelines on feeding of farmed fish and also information concerning therapeutic agents in aquaculture. The Session also discussed about: the role of fish-farm effluents in increasing the risk of fish diseases; problems from the use of the use of TBT as antifouling agent; the escape of farmed fish; the transportation of gage units, as well as transportation of fish by well boats, which could spread diseases; and effects on natural fish communities.

The Working Party also handled carefully a draft on standardization of methodology in fish-farm effluent research and monitoring prepared by Mr S.-Å. Carlsson. The modified document appears as an Appendix in this publication. The EIFAC Working Party on Fish-Farm Effluents recommended that this standardization be applied by Member States.

SITUATION OF FISH-FARM EFFLUENTS IN AUSTRIA

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Production figures on fish farming in Austria

Cold-water fish culture

Number of farms approx.	100
Annual production	2.900 t
Market-size fish (25o - 3oo g)	70 %
Fingerlings	30 %
Fish species - percentage by weight	
Rainbow trout (*Salmo gairdneri*)	80 %
Brown trout (*Salmo tr.fario*) Lake trout (*Salmo tr.lacustris*) Brook trout (*Salvelinus fontinalis*) Arctic Char (*Salvelinus alpinus*) Grayling (*Thymallus thymallus*) Huchen (*Hucho hucho*)	20 %
Imports	600 t

Warm-Water fish culture

Total pond surface area	2.500 ha
Annual production	1.300 t
Market-size fish	75 %
Fingerlings	25 %
Fish species - percentage by weight	
Common Carp (*Cyprinus carpio*)	83 %
Grass Carp (*Ctenopharyngodon idella*)	10 %
Silver Carp (*Hypophthalmichthys molitrix*) Tench (*Tinca tinca*) Pikeperch (*Lucioperca lucioperca*) Pike (*Esox lucius*) Pollan (*Coregonus lavaretus*) Catfish (*Silurus glanis*)	7 %
Imports	700 t

The import figures indicate that an increase in fish production is possible. This is, however, hindered, on the one hand, by cheap imports and, on the other, by opposition from conservationists and sportsmen, whose demands are anchored in provincial laws.

General legislation and government policy in effluent questions

In Austria the "Wasserrechtsgesetz" (Water Law) of 1959 provides the legal foundation for all matters concerning water. It states, among others, that a permit is needed to emit solid matter into a body of water. This concerns especially cleaning and rinsing reservoirs, sewers, and all tanks and ponds which hold water. Fish farms are therefore substantially affected by this legislation.

This law has been administrated liberally in the past. Only in the past few years has it been applied more strictly to new licenses and fish farm expansions. In order to fullfill the requirements of the law, guidelines have been established to determine commitments for keeping waters clean.

Guideline to limit waste-water emissions (Federal Ministry of Agriculture and Forestries, Vienna 1981) (Table 1).

The emission limits generally reflect minimum requirements, which are attainable by known waste-water treatment technologies. These limits take the type of water body into consideration with regard to their effects on the water quality. If these limits prove difficult to adhere to (for technical reasons), then a detailed individual evaluation by experts is needed, in order to determine the necessity and extend of a special regulation for the emission limit.

The emission requirements refer to running waters and reservoirs. For stagnant and running waters in the catchment areas of lakes, stricter standards must be applied when determining whether to permit a waste-water discharge; this is especially true for phosphates.

In order to adhere to the standards, discharges of waste water and pollutants are to be kept as minimal as possible by using appropriate operational procedures and work-specific water conservation measures, and sporadic discharges of waste water are to be equalized with appropriate retainment devices and subjected to treatment.

Provisional Guideline to limit loadings (immissions) in running waters (Federal Ministry of Agriculture and Forestries, Vienna 1987) (Table 1).

This guideline was drawn up to complement the guidelines to limit waste-water emissions. Its requirements provide a minimum framework for the water quality to be sustained or striven for in a river or reservoir of a river. The goal is to support a biological water quality II.

Guideline to keep Lake Constance clean (International Lake Constance Water Conservation Commission, in composition).

In the Lake Constance catchment area, cage cultures with feeding as well as intensive cultures with low water renewal and intensive aeration are not allowed. Feeding in angling ponds is not allowed, and in holding ponds only to the extend of sustaining the fish. While harvesting, small ponds with low rates of water replacement are to have mudremoving devices at the outlet. Units with high rates of water replacement and high feeding rates are to have settling basins, whereby the total amount of water is to be taken into consideration and a settling time of 30 minutes is required. The settling basins are to be cleaned in as small time intervals as possible and not during harvesting phases. Instead of settling basins, other equally effective mudremoving devices are acceptable.

Water Quality of Effluents

Carp Culture

Through fertilisation and supplementary feeding an average of 1,3 tons per hectare per year of grain (80%) and dry feed (20%) carp production in Austria reaches an average of 500 kg/ha. Due to varying climatic conditions within Austia, the production conditions are very variable.

During the growing period, fish ponds do not pose problems for the recipient body of water (E.Kainz, 1985). The annual harvest coupled with pond draining causes the greatest load to the recipient by mobilising pond sediments. Investigations referring to this in Austria are not known to me.

Trout Culture

The current investigations concern twelve trout farms with different forms of management, which account for approximately 30% of the trout production in Austria. For each fish farm, the water quality was examined at the inlet and outlet in tow-hours intervals over 12 hours (table 3 a) and the most important operations were recorded (table 2).

Many fish farms take all of their water (farm No. 3,4,7,1o,12) or the majority of their water (farm No. 1,2,6,11) from the headwater. Due to the lacking or minimal dilution of the fish farm effluent in the recipient, the Immission Guidelines are to be used (Table 1).

Table 1:

Emission limits for waste-water discharges into a body of water (1981) and loading limits for running waters (1987), as related to pond fisheries (Federal Ministry of Agriculture and Forestries Vienna).

Chemical Parameter	Emission limits, 1981	Immission limits, 1987
Total undissolved substances	3o mg/l (o,45 µm filter)	No increase in turbidity
Settleable substances	o,3 ml/l (2 hours settling time)	No silting which leads to covering of stones, burying of biological communities and hindering of primary production
Oxygen	to be determined in individual cases	should not fall below 8o% oxygen saturation
Ammonium/Ammonia	to be determined in individual cases	o,5 mg/l $(NH_4^+ + NH_3)$-N maximum limit otherwise limited by o,o5 mg/l NH_3-N
Nitrates	to be determined in individual cases	8 mg/l NO_3'-N
Nitrites	5,o mg/l NO_2' (1,5 mg/l NO_2'-N)	o,o5 mg/l NO_2'-N
Phosphorus	to be determined in individual cases 1 mg/l P average concentration at outlet */**	o,2 mg/l P (dissolved), to be decreased in catchment area of lakes and reservoirs
Dissolved Organic Carbon (DOC)	25 mg/l avg.conc.at outlet* 3o mg/l in spot checks***	2 mg/l (filtered samples, o,45 µm filter)
Chemical Oxygen Demand (COD)	75 mg/l avg.conc.at outlet* 3o mg/l in spot checks***	1o mg/l O_2 (total sample)
Biochemical Oxygen Demand (BOD)	2o mg/l avg.conc.at outlet* 25 mg/l in spot checks***	3 mg/l O_2 (total sample with nitrification hindering)

* The average concentration at the outlet over 24 hours should not be exceeded in 8o% of all cases

** When referring to settled waste water, at least 85% of the phosphorus should be removed

*** In spot checks 8o% of all values should lie under the stated value

Table 2:

Main features of 12 trout farms in Austria at time of investigation

Farm No	Production unit	Vol m^3	Source of water r:s	l/s	°C	renewal time min.	fish stockings species	t	kg/l.s	dry feed-feeding kg/d	kg/l.s	%	cleaning
1	concrete raceway	21o	1:o	19o	13-14	2o	R,S/e	6	32	75	o,4	1,2	continuous
2	concrete raceway	174o	1:o	96o	1o-14	3o	R/e	55	57	55o	o,6	1,o	continuous
3	concrete raceway	15oo	1:4	52o	1o	5o	R/f-e	5o	96	5oo	1,o	1,o	continuous
4	concrete raceway	477	1:o	22o	9-1o	4o	R,S/f-e	7	32	6o	o,3	o,9	continuous
5	concrete raceway bottom gravel	133oo	1:o	34oo	8-11	7o	R/e	15o	44	16oo	o,5	1,1	6x/year, effluent airated
6	earth raceway	193o	1:o	38o	8-1o	85	R/e	17	45	18o	o,5	1,1	2x/year
7	concrete racew.+ earth ponds	1159o	5:2	7oo	11-13	276	R/f-e	76	119	934	1,3	1,2	continuous, 1-2x/year
8	earth ponds	688o	3:1	4oo	8-1o	29o	R/e	4o	1oo	4oo	1,o	1,o	1-2x/year
9	earth ponds	42oo	o:1	2oo	1o-12	35o	R,S/f-e	8	4o	23o	1,2	2,9	6x/year
10	earth ponds	78oo	3:1	12o	15-18	78o	R,S/f	5	42	14o	1,2	2,8	1-2x/year
11	concrete tanks + earth ponds	155oo	4:1	71o	9-11	36o	R/e	55	78	865	1,2	1,6	1x/d 1-2x/year
12	tanks	35	o:1	5,1	1o	114	R/f	o,41	81	8,2	1,6	2,o	1x/day airation

r river
s spring

R rainbow trout
S other salmonids
f fingerlings
e edible fishes

feed not extruded

Table 3 a:

Water quality data: Concentrations in effluents of 12 trout farms (7 - 9 measurments per farm in two hours intervals). (F Feeding, C Cleaning, * Aeration).

farm No		1	2	3	4	5	6	7	8	9	1o	11	12	Average * (effluent) Increment (outflow-infl.)
Dissolved oxygen														
min.		72	49	48	9o	84	76	59	65	85	74	86	1o6	
max.	%	91	75	6o	95	94	93	1o3	83	1o2	84	94	123	
x̄		85	66	55	92	89*	85	87	71	95	78	91	112*	74*
														- 15,2
min.		7,1	5,2	5,1	9,6	9,1	7,9	6,4	7,o	9,2	6,8	8,5	11,4	
max.	mg/l	9,o	7,5	6,4	1o,o	1o,o	9,7	1o,4	9,o	1o,5	7,5	1o,4	13,3	
x̄		8,4	6,8	5,9	9,8	9,6*	9,2	9,o	7,7	9,9	7,2	9,4	12,1*	8,5*
														- 1,7
Ammonia as N														
min.		o,17	o,23	o,21	o,o8	o,16	o,o8	o,23	o,16	o,o9	o,37	o,o6	o,22	
max.	mg/l	o,24	o,45	o,32	o,13	o,22	o,12	o,33	o,25	o,16	o,55	o,44	o,64	
x̄		o,2o	o,35	o,27	o,o9	o,2o	o,1o	o,28	o,2o	o,11	o,47	o,33	o,52	o,26*
														o,25
Nitrite as N														
min.		o,oo4	o,oo5	o,oo2	n.n.	o,oo6	n.n	o,o15	o,oo3	o,oo4	o,o26	o,oo3	n.n.	
max.	mg/l	o,oo8	o,oo8	o,oo3	o,oo1	o,o22	n.n	o,o21	o,oo4	o,oo7	o,o31	o,oo6	o,oo4	
x̄		o,oo5	o,oo7	o,oo2	o,oo1	o,oo6	n.n.	o,o18	o,oo3	o,oo5	o,o28	o,oo6	o,oo2	o,oo7*
														o,oo4
Nitrate as N														
min.		1,11	3,47	1,36	1,33	1,o4	o,45	2,76	1,22	1,21	1,15	o,89	o,55	
max.	mg/l	1,25	3,68	1,57	1,34	1,12	o,49	3,o9	1,34	1,29	1,3o	1,11	o,74	
x̄		1,15	3,58	1,52	1,34	1,o8	o,47	2,83	1,3o	1,26	1,25	o,95	o,66	1,42*
														- o,12
Phosphate as P														
min.		o,o28	o,o16	o,o65	o,oo6	o,o22	o,o13	o,o29	o,o41	o,oo2	o,o45	o,o22	o,o16	
max.	mg/l	o,o56	o,o46	o,163	o,o2o	o,o97C	o,o3o	o,o72	o,o97	o,o11	o,o95	o,o8o	o,o36	
x̄		o,o37	o,o25	o,o96	o,o12	o,o27	o,o22	o,o46	o,o55	o,oo7	o,o73	o,o3o	o,o23	o,o38*
														o,o27
Total - P														
min.		o,o42	o,o38	o,o81	o,o12	o,o35	o,o2o	o,o53	o,o5o	o,o33	o,o98	o,o27	o,o32	
max.	mg/l	o,o78	o,o46	o,282	o,o29	o,o37	o,o53	o,o88	o,12o	o,o55	o,129	o,o52	o,o54	
x̄ F/C		o,1oF	o,17F			o,143C			o,56F			o,16C	1,61C	
x̄		o,o55	o,o47	o,134	o,o18	o,o36	o,o31	o,o68	o,o68	o,o47	o,118	o,o39	o,o43	o,o53*
														o,o4o
Suspended Solids as dry weight														
min.		3,1	1,8	o,8	3,3	3,8	1,6	2,8	o,7	3,6	6,4	o,9	1,3	
max.	mg/l	3,9	7,o	2,4	4,2	6,2	4,2	4,3	3,8	7,6	14,8	3,9	3,o	
x̄ F/C		5,2F	11,7F			17C	327C	32ooC	3oF	8o1oC		74C	84C	
x̄		3,5	2,8	1,5	3,7	4,4	2,4	3,3	1,5	5,4	11,4	2,3	1,9	3,7*
ign.residue %		47	41		42	35	44	49	56	36	42	42	71	1,8
BOD_5														
min.		2,2	1,7	2,3	1,5	2,3	2,2	2,5	1,2	2,1	4,o	1,6	2,4	
max.	mg/l	3,4	6,6	3,1	2,2	2,7	1,7	3,5	3,8	3,2	4,5	2,9	4,4	
x̄ F/C		4,5F	6,9F				54C	115oC	7,4F	519C		39C	5oC	
x̄		3,o	3,o	2,6	1,9	2,4	1,9	2,9	2,7	3,o	4,4	2,4	3,6	2,8*
														1,6
BOD_2														
min.		1,4	o,7	1,o	o,8	1,2	o,9	1,2	1,1	1,2	2,2	1,2	1,4	
max.	mg/l	2,2	2,8	1,5	1,4	2,8	1,3	1,8	2,o	2,4	3,4	2,1	3,1	
x̄		1,9	1,2	1,3	1,1	1,6	1,1	1,5	1,2	1,9	2,8	1,3	2,2	1,6*
														o,9
$KMnO_4$														
min.		15,2	12,3	8,5	1o,1	11,4	9,2	9,5	7,o	7,6	22,4	13,3	8,2	
max.	mg/l	17,4	18,o	8,8	1o,7	16,7	1o,1	11,4	1o,1	9,8	26,2	13,9	1o,1	
x̄ F/C		17,4F	17,7F						16,2F			5oC	1ooC	
x̄		16,2	13,3	8,7	1o,4	13,9	9,4	1o,1	8,1	8,9	24,o	13,8	9,o	12,2*
														2,8

Table 3 b:

Mean production of pollutants expressed as percentage of dry feed by weight

farm No.	1	2	3	4	5	6	7	8	9	10	11	12	Average
Diss.oxygen	-37,o	-14,2	-28,8	-8,2		-27,5	-14,5	-1o,2	-6,8	-15,6	-6,2	-36,4	-(16,9 ± 1o,6)
Ammonia as N	4,2	4,4	2,5	2,6	2,7	1,8	1,9	1,7	o,7	3,3	2,3	2,4	2,5 ± 1,o
Nitrite as N	o,o21	o,o27	o,o18	n.n.	o,o33	n.n.	o,o39	o,o24	o,o36	o,12	o,o35	o,oo8	o,o27 ± o,o33
Nitrate as N	-o,68	-1,o9	o,36	-o,44	-o,95	-o,16	-1,73	-2,o5	-o,6o	-5,o9	o,o9	-o,29	-(1,o5 ± 1,45)
Phosphate as P	o,18	o,22	o,57	o,19	o,59	o,31	o,29	o,43	o,o1	o,o8	o,24	o,o5	o,26 ± o,19
Total - P	o,52	o,42	o,78	o,28	o,51	o,39	o,38	o,63	o,29	o,2o	o,27	o,13	o,4o ± o,19
Solids - SS	27,o2	19,2	6,92	-1,85	23,8	13,7	14,44	15,o	37,4	46,7	5,58	12,1	18,3 ± 13,7
BOD_5	42,9	18,6	1o,8	6,7	24,2	11,7	16,9	1o,6	11,9	21,5	9,2	16,6	16,5 ± 9,8
$KMnO_4$	49,2	36,3	19,9	22,2	44,1	31,9	2o,1	15,9	24,6	46,5	49,2	21,6	28,5 ± 12,9

The measurments of nitrate, nitrite and total phosphorus lie far under the limits. The dissolved oxygen was under the reccommended limit of 80 % in five fish farms at the outlet shortly during feeding, and in two fish farms continually (farm No. 2,3), to the ditriment of their own fish stocks. The oxygen decrease due to fish culture amounted to an average of 1,7 mg/l O_2 or 15% of saturation. Not contained in this average is the farm with oxygenation (No.12) and the one with an aerationarrangement (turbulence) at the outlet (No. 5). Due to turbulence of the water, saturation in the recipient occured very quickly.

Of the twelve fish farms, two did not comply with the limit for ammonium, namely the one with a high stocking density made possible by oxygenation (No. 12) and the one with highly eutrophic ponds (No. 1o). The increase in ammonium concentration due to fish culture amounted to an average of o,25 mg/l $N\text{-}NH_4^+$.

As any increase in the concentration of suspended solids leads to an increase in turbidity, this guideline is hardly attainable. The emission limit of 30 mg/l dry weight was reached temporarily by only one farm (No. 8) under normal operation. The average daily increase in the concentration of suspended solids due to fish culture, was 1,6 mg/l dry weight; the ignition residue amounted to an average of 46%. When cleaning the production units, settled amounts of silt are mobilised, causing suspended solid concentrations of 17 - 8ooo mg/l dry weight and 2 - 75 ml/l settleable solids (integrated sample) in the effluent. Silt deposits were found in calm area and backwater zones of recipients.

When measuring the organic substances (BOD, $KMnO_4$) the suspended solids were included. The recommend limit of 3 mg/l BOD was in 8 farms temporarily and in two (No. 10, 12) continually exceeded. Under normal operation the increase in

BOD due to fish culture amounted to an average of 1,6 mg/l O_2.The mobilisation of silt during cleaning of the production units led to BOD values of 4o - 115o mg/l O_2 at the outlet (integrated samples). The solid particles also led to an increase in the phosphorus concentration, which was, however, only measured in two fish farms (No. 11, 12).

The concentrations and loads of pollutants in the effluent of the individual fish farms depend mainly on the water supply and on the kind and intensity of management. To compare the measurments of the farms, the pollutant loads are expressed as a percentage of feed (Tab. 3b).

The ammonium load in fish culture lay between o,7 and 4,4 % of feed, 2,54 % on average. The values are on the scale of those quoted in the literature (J.Querellou a.o., 1982 EIFAC T41).

The solids corresponded on average to 18,3 % of the amount of feed. There is a correlation between the solid load and the retention time of the water in the production units (figure). In concrete raceways the solid load sank from 27 % with a retention time of 2o minutes (No. 1) to 6 % of the amount of feed with a retention time of 5o minutes (No. 3). Within the raceway farm 4 the quantity of the sedimentation was higher than the load of suspended solids in the effluents.

In the earthen raceways the suspended solid load increases again when compared with concrete raceways in spite of the longer retention time. In earthen ponds solid concentration is increased by biological production in the ponds and by swimmingactivities of fishes near the outflow.

The BOD loads amounted an average to 16,5 % of the amount of feed. The course of the BOD load follows that of the solid load. In ponds with retention time of 6 to 12 hours, the BOD load fell short in relation to the solid load (Tab. 4).

Cleaning of Production Units in Trout Farms

In concrete raceways with high water renewal and high stocking density, a continuous silting out of solids ensues. The solid load is raised by the inceased activity of the fish during feeding, harvesting, etc.

With increasing water retention time, sedimentation increases within the fish farm, which requires own cleaning precautions.In practice this is accomplished mostly by draining the water and sweeping out the bottoms of the production units.

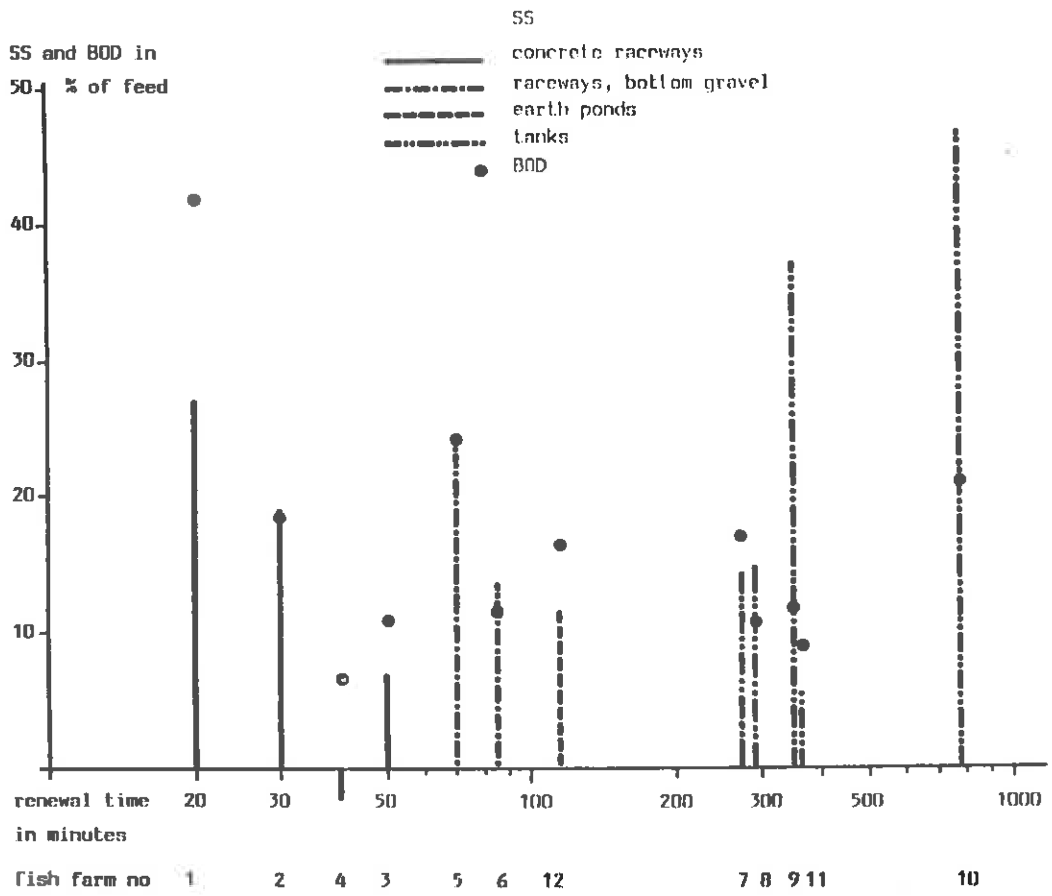
Table 4:

Loading of solids in waste waters during cleaning manipulation in some trout farms (n=1)

Fish Farm No.		9	6	5	7	11	12
Production units		earth ponds	earth racew.	bott.gravel concr.racew.	concr.racew.	concr.tanks	tanks+oxygen
Production area	m²	7ooo	24oo	19ooo	134o	17oo	35 m³
Renewal time	min.	35o	85	7o	45	6o	114
Cleaning manipulation							
treated area	m²	112	6oo	484o	134o	17oo	35 m³
% of total fish farms		2	25	25	1o	1o	1oo
treatment		draining spilling	draining spilling	draining brushing	suckering of settl.area	suckering of tanks	draining
time of treatment		2o min.	2,5 hours	5 hours	3o min.	35 min	15 min.
last treatment		2 month	half year	5 weeks	3 days	daily	daily
Waste water concentration							
settl. solids	ml/l	7o	2,7	1,7	74	o,8	2,8
susp.solids ds	mg/l	8o1o	327	17	32oo	74	84
ignition residue	%	24	29	34	72	6o	72
BOD-5	mg/l	519	54		115o	39	5o
Waste water load							
discharge	m³	7	428o	16ooo	26	263	4
settl.solids	l	5o4	114oo	1326o	1934	216	11
susp.solids ds	kg	58	14oo	11oo	83	19	o,33
BOD-5	kg	3,7	231		3o	1o	o,2o
Load in % of C+(E-I-C)+I=1oo%*							
discharge	%	<1 + o + 99	13 + o + 87	5 + o + 95	<1 + o + 99	<1 + o + 99	1 + o + 99
susp.solids ds	%	49 + 48 + 3	95 + 2 + 3	46 + 16 + 39	32 + 52 + 16	13 + 18 + 69	3o + 61 + 9
BOD-5	%	17 + 81 + 2	79 + 7 + 14		14 + 45 + 41	6 + 47 + 47	12 + 73 + 15
Removal of solids		settlement tank	no	settlement tank	settling area in raceway 18o m³	no	no
volume of tank	m³	56		112o			
settling time	min.	3o - 6o		1o - 2o	6		
efficiency	%	95		<1o	~2o		

* Load of effluent (E=1oo%), composed of load of inflow (I %), normal farm-operation (E-I-C%) and of cleaning manipulation (C %).

Production of suspended solids (SS) and BOD expressed as percentage of feed in relation to renewal time of water in twelve fish farms (1 - 12).



A varying amount and composition of solids occurs by sweeping of fish farms (Table 4). In earthen ponds and earthen raceways, the percentage of organic substances in the removed solids is relatively low (ignition residue 24 - 34 %), in concrete raceways and tanks with higher water renewal rates, relatively high (ignition residue 6o - 72 %).

In daily cleaning of the fish tanks by draining (No. 12) and suction (No. 11), approx. 30 % of the solid-load and approx. 10 % of the BOD load are registered in less than 1 % of the daily operating water amount of the cleaned production units.

In farm 7 twice a week the settleable solids are sucked from the bottom of a part of the concrete raceways kept free of fish with a water renewal time of 6 minutes. Subsequentely the settleable solids are spread on farmland. Approximately 20 % of the daily settleable solid load are registered in less than 1 % of the daily operating water amount within the settling area.

In the ponds and raceways with earthen bottoms, a part of the production area is swept out in intervals of 1 to 6 months. By this operation, 58 - 14oo kg dry weight of suspended solids (No. 9, 6, 5) and 4 to 231 kg BOD (No. 9,6) are mobilised within a few hours. The swept out amount of silt had 46 - 95 % of the daily load of solids and 17 - 79 % of the daily load of BOD within an amount of 1 - 13 % of daily operating water.

In the farm with earthen raceways (No. 5), the used cleaning water was introduced into a settling basin with a retention time of 1o - 2o minutes. No cleaning ability of the settling could be proved.

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CZECHOSLOVAKIA - FISH FARM EFFLUENTS

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1. INTRODUCTION

Czechoslovakian fish farms produce about 15 thousand tons of market fish as an average per annum; almost all this amount is represented by carp. The total figure also includes 650 tons of market rainbow trout, reared on specialized trout culture facilities.

The carp is produced in ponds. The number of the ponds is about 7 thousand and the total area is about 52 thousand hectares).

There are three categories of ponds, divided according to the method and intensity of their management. The category of ponds producing above 1.6 tons of fish per ha is watched most closely as for water quality. The water management authorities monitor the quality of the water leaving the ponds, using all the water quality criteria as prescribed by the Czechoslovak State Standard. All the intensification practices, including fertilization and feeding, are performed in agreement with the State Water Management Inspection, current inspection of the quality of the water flowing from the ponds being the main conditions on which the above mentioned practices can be performed.

2. INVESTIGATION

Investigation of the influence of fish culture intensification upon water quality was part of the state research project of the study on environmental conditions and fish protection in intensive fish farming practices. Some of the results of this investigation can be cited here:

The saprobity index, evaluated according to the phytoplankton, is favourable in all cases. The parameter prescribed for the water courses serving as drinking water sources has never been exceeded.

No smell associated with pond water has ever been recorded even immediately after the application of pig slurry.

Colour changes are observed regularly but more or less independent of the intensity of fish culture even in depths of 10 cm under surface, but this is caused by vegetation or by turbidity as a result of the raising of bottom mud by the fish - this obviously should not be considered as a drawback and should be tolerated in fishponds.

No case of disturbance of the self-cleaning ability of water has been recorded.

The concentration of oxygen has been favourable in the ponds in the majority of cases.

Cases of exceeding the admissible BOD_5 level of 8 mg per litre have been recorded. As known, in stagnant water the BOD_5 value may be about twice higher without any change in water quality, as compared with flowing waters: it is therefore recommended for the fish ponds to raise the obligatory BOD_5 level to 16 mg per litre for unadjusted water samples.

The same can apply to the admissible level of COD_{Mn} (higher than 20 mg per litre): like with BOD_5 , it is possible to recommend for the unadjusted water samples from ponds a value twice higher; however this level of the content of organic substances is unfavourable to water culture and requires the use of chemical preparations - it would be therefore useful to determine a lower limit for additional fertilization in accordance with the technology of production.

As the COD_{Mn} value can be determined easily and readily, its level should be regarded as sufficient criteria for the content of organic substances in pond water. This view is supported by the finding that in some cases the BOD_5 value is unproportionally low in comparison with the COD_{Mn} value in the same samples (cases of phytoplankton depletion with mass development of water fleas, or toxicity of inflow water). This is probably due to the insufficient inoculum of bacteria which are not added regularly to the samples, not even in water-management practice.

The influence of fish culture on a number of various parameters is negligible and the intensification of fish culture does not involve any hazard of exeeding the levels admissible for the water courses used as sources of drinking water: this applies to chlorides, sulphates, calcium, magnesium, total hardness, nickel, copper, cadmium, chromium. With no relation to fish culture, values of dissolved substances, fluorine and zinc, exceeding the admissible level for drinking water supply sources, occurred in exceptional cases, but there is no danger even in these cases that the parameters for other surface waters would be exceeded: on the contrary, the concentrations of metals decrease considerably in the ponds.

Ammonia concentration and the concentration of ammonium ions decrease in the ponds, as compared to the inflowing water.

On the other hand, owing to water stagnation and better conditions for the primary production, the pH is much higher inside the ponds than in the inflowing water.

The admissable values of iron concentration (1.5 mg per litre for the category of other surface waters) have been exceeded in the ponds with a slight dependence on the intensity of fish culture: it is recommended for the fish ponds to tolerate 3-5 mg per litre.

Manganese concentration in pond water is also largely higher than the admissible level for drinking water sources (0.5 mg per litre). It is recommended to use the admissible value of 1 mg per litre for the ponds.

Ponds located in watershed areas with fields were observed to contain more nitrates; nitrate concentrations are reduced rapidly in the ponds, the rate of this decrease growing with the intensity of fish culture.

Irrespective of the intensity of fish culture, faecal pollution is generally eliminated in the ponds: while the admissible value of the coli index for the water supplied to waterworks was observed to be exceeded in some inflows, no case of exceeding the admissible levels was observed inside the ponds.

3. A CASE STUDY

The quality of the water leaving the rainbow trout culture facilities was studied, as a model, on the trout farm of Annin in the West-Bohemian region of the Czechoslovak Socialist Republic. This farm produces about 70-80 tons of rainbow trout annually. It can be stated that the results of this investigation of water pollution caused by intensive trout culture correspond generally with what is said in literature. Greater pollution levels were recorded in the case of insoluble substances: 18.54 g per kg per day, as compared with the maximum values asserted by LIAO-MAYO: 15.6 g per kg per day. This is ascribed to the larger amount of food residues and to the hydraulic conditions of operation.

The pollution level in the biological oxygen demand at 8.76 g per kg per day correlates with other authors' data, and the same can also be said of the chemical oxygen demand (54.48 g per kg per day) and of ammonium nitrogen (0.89 g per kg per day).

The actual specific stock density was 6.35 kg per cubic metre and the maximum was 30.2 kg per cubic metre. These values are by far lower than the specific densities used in other countries.

The Annin trout farm appears to retain a great reserve as for the specific stock density and as for the admissible concentration of undissociated ammonium nitrogen.

4. CONCLUSIONS

It can be stated in conclusion that the waters flowing from the fish culture facilities in Czechoslovakia (fish ponds, rainbow trout rearing facilities) do not raise any problems associated with the quality of water. In spite of this, however, water quality is regularly monitored and inspected by the water management authorities.

REPORT ON SUSPENDED SOLIDS FROM FISH-FARMS IN FINLAND

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SUMMARY

Annual food fish production in Finland is nowadays about ten million kgs. The Finnish authorities seem to take up a restrictive attitude towards the size of fish farms. Environmental impacts are maybe the most important reason preventing the otherwise rapid development of fish farming in Finland.

In the experiments the observed loading of solids has varied between 22 and 255 g (dry weight of sludge per kilogram of feed used). Practical observations regarding effluents of farms have been somewhat higher.

A special sampling apparatus is developed in Finland for reliable sampling of fish farm effluents. The loading figures of solids are not complete because in Finland the authorities take into account nutrients above all and not so much suspended solids and direct oxygen uptake. The quality of feed is very decisive for nutrient loading.

Techniques for solid removal are being developed. The problem to treat effectively fish farm effluent is not any more so much techmical but also economical.

1. INTRODUCTION

1.1. Development of fish farming in Finland

Fish farming has increased rapidly in Finland in the last few years. The number of farms and annual fish production for human consumption are presented in figure 1.

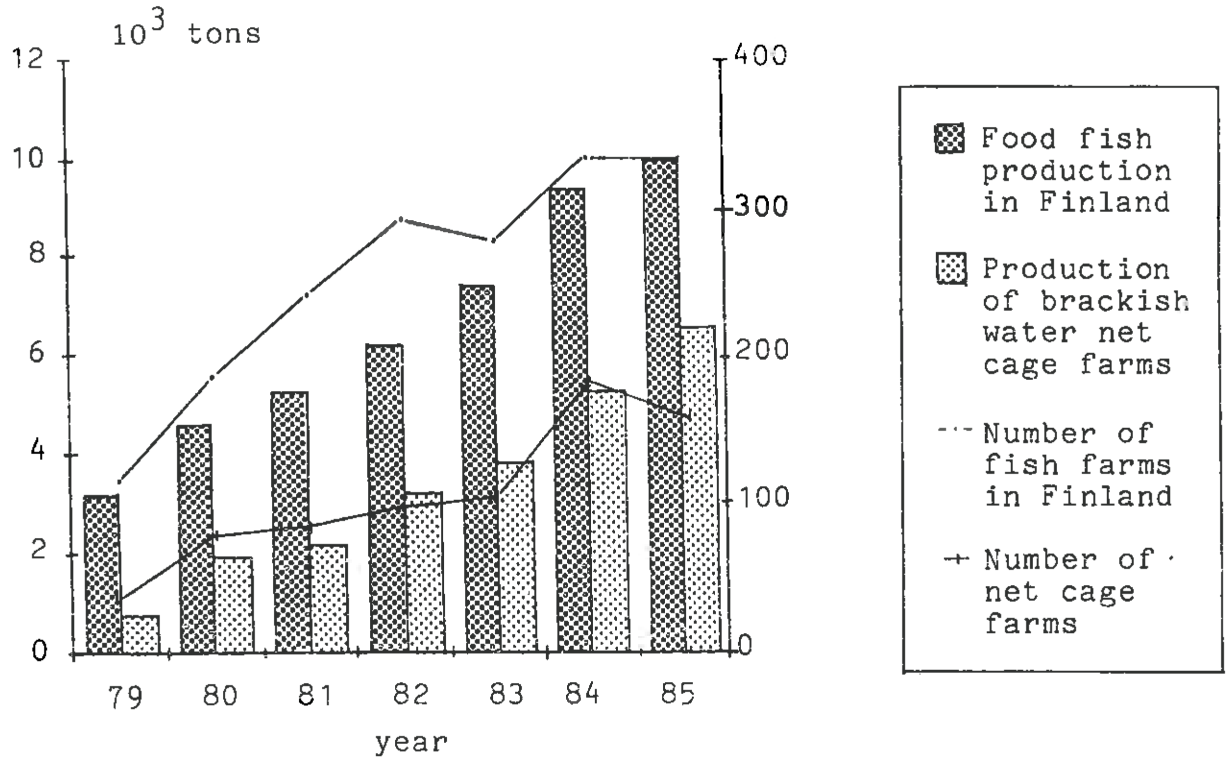

Figure 1 Food fish production and number of farms in Finland

The value of food fish production in 1979 was 59 million marks (about 15 million U.S.dollars) and in 1985 227 million marks (about 57 million U.S. dollars).

The average size of farms in Finland is about 20-30 tons' annual production. One fifth of the farms with biggest annual production is producing about 50 per cent and one fifth of the ones with the smallest annual production only 5 per cent of the total rainbow trout production.

In the last few years the sea production has increased most rapidly (see figure 1). The major part of the production takes place nowadays in the southwestern archipelago: between Hanko peninsula SE and the city of Pori N along about 200 km long coastline with 125 farms which are producing about 6 000 tons yearly. The financial value of farmed fish has exceeded since 1985 the value of catched fish on this area.

In 1983 the value of the whole fish farming production (farming for stocking purposes included) was already over 50 per cent of the value of the catched fish (the total catch was about 150 000 tons, and value about 421 million marks, about 105 million U.S. dollars). The total amount of farms in Finland (farms producing only fingerlings in tanks or natural rearing ponds included) was 677 in 1985.

Fish farming employs in Finland directly about 1 000 persons.

The fish feeds used in Finland (last year about 20 million kgs) are mainly dry feeds - only a very little part is fresh or semimoist feed used at brackish water net cage farms.

The main part of production consists of large rainbow trout (average weight 1.5 - 2.5 kg), with relatively small salmon production - only about 25 tons per year. There is no market for 'portion fish' in Finland, and none is produced. Part of the largest fish are exported. The amount going to the export has been about 20 per cent, e.g. in 1985 2.02 million kgs were exported. Due to the changes in prices the exports were in last year of minor importance.

Traditionally it has taken three growing seasons to produce such large rainbow trout, mainly because the optimum temperature period is so short. Heated water is also used nowadays , which makes it possible to stock the net cages already during the first summer. This enables to rear large rainbow trout in only two growing periods. In case this method becomes more popular, it means that more and more of the production takes place in the brackish water on the coastal zone.

Finland also produces large amounts of fingerlings for stocking into natural waters, e.g. the annual of salmon smolt stockings into the Baltic Sea are at present about 2.5 million specimens per year. Brown trout stocking have been over two million fingerlings yearly. Major part of salmon, trout and whitefish catches is based on stockings.

The fingerling raising in Finland includes one unusual feature: the maintaining of salmon, sea trout and whitefish brood stocks at the freshwater, mostly state-owned central farms. This is due to historical reasons, since it has not always been possible to obtain enough natural brood fish from nature.

1.2. The water authorities' policy in Finland

The present public opinion in Finland is very favourable, as it is all over in Europe to the conservation of waters. This has lead to discussions as well as to free speculations on the impacts of fish farming.

Licences for establishing new farms exceeding a certain size are granted by water courts. National Board of Waters represents general interest and is also supervising the farms and their loadings. In the last few years smaller and smaller farms in inland waters have been obliged to make application to water court for a licence. The maximum size of a farm needing a licence without water court handling is now under five tons' annual production.

The trend has been nearly the same in brackish water area.

When farming started in the sea it was uncertain if a licence was needed or not, but now all farms with yearly production over some ten tons are obliged to water courts.

The obvious attitude of Finnish authorities to fish farming is to restrict the size of the farms. Authorities would like to keep 50 tons annual production as a maximum limit for farms in brackish water areas. This has made licences more and more strict. Environmental impacts are the most important reason preventing the rapid development of fish farming in Finland.

The supervising directives for fish farms made by the National Board of Waters and Environment includes some orders concerning farm activities, e.g. before feeding feed dust must be removed and fresh feed (fish) must be cut (not grinded). The farm shoulkd have for its effluent a sedimentation lagoon (if any other treatment is not in use) with detention time of 20 - 40 minutes and with possibility of byflowing. So that sludge can be removed periodically.

The National Board of Waters and Environment is revising these supervising directives. According to the draft new licences would always restrict the amount of allowed feed and at landbased farms also nutrient loading. In addition to these restrictions, also limits for maximum annual growth and for maximum tank, pond or net cage volume are to be followed.

Furthermore there will be a recommendation to restrict the nutrient content of the feed used at the farm. The draft recommends also to make feed conversion rate higher and nutrient content lower. Fresh feed should only be used if it is first pelletized.

For net cage farms the draft directive recommends an order to arrange sludge collection system under cages. If this is not arranged, such a farm may have to pay the water conservation charge. This payment has been about 0.1 marks (0.02 U.S. dollars) per kilogram fish produced.

2. LOADING OF SUSPENDED SOLIDS

Suspended solids from fish farming are either undigested feed (excreta) or feed waste. In nutritional studies the average digestibility of proteins is estimated as 90 per cent (Elliot & Davison 1975), lipids as 85 per cent (Phillips 1969) and that of carbohydrates varying between 40 - 80 per cent (Bergot 1979, average maybe 50 per cent nowadays).

With the help of a typical dry feed composition (10 % water, 40 % protein, 18 % lipids and 22 % carbohydrates and assumed 10 % of undigestible ash and fibres) it is possible to calculate an average digestibility of 75 % for the whole feed (72 % for dry weight). This means about 250 g solids formed per kg feed used. With fresh feed (fish) without carbohydrate digestibility is higher.

The feed quality and environmental factors effect the growth of fish and feed conversion, thus bringing about great differences and fluctuation in suspended solids loading.

When carefully removing sludge, with the help of the funnel shaped tanks, before each feeding, the dry weights of sludge per kg of used feed has varied between 22 - 255 g in nutrient budget experiments at Laukaa Fish Culture Research Station.

In Finland is above all taken into account nutrient loading and not so much organic loading and direct oxygen uptake. That's why the data of suspended solids loading are not so perfect as the figures of nutrient loadings measured by farms with water court licences. As an example, table 1 presents the loading of solids on a big fish farm in Central Finland (Savon Taimen corporation at Rautalampi water course, producing about 400 tons large rainbow trout and salmon fingerlings; landbased farm by the river Tyyrinvirta, mainly with earthen 'danish-type' ponds).

Table 1. The feeding amounts and loading of solids from Savon Taimen fish farm in 1979-1986

year	feeding tons/year	solids tons/year	solids kg/kg feed used
1979	769.2	216.9	0.282
1980	800.7	213.3	0.266
1981	817.2	46.6	0.057
1982	789.5	206.1	0.261
1983	784.4	310.0	0.395
1984	783.2	254.4	0.325
1985	703.9	418.0	0.594
1986	682.5	572.6	0.839
average	766.3	279.7	0.377

If the amount of feed waste is estimated on this data by assumed average digestibility of 75 per cent of feed, it makes 12.7 per cent on an average. However it must be kept in mind that variation in loading figures is very big. According to the observations in practical farming it is also clear that the amount of wasted feed in every circumstances is very little, rather under than over 10 per cent in every case.

The nutrient loading varies as much as solids according to growth enhanced and also according to contents of nutrient in feeds. The correlation between solids and nutrients is often contradictory (content of e.g. phosphorus decreases with increasing amounts of excreta and vice versa) but the dependency is not very regular.

Observed variation of loading values in Finland is presented in table 2 (Mäkinen 1985).

Table 2. Observed loading values of fish farming in Finland

loading factor	g/kg feed	g/kg fish produced
suspended solids	80 - 280	110 - 520
BOD 7	100 - 370	145 - 720
nitrogen	37 - 48	51 - 86
phosphorus	4.7 - 10.8	7.1 - 18.4

A special sampling apparatus for reliable effluent sample collecting has been developed in Finland. It consists of a pump and a cooled container. By this system it is possible to collect water samples for a few days with sampling intervals of only some minutes (Kivinen 1986). Sampling of effluents with high suspended solids contents is, however, still difficult, results have proved to be unreliable.

3. REMOVAL OF SOLIDS

The first and most effective way to reduce loading from fish farming is to develope feeds and feeding. Estimated phosphorus loading per kilogram of produced fish with different feeds is presented in figure 2.

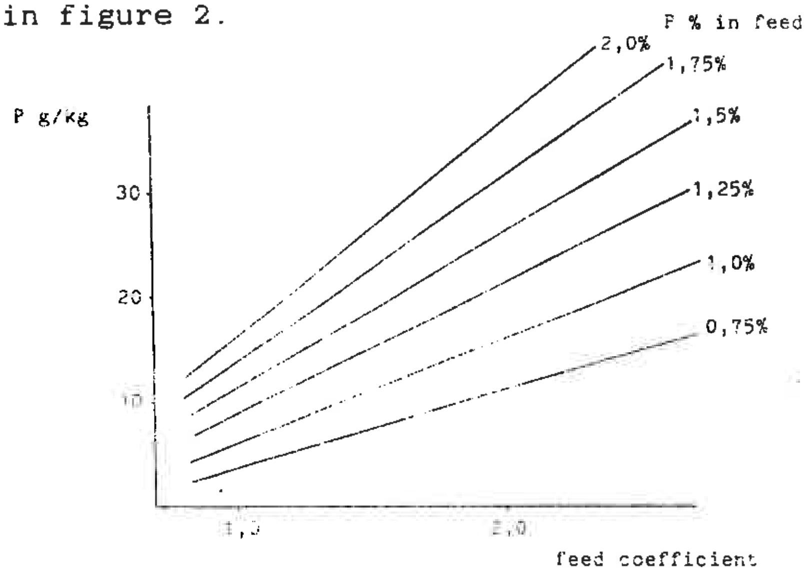

Figure 2 Estimated phosphorus loading per kilogram of produced fish with different content of phosphorus in feed and with different feed coefficients (Mäkinen 1985)

The quality of feed is very decisive for loading figures. The development of feed, especially that of its nutrition value in ordfer to improve feed conversion and the lowering of excess nutrient contents, can thus give far better results than any treatment of effluent waters. The lowering of phosphorus and nitrogen contents in relation to the content of metabolizable energy in feed and the optimatization of feeding (see Ruohonen & Mäkinen 1987) can together quite easily reduce the nutrient loading to one third.

On the basis of costs and outcomes after having improved the feeds actions will follow to separate solids from the effluent.

Sludge removal from 'danish-types' earthen ponds has been very laborous and uneffective, although some experiments have shown somewhat better results for nutrient reduction (Helkiö 1984).

The first condition for effective removal of solids is selfcleaning of tanks. In practice this means use of circular plastic, steel or concrete tanks or ponds. Experiments at Laukaa have proved it that self cleaning secondary flowing (Burroughs & Chenoweth 1955, Mäkinen 1986) is reached in concrete circular basins (28 - 120 m2) if flow speed exceeds 0.15 m/s measured at the surface near the basin edge. Flow speed in pipe lines and canals should exceed 0.3 m/s in order to transport all settleable solids to treatment for removal. Design for rapid transport of sludge from basins of a farm is important to avoid leaching and resuspension of solids and leaching of nutrients as a consequence(see figure 3, Manninen 1982).

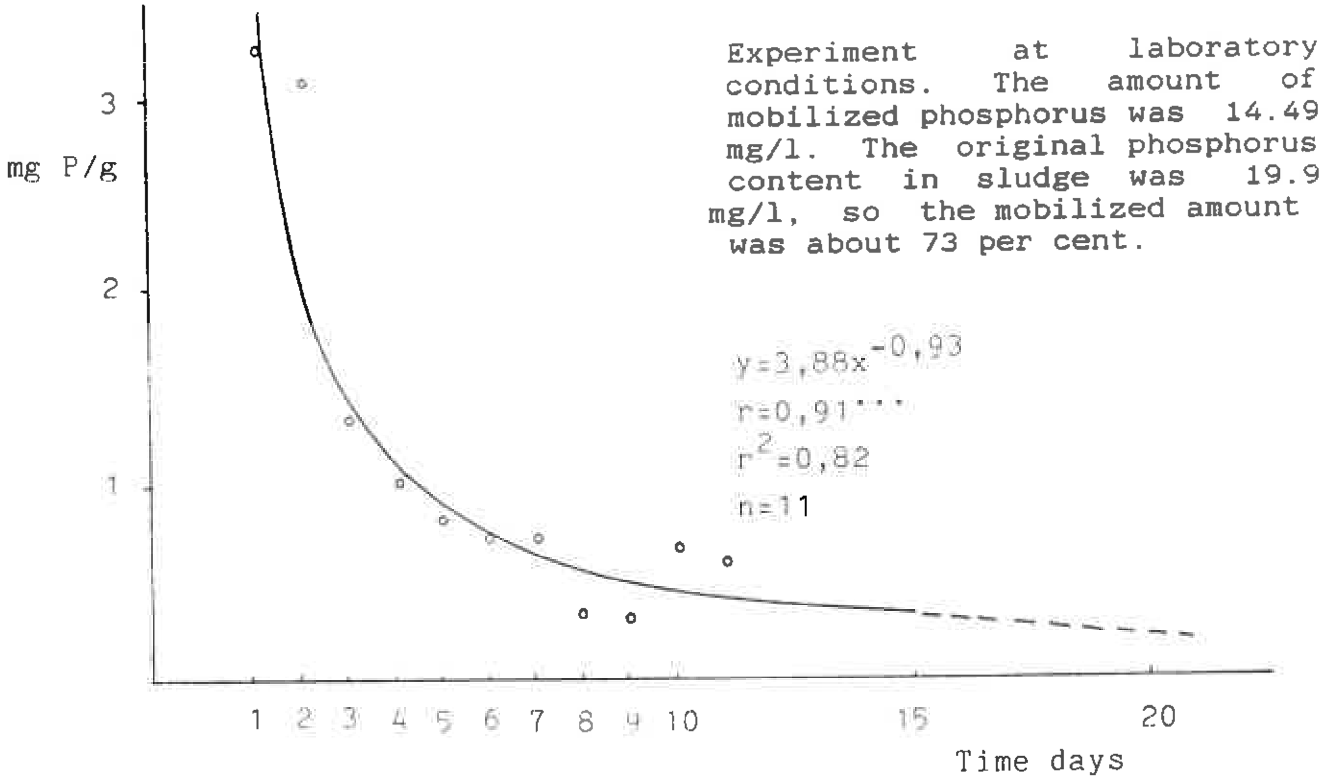

Figure 3 The regression of time versus the amount of leached phosphorus per dry weight of sludge (Manninen 1982)

Swirl concentrator is a simple and suitable devie for sludge removal. Recommendations for dimensioning of the swirl concentrator is published in Finland (Mäkinen & Naukkarinen

1982). Some commercial swirl concentrators are nowadays available in Scandinavian countries. Most effective combination is selfcleaning circular tanks and swirl concentrators. Observed reduction of solids by the swirl concentrator has varied between 50 - 80 %. The reduction of phosphorus estimated by subtracting the amount of phosphorus in plusgrowth of fish and outflowing water has varied from 42 per cent (Mäkinen 1984) to 20 per cent in experiments in 1985. Combination presented in figure 4 (Vääränen 1985) was also tested in 1985.

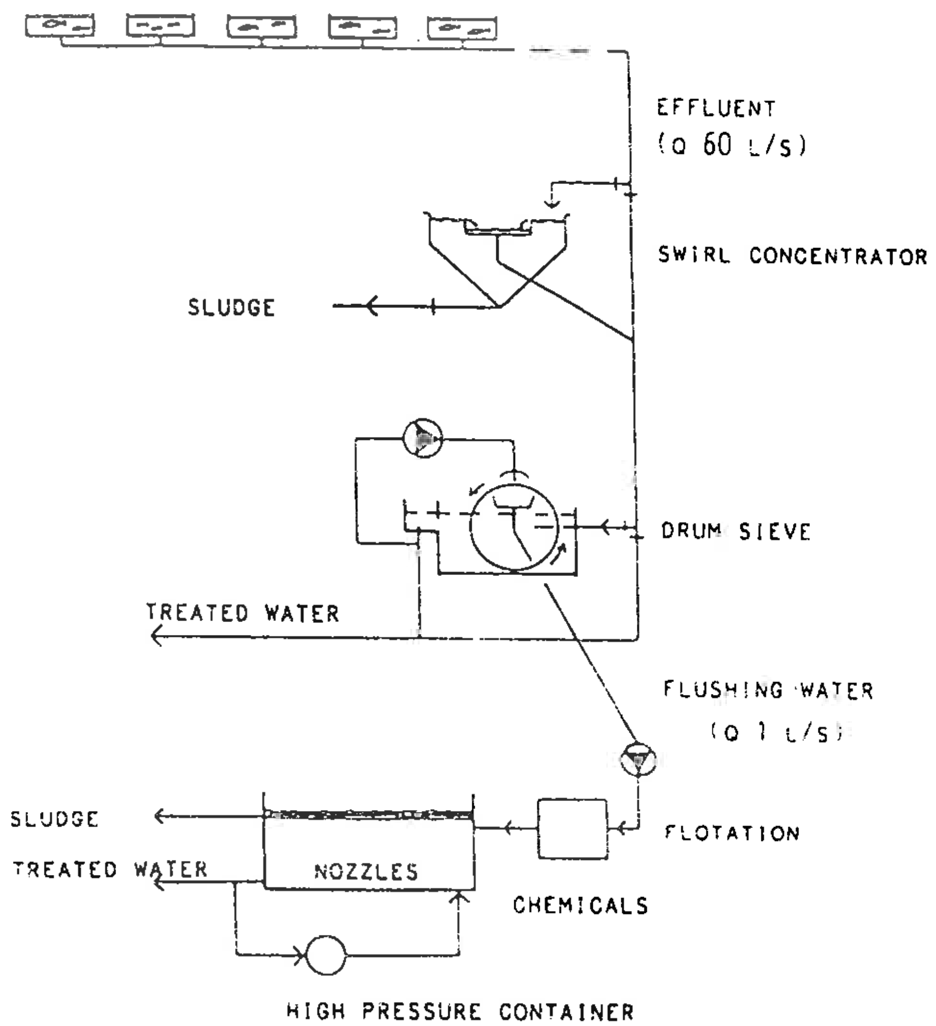

Figure 4 Schematic flow diagram in experiments at Laukaa Fish Culture Research Station in 1985

In this combination swirl concentrator, drum sieve and flotation device worked together. The last one was treating the flushing water from drum sieve. The reduction of suspended solids of this system was over 90 per cent and reduction of phosphorus about 80 per cent. The so called triangel filter was also tested later parallelly with drum sieve. The results were very similar with both sieving systems.

The triangel filter which had low amount of flushing water and big hydraulic loading, was tested in 1986 at Hankakoski fish farm. The phosphorus reduction in the water treated by the filter was about 80 per cent. Although in this experiment only about one tenth of effluent water from the bottom of the center of circular tanks was treated by one triangel filter the total effluent phosphorus reduction was over 50 per cent (Mäkinen et al. 1987).

Triangel filter seems to be to day most interesting device for high standard effluent treatment. Although flotation gives always the best results (effluent became in some cases purer as the incoming water of the farm !), it is just like some other alternative and wellknown systems for producing of household water, too expensive for a total effluent treatment.

The problem to treat effectively fish farm effluent is not any more so much technical but also economical. Triangel filter or similar devices have proved to be suitable for farms with high standard effluent treatment and for the ones with high price products. The costs need to be lowered to make sieving more general.

4. SLUDGE UTILIZATION

Out of swirl concentrator or sieving apparatus concentrated suspensions of sludge is periodically pumped. They can be clarified by adding chemicals and settling. Major part of usual chemicals have proved to function well in this connection (Selänne et al. 1983) but using of the standard powder chalk ($Ca(OH)_2$) can give the best results because it stabilizes also the settled sludge and makes it even more suitable to be used as reconditioner for agricultural land.

The settled sludge can be stored and dried in earthen basins with the help of drain pipes under a sand layer. On top of the sand layer, a peat layer may be used. The stabilizing of the sludge layer can be confirmed by adding chalk on it (also useful gainst bad smell). The sludge basins can be emptied once a year and peat layer changed at the same time.

The heavy metal content of fish farming sludges does not obstruct the use of sludge for agricultural purposes since the analyzed contents have been very low (Järvi 1984).

On the municipal and industrial sewage plants, many highly developed sludge utilization techniques (e.g. biogas production) are wellknown but their usefulness for fish farming sludges has been unimportant.

5. CURRENT RESEARCH AND RESEARCH NEED

Contrary to Swedish results (Enell et al. 1984) the Finnish outcome has been very poor when experimenting sludge collecting under net cages. The estimated phosphorus reduction has varied between 24 per cent (Leminen et al. 1986) and 10 per cent (Kehitysaluerahasto OY). Although on a very sheltered area with a lake net cage farm, estimated reduction was a little better (Sokka 1986), the water courts are recommended not to allow the use of net cages in inland areas, because there is not any effective treatment method for such a farm. In brackish water area a Scandinavian cooperation has started on national level each country involved to seek for to plan better use of coastal areas and site selection optimization of circumstances for net cage farming in the sea (Håkansson et al. 1987)

On older Danish-type farms with long earthen canals as farming ponds, the removal of solids is very laborous and expensive. It has been planned to study sludge removal technique for these farms.

As concluded already earlier in this paper, the most effective way to reduce loading from fish farming is to develop feeds and feeding. Basic research of fish nutrition and verall development of feeding techniques should be encouraged. The thorough knowledge of nutritional requirements and effective techniques which fulfill the needs exactly will give optimum minimization of loading.

A selective breeding program for rainbow trout (Sumari et al. 1984) has started last year. A selected rainbow trout strain will have in addition to better growth also better feed conversion efficiency and therefore also small nutrient loading to the recipient.

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NATIONAL REPORT FOR THE FEDERAL REPUBLIC OF GERMANY ON SUSPENDED SOLIDS FROM LAND-BASED FISH FARMS

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SUMMARY

Some informations are given about fish consumption, freshwater fish production and the Waste Water Charges Act.

The load and composition of suspended solids are described tor trout and carp ponds. In general relatively small amounts of suspended solids are washed out only during the farming period. The outflow of suspended solids occurs during the fishing-out of trouts and in the last phase fishing-out of carps.

Possibilities of removal of suspended solids or slugde are discussed.

1. INTRODUCTION

There is a relatively great market for consumption fish in Germany, but only a small one for freshwater fish - i.e. maximum consumption of roughly 1 kg per person per year. Freshwater fish species of economic importance for consumption are rainbow trout an carp. Yearly 30,000 - 32,000 tons of rainbow trout and 12,000 - 13,000 tons of carp are demanded. The domestic production capacity is approximately, 16,000 tons of rainbow trout and 8,000 tons of carp - and, in addition to this, roughly 8,000 tons other fish species, trouts and carps from hobby-ponds and fingerlings of other fish species (Bohl, 1985a).

These yields are produced in about 3,500 trout and 7,000 carp pond cultures with different sizes and under different degrees of intensification (Bohl, 1985b; v. Lukowicz, 1986).

The legislative regulation in effluent questions is fixed in the Waste Water Charges Act (Abwasserabgabengesetz or "Abw AG") (Bohl et al., 1982). As ponds are treated like natural waters in German justice dictions, they are not touched by this law, except from the more intensive holding systems. Parameter demanded are listed in Table 1.

In the meantime the maximum of inland freshwater fish production capacity is almost reached. Facing too high losses caused by itensification in pond culture in the past, now the stocking density is commonly reduced. In some pond cultures with poor water supply the use of technical oxygen for aeration is successful. Only a few numbers of modern aquaculture systems, as recirculating plants, are used for fish production.

TABLE 1. Parameters of the so-called **minimum** requirements according to the Waste-Water Charges Act.

Parameters		Random sample	2-hour-composte sample
Suspended solids	ml/l	0,3	-
COD	mg/l	-	30
BOD_5	mg/l	-	10

2. LOADING OF SUSPENDED SOLIDS

The nature of suspended solids varies depending on different factors. The main difference originate from the type of pond or holding facility, especially between carp and trout ponds. In Germany the extensive carp production is spread widely; intensification is not considered to be economical everywhere. Therefore these suspended solids consist of mineral substances in high proportions - see table 2 (Bohl, 1985a). They were sedimented in the settlement basin of our research station; but they are mixed with a certain quantity of sludge originating from trout ponds.

TABLE 2. Analysis of sludge from settlement basin of the research station Wielenbach.

	a)*	b)*	
dry matter (dm)	348.40	315.40	g/l
water content	78.87	73.60	%
residue on ignition 550°C	301.24	279.64	g/l
volatile matter 550°C	47.18	35.76	g/l
inorganic dry matter 550°C			
in relation to dry matter	85.94	88.70	%
organic dry matter 550°C			
in relation to dry matter	14.06	11.30	%
CO_2 + CO_3 in relation			

to dry matter	13.74	17.30	%
silicate, clay etc.	72.20	71.40	%
ph	6.53	6.79	
BOD_5	10.20	6.43	g/kg dm
COD	235.70	122.46	g/kg dm
NH_4^+	0.370	0.019	gN/kg dm
NO_2^-		n.n.	
NO_3^-		0.08	gN/kg dm
Org. N	8.93	5.78	gN/kg dm
Tot. N	9.30	5.88	gP/kg dm
Tot. P	1.67	1.20	gP/kg dm

* = two random samples

The composition of suspended solids depends on different factors; besides fish-farming activities and farming facilities the ration of food is very important. The good results in decreasing the load of fish-farm effluents by the use of highly digestible, protein- and fat-rich ration are well known. Our investigations conducted with a "normal" and a "high energy" dry food in semi-intensive rainbow trout ponds (=concrete tanks) showed some clear differences, for example in COD, BOS_5 and organic nitrogen - see Tables 3 and 4 (Bohl, 1984) and a reduction of sludge of about 40 %.

Table 3. Sludge from trout pond (concrete tank) - fish fed with "high energy" dry food.

DATE	24.02.	18.03.	14.04.
smell	silage	grass	grass/corn
colour	dark brown	dark brown	dark brown
dry matter 105°C g/l	30.776	105.580	89.878
residue 550°C g/l	11.096	59.310	55.168
residue 800°C g/l	9.550	44.608	39.648
water content %	96.92	89.40	91.01
inorg. dry matter % dm	36.0	56.2	61.4
org. dry matter % dm	63.9	43.8	38.6
$CO_2 + CO_3^{2-}$ % dm	5.0	13.9	17.3
silicate, clay etc. %	31.0	42.3	44.1
pH	6.47	6.83	7.20
COD gO_2/kg dm*	931	811	660
BOD_5 gO_2/kg dm	254	211	206**
NH_4^+ gN/kg dm	2.08	0.93	1.19

NO_2^- gN/kg dm	0.010	0.013	0.013
NO_3^- gN/kg dm	n.n.	n.n.	0.026
org. N gN/kg m	36.13	30.73	26.91
Tot. N gN/kg dm	38.22	31.67	28.14
Tot. P gP/kg dm	19.43	21.77	16.82

* = sludge samples were homogenized with ultrasound
** = 14.04. BOD_5 was measured out of fresh sample

TABLE 4. Sludge from trout pond (concrete tank) - fish fed with "normal" dry food.

DATE	24.02.	18.03.	14.04.
smell	silage	grass	grass/corn
colour	dark brown	dark brown	dark brown
dry matter 105°C g/l	63.698	61.184	34.922
residue 550°C g/l	20.626	19.412	15.100
residue 800°C g/l	16.348	16.188	11.074
water content %	93.63	93.88	96.51
inorg. dry matter % dm	32.4	31.7	43.2
org. dry matter % dm	67.6	68.3	56.8
$CO_2 + CO_3^{2-}$ % dm	6.7	5.3	11.5
silicate, clay etc. %	25.7	26.5	31.7
pH	5.89	6.46	7.12
COD g O_2/kg dm*	1084	1134	1054
BOD_5 g O_2/kg dm	280	302	347**
NH_4^+ gN/kg dm	1.67	0.97	1.06
NO_2^- gN/kg dm	0.010	0.013	0.012
NO_3^- gN/kg dm	0.026	n.n.	n.n.
org. N gN/kg dm	39.17	42.14	28.20
Tot. N gN/kg dm	40.88	43.12	29.27
Tot. P gP/kg dm	14.96	22.50	17.01

* = sludge samples were homogenized with ultrasound
** = 14.04. BOD_5 was measured out of fresh sample

The content of phosphorus in fresh sludge of trout ponds reaches a maximum of 76 % of total faeces (Löffler, 1987).

Times of settlement differ too; it depends on the ration of dry feed, water quality and age of sludge, for example - see Figure 1 (Bohl, 1985a).

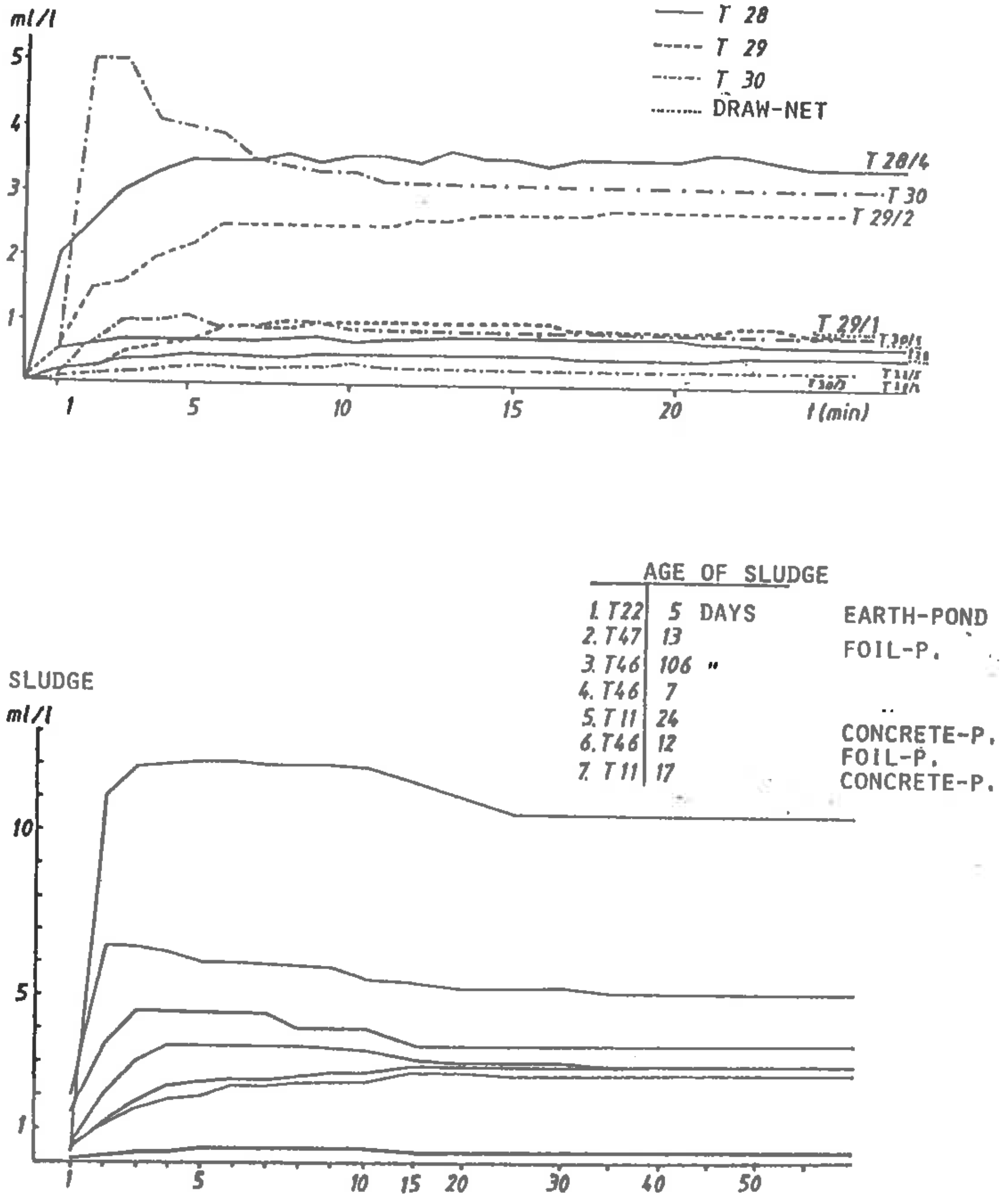

FIGURE 1. Time of sludge settlement from different trout ponds in Imhoff-Funnel. (T = ponds)

The estimated production of suspended solids amounts approximately 30,000 tons per year in the Federal Republic of Germany, if the quantity of sold fish feed and the experience-value, that one ton dry food produces 1 m^3 sludge is taken into account.

We know, however, hat there is only a small amount of outflowing suspended solids during the production period, even in trout ponds. During the investigation period - even at a stocking density of 40 kg trout/m^3 water - suspended solids 0.1 ml/l would be stated occasionally (Jensen, 1972). Table 5 shows first results from a current research program: From each pond culture a different number of random samples were taken (Horst, 1987). Therefore these data are given only for an additional contribution to demonstrate the great variety.

TABLE 5. Total effluent of suspended solids at pond fishing-out.

Fish species (age years)	yield kg	pond vol. m^3	pond area ha	susp.solids ml/l
brown trout (2)	775	102	0.011	0.137
brown trout	965	133	0.013	0.278
carp (3), tench (3) roach etc.	10500	400,000	15	0.125
carp (1), grass carp and silver carp (1)	510	2,700	0.35	0.693
pike perch (1), carp and grass carp (2)	2,150	11,000	0.9	1.019

The situation in carp ponds is different. Usually there is no through flow; most of the initial time during fishing-out the outflow is clear. The outflow of suspended solids begins by the concentration of fish in the fish pit in front of the monk. Generelly it seems to exist a relationship between the fish yield and the amount of the washed out suspended solids (Horst, 1987).

The situation in extensive carp ponds - based on several nivellement of the water volume and related quantity of suspended solids by random samples - are shown in Table 6.

TABLE 6. Relation between suspended solids and area of pond (per hectare), based on several investigations at single carp ponds.

	Suspended solids tot. m3	Suspended solids m3/ha	Weed cover % of area	Fish yield kg/ha
pond 5 ha 1. year	2.15	0.43	0	381
pond 5 ha 2. year	2.40	0.48	0	377

pond 0.2 ha	0.95	4.75	20	600
pond 0.2 ha	0.45	2.25	100	245
pond 0.2 ha	0.10	0.50	100	145
pond 0.2 ha	0.70	3.50	0	443

In general, only relatively small quantities of suspended solids are washed out, but that is the end of fishing out period.

3. REMOVAL OF SOLIDS

The most effective method is a settlement pond or basin, but unfortunately not a cheap one. The retention time of water has to be 30 minutes at least. Recent investigations showed that shorter retention times are possible. Encouraging results have been noted with a swirl-concentrator and a clarification-pond behind a trout pond culture (Dvorak, 1987). By correct professional farming activities and pond management most of the sludge would remain in the pond; sludge-pumps can transport it on dry beds, for example.

If the fish is yielded from ponds with closed outlet, no sludge flows out; but this is not the best way from the point of good care of the fish.

Another method is to dam up slightly the receiving water about 20-30 cm above the bottom. The most outrunning sludge will settle down in this dammed section; after that the sludge has to be removed with a suitable measure.

There exists a further possibility protecting the receiving water after fishing out of the carp ponds; the monk has to be closed partially with few baffles for a while until the liquid sludge is stabilized and settled, in order to retain sludge in case of heavy rainfall.

ACKNOWLEDGEMENT

Many thanks to Dr. Scherb, Waste Water Research Field Munich-Grosslappen, Bavarian Water Research Agency, for the analysis of sludge (Tab. 2 bis 4).

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REPORT ON SUSPENDED SOLIDS FROM LAND BASED FISH FARMS IN GREECE

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1. INTRODUCTION

In Greece, the fish farms in freshwater concern a rather small part of the agricultural economy.

Today there exist ~140 fish farms in freshwater, where there are cultivated the following species:

Salmo gairdneri, Cyprinus carpio, Anguila anguila, Salmo salar, Tilapia sp.

The total productivity of these farms for 1986 is 2641 tn (Fisheries Direction, Min. of Agr., 1986) and from Table 1 and Table 2 we can see that salmo gairdneri, or as we say the rainbow trout, is the first of the cultivated species.

Table 1. Total Production/yr per each species

SPECIES	TOTAL PROD.(TN)	%	PRICE 10^3 DR/TN (MEAN)
Salmo gaird	2.282	86,41	350
Cyprinus Carp.	290	10,98	300
Ang. ang.	20	0,76	1.000
Salmo salar	4	0,15	1.800
Tilapia sp.	45	1,70	350
	2.641	100.00	

Table 2. Production/yr for the 3 first species

YEAR	T. PRODUCTION (TN)
1980	2.200
1981	2.500
1982	2.000
1983	1.900
1984	1.600
1985	2.100

All the above mentioned fish farms are land based except one, the "S.A. EYRYTANIA" which, in collaboration with the Institute for oceanographical and fisheries research of Athens has begun an experimental cage culture in the Lake of Kremaston, Prefecture of Eyrytania, since 1983.

These freshwater cages are used for the production of Carp (Cyprinus carpio), rainbow trout (Salmo gairdneri) and eel (Anguila anguila).

The production of this cage farm was for 1986:

- Rainbow trout: 20 tn → 0,9% of total product. from fish farms
- Carp : 90 tn → 31% of total product. from fish farms

We must include in the land based fish farms two National hatcheries for the production of rainbow trout fingerlings (one in the Prefecture of Ioannine and the other of Pella); each of them produces 1.500.000 fingerling trout per year. The aim is the production of young fish either for restocking free waters (rivers and lakes) or for fattening into fish farms. They are also able to hatch eggs of the species: coregonus lavaretus and salvelinus fontinalis.

Two more national hatcheries are building for the production of Carp fingerlings (in the Prefecture of Florina and Prefecture of Arta).

There exists one hatchery (this one of Lake Ioanninon) for Carp fingerlings production; it produces 2.000.000 fingerlings per year.

The permission for fish farm installation is given by the local official fisheries office, which in each Prefecture, is the Fisheries Department of the Ministry of Agriculture. The needed documents are:

- nature of fish farm, surface, site, quality and quantity of water, neighbours fish farms, density of fish, management of fish farm, certificate of a Technical school for fish farmer or following of special seminars in one of the National hatcheries.

According to the Health Directive No. A5/1738/82, and concerning the quantity and the quality of fish farms effluents and the quantity and uses of the current, it is demanded the installation of treatment of effluents, especially for removal of suspended solids (see Fig. 1).

According to the Ministerial Decision No. 46399/1352/3.7.86, which includes the E.E.C. Directive 78/659, (about the good survive of Salmonids and Cyprinids) the free freshwaters (rivers and lakes) of our country are submitted to a systematic control of their quality.

For trout fish farms, there exist a standing because of the saturation with trout of the country market, although the trout fish farms capacity is much higher than their productivity. This is due to the selection of Greek consumer to sea fishes (only the continental departments of our country demand fresh water fishes),

Carp is limited only to the North West of Greece.

Eel consumption is very limited (< 1% of total production) by Greek people but contrary to this, eel is very much exported.

The trend of development for eel and Atlantic Salmon farms is going increasing; although Atlantic Salmon culture is still in an experimental phase, the same trend seems to be for the species Astacus leniusculus.

2. LOADING OF SUSPENDED SOLIDS

The wastes from a fish farm can be divided into two major fractions, solid and soluble waste. The solid fraction is largely composed of uneaten food and faeces, with a smaller proportion of fish scales, mucus and other detritus. These wastes are generally denser than water and therefore must eventually sink to the bottom sediments (Phillips M.J., 1985). Petit (1985) found that 86% of the suspended solids from a tank farm discharge settled out of the water.

For the fish itself, the impact of suspended solids, in high concentrations can be the damage of the gills. In the same time they are the base where micro-organisms can cause several diseases or can facilitate the risk of contamination.

For environment, the impact from suspended solids is largely due to the consumption of O_2 which is demanded for the biological destruction of organic matter and thus it will cause an O_2 deficience.

a. For salmonid cultivation, where the first and principal question is water, the evaluation of the quantity of water demand is for our country (Prefecture of Ioannina Decision 9.5.86) > 70 ÷ 100 lt/sec/stremma (=1000 m^2), corresponding a 5 ÷ 6 lt/sec. tn trout for density 15 tn/stremma.

b. Evaluation of Susp. solids for a Salmonid farm, where trout is intended for consumption and it is concerned that:

- the quantity of water demand is: 22,8 lt/sec. tn trout (Leger's formula gives : 16 lt/sec. tn trout)
- the concentration of S.S. in the influent and effluent water is given by the following figure (Tervet 1981)

INPUT S.S. (mg/lt)			OUTPUT S.S. (mg/lt)		
min	μ	max	min	μ	max
1,00	8.0	16,00	1,00	11,00	47,99

μ = mean

The difference between μ water input and μ water output is: 3 mg/lt, that means: every lt of water, which comes out of the fish farm concerned, is charged with about 3 mg/lt (mean) of suspended solids.

* In one day (= 86.400 sec) the quantity of effluent water, for the above mentioned fish farm is : 1.969.920 lt.tn trout.

So: The S.S. in the quantity of effluent water is 5,9 Kg/day tn trout

The value of suspended solids found is very much comparative to what several studies on solids production from land-based Salmonid farms give us (Table 3)

Table 3. A review of solids production from land based salmonid farms

SOLIDS PRODUCTION	SOURCE
0,474 ÷ 4,015 tonnes/tn fish production (mean 1,24 l/t)	Alabaster, 1982
5 g/Kg of fish held per 24h	Warren - Hansen, 1982
3,02 g/Kg of fish held per 24h (range 0,9 ÷ 7,9)	Bergheim et al 1982

3. REMOVAL OF SOLIDS

For small scale fish farms (1 ÷ 2 stremma, or less), which do not have special system for sedimentation or absorption of suspended solids, these may be subject to dissolution and dispersion by the river, where these are discharged to.

One solution, for avoiding maximum values of pollution by the above mentioned farms effluents, when emptying the tanks, is, for the farmer, to prevent continuously feaces sedimentation in the tank; and even using high water quantities and surface oxygenerators, which dissolve wastes. The farmers must also use foods with low sedimentation velocity, and must use, as far as possible, the exact quantity of food for fishes wanted.

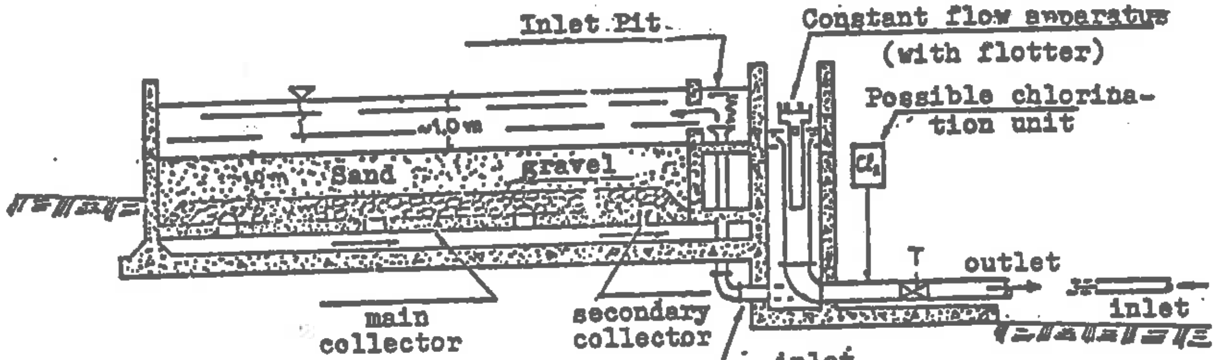
For bigger fish farms (> 15 stremma) it is demanded, according to the Health Directive No. A5/1738/82, special systems for the absorption of suspended solids, as it is described in the design of Figure 1.

In the Table 4, we are giving some parameters of Louros river. The analysis of these parameters is applicated by U.E.B. (Data by the Direction of Improving Agriculture of the Ministry of Agriculture) monthly from the site "Bridge of Kalogeri". It is given that, the higher percentage of Salmonid fish farms in Greece, function along Louros and Aoos rivers, in the Prefecture of Ioannina.

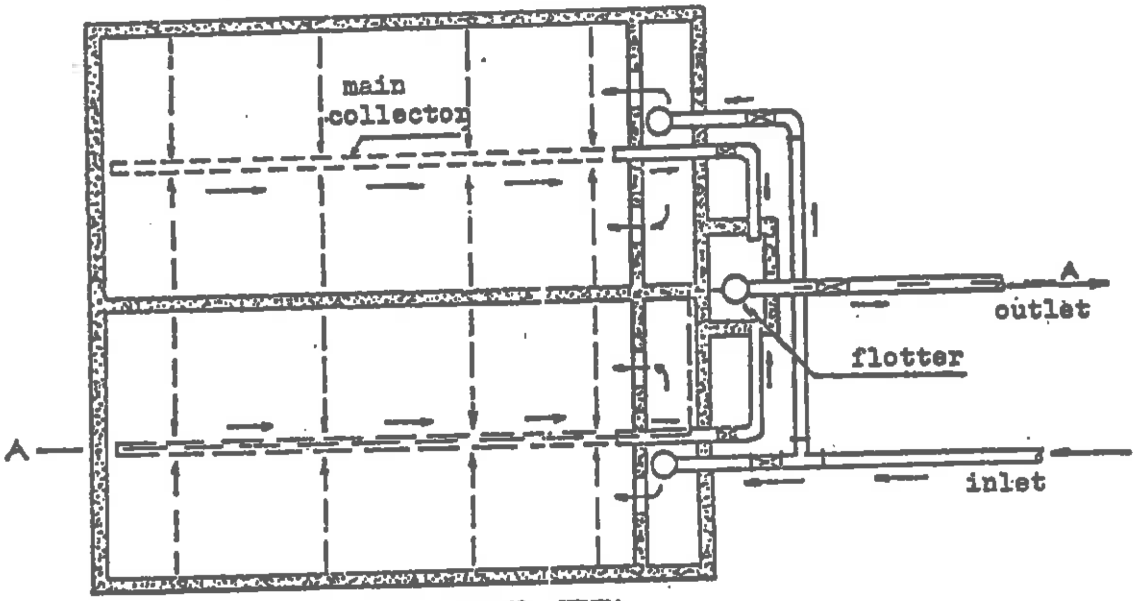
Table 4. Some parameters by Louros River (Bridge of Kaloyeri)

PARAMETERS \ YEAR	1984	1985	1986
Quantity of water (m^3/ sec)	min: 5,5 max: 35	min: 10 max: 24	min: 10 max: 24
Temperature (°C)	13° ÷ 16°	11° ÷ 15°	11° ÷ 15,5°
Susp. Solids (mg/lt)	0 ÷ 13,4	0,7 ÷ 31	0,2 ÷ 38,5
PH	7,2 ÷ 8	7,6	7,7
O_2 (percentage saturation)	84 ÷ 96,1	78,7 ÷ 100	86,5 ÷ 100

Figure 1. A. INDICATIVE PLAN SANDFILTER

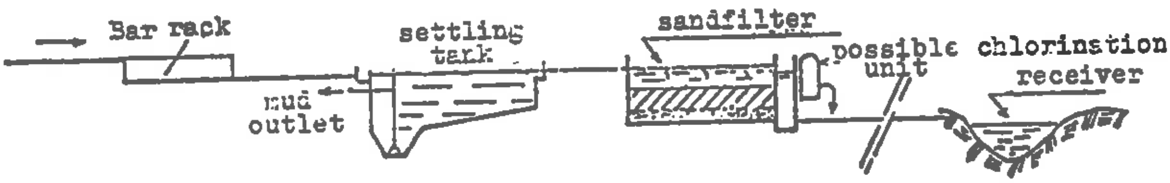


SECTION A - A



PLAN VIEW

B. LAYOUT DIAGRAM OF SEWAGE TREATMENT AT HATCHERY



Note: 1. Filtration speed: $U=5-7\ m^3/m^2.\ d.$

2. Sand (preferably silicon sand)

-Activated diameter: $D_{10}= 0,25-0,30$ mm

-Uniformity coefficient: $D_{50}/D_{10}= 2,0-3,0$

3. Sandfilter cleaning: removal of 2-3 cm sand (add sand when sand thickness becomes appr. 50 cm)

4. LITERATURE

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CASE STUDY ON SUSPENDED SOLID MATTER CONTENT OF EFFLUENT WATER OF A STATE FARM FISH POND IN THE HARVESTING PERIOD IN THE GREAT HUNGARIAN PLAIN

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1. INTRODUCTION

In Hungary it is a basic problem of earthen fish ponds that during the growing season the erosion caused by wind-waves washes the dams back into the bed. Time at disposal for autumn harvest is relatively short (October, November), that is max. 2 months, therefore, a rapid drainage of pond water is desirable. Size of ponds is of wide range 50-100-200 ha, with a water depth of 1-1.5 m, thus during drainage the sediment washed back from dams gets out of ponds by the heavy turbulent water-moving. This effect is rather harmful for two reasons; in one hand it pollutes environment by a probable erosive fill-up and organic matter loading of the receiving area, in the other hand there will be a lack of soil at dams, which, however, should be supplied back in the reconstruction period. Additional expenses arise by maintenence of the receiving area as well as that of the pond. A research project was started on the estimation of the suspended solid matter outflow of our fish ponds.

2. MATERIAL AND METHODS

Duration of investigations: 10.17.-11.04.1986

Location: Fisheries Research Institute, Szarvas, Hungary

Technological parameters of the site investigated:

Area of fish pond 31.5 ha, reconstruction finished in spring of 1986, total inflow volume 315,000 m^3, stocking for rearing fingerlings in polyculture, summer water treatment, dosage of artificial fertilizers N and P about 150 kg N/ha, 20 kg P/ha, season, carp feeding on rearing food.

By reconstruction we mean a total bed readjustment, dam-building, construction of completely new inlet-outlet structures as well as a new external harvesting pit.

The aim of investigations was to determine the suspended matter content of effluent water of a completely new fish pond during the harvesting, including the organic-inorganic solid matter content.

To this end, samples were taken at the outlet, right after the drainage started, during the drainage period (in two-day intervals always in the same time). After filtered through a Whatmman membrane filter, the dry matter content at 105°C, the ash content at 550°C were determined as well as organic matter content of the samples was calculated. Average speed of sinking concerning the time of taking samples, was measured and the amount of outflow water was calculated.

Measurements were made till about the two third of the water was drained.

3. RESULTS AND DISCUSSION

Results of investigations are shown in Table 1. The effluent water of the new-built rearing pond in time of harvesting had a dry matter content of 0.120-0.535 g/l, including - except for one case - 0.040-0.098 g/l organic and 0.080-0.449 g/l inorganic matter. It can be pointed out, that inorganic mineral particles of the sediment formed the main part of solid matter escaped by effluent water.

Table 1. Analyses of solid matter content of effluent water of the rearing fish pond investigated.

Date 1986	Dry matter g/l	Ash g/l	Organic matter g/l	Speed of sinking cm/day	Volume drained m^3	Dry matter kg	Ash kg	Organic matter kg
10.17.	0.120	0.080	0.040	2.00	6,300	756.00	504.00	252.00
10.20.	0.170	0.130	0.040	3.30	31,500	5,355.00	4,095.00	1,260.00
10.22.	0.248	0.205	0.043	3.50	22,050	5,468.40	4,520.25	948.15
10.24.	0.394	0.296	0.098	4.50	28,350	11,169.90	8,391.60	2,778.30
10.27.	0.162	0.082	0.080	3.50	33,075	5,358.15	2,712.15	2,646.00
10.29.	0.166	0.108	0.058	2.25	14,175	2,253.05	1,530.90	822.15
10.31.	0.444	0.102	0.342	2.00	12,600	5,594.40	1,285.20	4,309.20
11.03.	0.535	0.449	0.086	3.67	34,650	18,537.75	15,557.85	2,979.90
11.04.	0.218	0.152	0.066	8.00	25,200	5,493.60	3,830.40	1,663.20
Whole period total					207,900	60,086.25	42,427.35	17,658.90

Dry matter content of water to be drained is influenced by the speed of drainage. An increasing speed of drainage implies an increasing amount of dry matter, in which, naturally, both the increasing turbulence and the sediment-mixing activity of fishes have a role, too.

During the period of investigations, 210,000 m^3 outflow water contained dry matter of about 60 tons which got out of pond to the external harvest pit where it partly sedimented and did not get directly to the receiving area. About 70 % of the dry matter escaped were inorganic minerals, while the remaining 30 % was organic matter.

4. CONCLUSION

During the present study solid dry matter content of the effluent water of a completely reconstructed fish pond was investigated at the end of the first year, at a commonly used harvesting technology. Fish ponds operating for several years were not the subjects of our investigations.

The fish pond investigated is the integral part of a fish pond system constructed on hard silty soil in the central part of the Great Hungarian Plain.

Essential findings: With about 210,000 m^3 outflow water about 60 tons of dry matter escapes with a composition of about 70 % inorganic solid minerals and about 30 % organic matter, respectively.

Solid dry matter content of the effluent water will grow along with the increase of turbulence.

SITUATION OF TROUT FARM EFFLUENTS IN ITALY

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1. INTRODUCTION

In Italy freshwater aquaculture, in its modern meaning, developed in the sixties and in 1986 reached a remarkable level in production and technology.

In the last years also salt water aquaculture worked new technics out for the rearing of particulary valuable species as sea bass (Dicentrarchus labrax), sea bream (Sparus aurata), shrimps (Penaeus japonicus) and mussel (Tapes semidecussatus).

The total amount af aquaculture production in 1986 is presented by the following figures:

mussel	70.000 tons
trout	25.000 tons
brackish water lagoon	5.700 tons
eel	2.200 tons
catfish	1.300 tons
carp	300 tons

Aquaculture, like every zootechnic branch, presents problems closely linked with the specificity of rearing (i.e. feeding, management, sanitary condition, commercialization).

One of the aspects taken in consideration, above all in the last year, is the environmental impact caused by intensive fish culture.

In 1976 Italian Government issued a decree for water protection (Law 319, 10.5.1976) and also fish farmers were obliged to comply with the provisions of the law (Tab. 1).

pH	5.5 - 9.5
settleable solids	0.5
suspended solids	80
total phosphorus as P	10
ammonia as NH_4^+	15
nitrite as N	0.6
nitrate as N	20
BOD	40

Tab. 1: Maximum limits set to descarge effluents by law 319.

In order to value the quality of immissions and emissions of fish farms, in 1984 and 1985 effluents of 69 trout farms were controlled. We were interested in trout farms because trout culture is the most important of the fresh water intensive rearings.

The chosen fish farms are in Friuli, in North-East of Italy, Region that can boast 1/3 of the total italian trout production.
The drawings of the samples were done different seasons and water characteristics conditioned by fish culture were took in consideration.
Furthemore we analized effluents of the two greatest farms effluents as regards esclusively suspended solids and "feeding effect".

2. WATER QUALITY

The 69 trout farms considered in our research are placed in the "Spring area" that is one of the most suitable regions to Salmonid culture as regards abundance of water with proper chemical-physical characteristics.
Spring water have constant flows and temperatures all year round (9-15°C) favouring the production of the commercial size of 4 trouts/kg in 14-18 mounths. These trout farms studied reflect, with good approximation, general situation in Italy about installations, water-fishes ratio, kind of fish foods and so on.
The drawings of samples of inlet and outlet water were taken for two years with a frequency of six mounths. In trout farms with great productions (over 50 tons/year) samples were taken more frequently.
Analyses were made with standard methods.

In general our data confirmed that chemical-physical characteristics of inlet waters are excellent for Salmonids rearing, even if hardness is higher than recommended (297 mg/l $CaCO_3$) (Tab. 2).

		inflouw				outflouw			
		min.	max.	mean	dev.st	min.	max.	mean	dev.st
temperature	°C	4.0	18.0	12.0	2.60	4.0	19.0	12.2	2.81
hardness ($CaCO_3$)	mg/l	139.6	429.6	297.1	53.70	150.3	438.5	298.9	53.70
pH		6.8	8.5	7.5	0.35	6.7	8.5	7.5	0.35
dissolved oxygen	mg/l	5.5	13.5	9.9	1.33	3.4	14.6	8.5	1.70
BOD_5	mg/l	0.0	4.9	1.5	1.18	0.2	8.0	2.7	1.83
ammonia (NH_4^+)	mg/l	0.00	0.40	0.09	0.09	0.00	0.80	0.25	0.16
nitrite (NO_2^-)	mg/l	0.00	0.24	0.04	0.05	0.00	0.40	0.07	0.06
phosphate ($PO_4^{\equiv}$)	mg/l	0.00	1.90	0.20	0.29	0.00	3.60	0.32	0.46
settleable solids	ml/l	0.00	0.50	0.01	0.05	0.00	0.70	0.04	0.10

Tab. 2: Physical and chemical characteristics of water of 69 trout farms.

The comparison between effluents and inlet waters made with the method of analysis of variance showed a significative increment of NH_4^+ , NO_2^- , PO_4^{3-} , settleable solids and a significative reduction of dissolved oxygen (Tab. 3).

	T °C	$CaCO_3$ mg/l	pH	O_2 mg/l	BOD_5 mg/l	NH_4^+ mg/l	NO_2^- mg/l	PO_4^{3-} mg/l	S.set. ml/l
Inflouw (mean)	12.0	297.1	7.5	9.9 A	1.5 B	0.09 B	0.04 B	0.20 B	0.01 B
Outflouw (mean)	12.2	298.9	7.5	8.5 B	2.7 A	0.25 A	0.07 A	0.32 A	0.04 A
Degrees of freedom	473	475	485	478	469	474	478	454	481
Residual	7335	8902	0124	2304	2329	0017	0003	0145	0007

Tab. 3: Analysis of variance of data reported in Table 2.

Such variations depend on enrichment of uneaten food, feces and excreta of water flowing in fish ponds.

Feeding of almost all intensive reared species is usually based on the use of dry pellets. The mechanical feeding causes losses of food extimated about 15% of total food weight. This high percentage derives from the presence of "dust" of fish food, on overfeeding and on inaccuracy of distribution.

Food uneaten or not digested deposits on the bottom of basins where it is exposed to processes of breakdown and resuspension because of solvent action of water, degradative activity of mineralizating bacteria and water movements caused by swimming fishes.

Other sources of pollution are fishes feces. Their amount is in function of the kind of diet adopted, species cultured and their sizes. Salmonids product about 200-400 g of feces per kg of dry food.

In spite of the statically significative variations of some parameters, water effluents of fish farms observed keep their fitness for intensive rearing and their chemical-physical characteristics comply with the limits stated by the law.

Only settleable solids, usually because of not accurate management, exceeded legal limits. The highest value found was 0.7 ml/l.

3. SUSPENDED SOLIDS

We analyzed the affluents and effluents of two farms, out of 69 studied yet, to know the increment of suspended solids in outlets due to the distribution of food. The farms were different for dimensions, water origins and amount of productions. The drawings of the samples of inlet and outlet waters have been taken over one day from 8.00 to 16.00 at intervals of one hour.

In the two farms food distribution was from 8.30 to 10.30; the research took in consideration only the feeding in the morning (in the afternoon, after 16.00, there was another lighter one).

The structural characteristics, quality of water utilized, fish breeded and food rate are described in Table 4.

characteristics of farm		farm 1	farm 2
surface of farm	m^2	3600	18600
water supply		river	river spring
quantity of water	l/sec.	1200	1600
retention period of water in farm	min.	35–40	45
quantity of fish	tons	60.3	52
size of fish	g	75-315	40-230
type of feeding		dry	dry
food	% b.w.*	1.5	1.0
time of feeding		8.20–10.30	9.00–10.30
type of pond (bottom) (edge)		stone concrete	stone earth

Tab. 4: Summary of characteristics of two fish-farms considered (* b.w. : body weight)

parameters		inflow	outflow								
samplig time	h	8.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
temperature water	°C	10.2	10.5	10.5	10.7	11.1	11.5	11.5	11.7	11.7	11.6
pH		7.9	7.8	7.5	7.5	7.5	7.6	7.7	7.7	7.7	7.8
oxygen	mg/l	9.8	8.3	9.3	9.2	8.6	8.6	8.5	8.5	8.9	9.4
BOD_5	mg/l	0.7	0.5	3.7	3.5	2.6	2.7	2.0	1.3	1.3	1.8
ammonia (NH_4^+)	mg/l	0.00	0.20	0.20	0.20	0.20	0.30	0.30	0.35	0.35	0.30
nitrite (NO_2^-)	mg/l	0.00	0.06	0.06	0.06	0.03	0.03	0.06	0.06	0.03	0.02
phosphate (PO_4^{3-})	mg/l	0.2	0.4	0.5	0.6	0.3	0.3	0.3	0.6	0.5	0.6
suspended solids	mg/l	1.8	3.8	7.4	5.6	3.9	3.2	3.0	3.2	2.4	2.2
settleable solids	ml/l	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0

Tab. 5: Fish farm 1: physical and chemical characteristics of water

parameters		inflow	outflow								
sampling time	h	8.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
temperature water	°C	6.5	6.5	7.0	8.9	9.2	10.8	11.0	11.0	12.0	11.0
pH		7.7	7.7	7.8	7.9	7.9	7.9	7.9	7.9	7.9	7.9
oxygen	mg/l	8.1	8.9	8.9	9.8	9.6	9.9	10.0	10.2	10.3	9.9
BOD_5	mg/l	1.5	1.8	1.7	1.3	2.4	1.8	1.7	1.8	1.3	2.8
ammonia (NH_4^+)	mg/l	0.20	0.20	0.30	0.30	0.30	0.30	0.35	0.40	0.35	0.40
nitrite (NO_2^-)	mg/l	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.01	0.01
phosphate (PO_4^{3-})	mg/l	0.3	0.3	0.4	0.4	0.6	0.3	0.4	0.4	0.4	0.5
suspended solids	mg/l	1.6	1.2	7.2	3.2	4.0	3.4	2.4	3.0	1.8	2.0
settleable solids	ml/l	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1

Tab. 6: Fish farm 2: physical and chemical characteristics of water

Tables 5,6 show for both trout farms values found for suspended solids and the other parameters conditioned by intensive breeding.

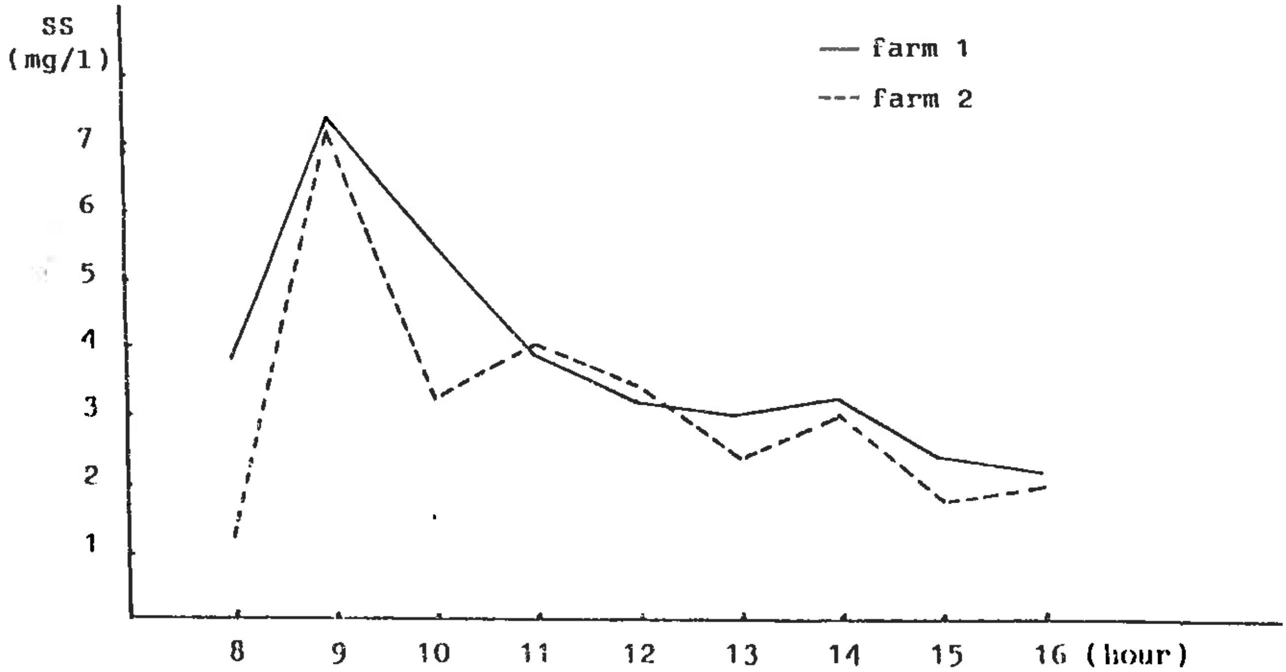
Chemical-physical characteristics of water were superimposed on those of Table 2.

The values of suspended solids in effluents were included from 1,2 to 7,4 mg/l with an average of 3,8 mg/l for the farm 1 and 3,2 mg/l for the farm 2. These values are representatives of general situation in Italian trout farms.

Sometimes it's possible to found higher concentrations ascribing to particular operations such as cleaning of basins.

In our research highest data for suspended solids were recorded during the distribution of food.

Suspended solids derive from dust of pellets, from their fractions not eaten and from sludges resuspension caused by turbolent swimming of fishes during the feeding. The differences observed for the two trout farms depend on quantity of fish per m (farm 1: 16 kg/m ; farm 2: 2,8kg/m) and on quality of fish food distributed (farm 1: 1,5% b.w.; farm 2: 1% b.w.).



Graphic: Increase of Suspended Solids in two trout farms effluents.
Time of feeding of farm 1: 8.30-10.30
farm 2: 9.00-10.30

The graphic above shows the fluctuations of suspended solids concentrations; after three hours from feeding time values turned back to standards.

We observed the increases of BOD and settleable solids associated with the augmentation of suspended solids. The other parameters (N and P compounds, could increase some hours after feeding as consequences of metabolism products and solubilization of uneaten food). The differences found among the two trout farms could depend on more or less accuracy in distribution of food and on different frequency in cleanings of basins besides structural characteristics of farms, flows of inlet water and quantities of fishes cultivated.

4. CONSIDERATIONS

Effluents water quality affect environment causing eutrophication in consequence of increasing -even if limited- of phosphorus, nitrogen, BOD, settleable and suspended solids.

This aspect is more evident in receiving waters of fish farms with great productions or with long time of activity. From many years technical and structural solutions have been investigated trying to limit these negative consequences. So solutions of sure efficiency such as filters and concentrators of high technology or settling ponds of easy construction and low costs have been proposed.

Even if these systems of effluents treatments are not obligatory by provision of the law, it's advisable their adoption above all in those regions with high density of fish farms which put their effluents in the same catchment basin.

Furthermore fish farmers should apply a correct management by removing sludges from ponds avoiding nutrient solubilization and solids resuspensions reducing overfeeding and spreading fish food with more accuracy.

5. CONCLUSIONS

Effluents from 69 trout farms analyzed presented, in comparison with affluents, statistically significative increments for BOD_5 (+1,2 mg/l), NH_4^+ (+0,14 mg/l), NO_2^- (+0,03 mg/l), $PO_4^=$ (+0,12 mg/l), settleable solids (+0,03 ml/l) and reduction of dissolved oxygen 8-1,4 mg/l).

The data for suspended solids in effluents of two trout farms analyzed are included from 1,2 to 7,4 mg/l with an average of 3,8 mg/l for farm 1 and 3,2 mg/l for farm 2.

The highest data were found during feeding time. These values, representative of Italian situation, could increase particulary during cleanings.

6. RELEVANT LITTERATURE

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WASTE PRODUCTION AND DISCHARGE OF INTENSIVE CULTURE OF AFRICAN CATFISH, *Clarias gariepinus*, EUROPEAN EEL, *Anguilla anguilla*, AND RAINBOW TROUT, *Salmo gairdneri*, IN RECIRCULATION AND FLOW-THROUGH SYSTEMS IN THE NETHERLANDS

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INTRODUCTION

Despite the fact that the Netherlands have a long tradition in fisheries and fish trade, the production of cultured fish has been and still is of minor importance. Untill recently, rainbow trout, *Salmo gairdneri*, was the main species cultured with a fairly stable production of 250 tonnes per year (table 1). Less than half of this is produced on land-based farms. The remainder is produced in cages, both in fresh and seawater.

More recently, the introduction of and the research on culture of the African catfish, *Clarias gariepinus*, by the Department of Fish Culture and Fisheries of the Agricultural University Wageningen, together with research on water recirculation systems by the Department of Water Pollution Control of the same University, have stimulated the development of the culture of warm water species in recirculation systems in the Netherlands.

Production figures of fish culture in the Netherlands are given in table 1.

Table 1. Fish culture production in The Netherlands (in tonnes per year)

	Production			Production capacity
	1985	1986	1987	1987
African catfish (no. of farms)	< 100	250 - 300 (± 50)	?	500 - 1000
European eel (no. of farms)	< 100	100 (6 - 10)	200 - 250	400 - 500
rainbow trout (no. of farms)	250	250 (± 10)	250	250

The production of warm water species, African catfish and European eel, *Anguilla anguilla*, has been expanding rapidly. Due to market problems the future trend of the production of the African catfish is uncertain. The expansion of eel culture is at the moment hindered by the quantity and/or quality of the stocking material (wild catch young yellow eels) available. It is believed that the developments in the production of stocking material from glass eels are such that in the future eel culture will grow considerably. Prognoses for 1990 range from 1000 - 2000 tonnes of eel production per year.

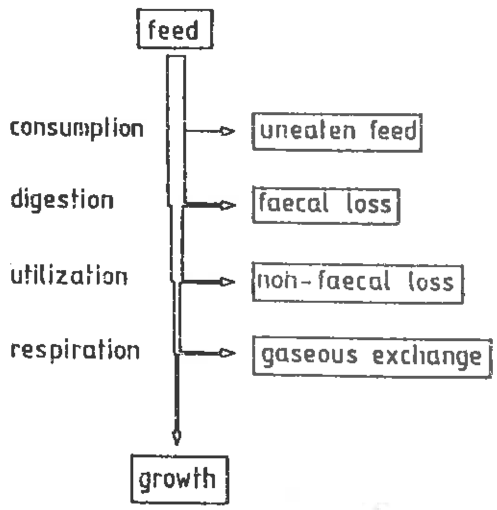
WASTE PRODUCTION OF INTENSIVE FISH CULTURE

Due to the recent nature of intensive fish culture in the Netherlands and the amount of work involved in actually measuring the waste production thereof, no excact figures are known to date (a report on waste production of trout cage culture in sand/gravel pits is in preparation; Steinmetz, pers. comm.). A theoretical estimation of this waste production can however be given based on research on growth and feed utilization of the fish species involved. In this report this will be done via the flow diagram and methods used by Bovendeur et al (1987) (Fig. 1).

Uneaten feed not taken into consideration, the quality and the quantity of the waste produced depend on feeding level, feed composition, feed digestibility and utilization of digested feed.

Feeding levels for the African catfish and the eel are taken as the optimal (recommended by the feed manufacturer) levels at 25 °C. Although rainbow trout is cultured in outdoor conditions with fluctuating water temperatures, the feeding level for this species is taken as the recommended level at 16 °C.

Figure 1. Flow diagram illustrating the relation between feed, growth and production of waste materials (from Bovendeur et al, 1987)



The feed composition is taken to be that of a commercial trout feed, Trouvit (Trouw & Co. B.V., Putten, The Netherlands).

Depending on the methodology of determination of digestibility, the settleable faecal loss (settling) or the total faecal loss (intestinal dissection) is determined. The non-settleable faecal loss is calculated as the difference between total and settleable faecal loss.

The amount of matter deposited as growth (per kg feed) can be calculated from the feed conversion and the body composition of the species involved at stocking and at harvesting (table 2).

Finally the non faecal loss is calculated as the difference between the amount fed and the sum of faecal loss and growth.

Table 2. Feeding level, feed conversion and body composition of Afican catfish, European eel and rainbow trout

	African[a] catfish	European[b] eel	rainbow[c] trout
Feeding level ($g\ kg^{-0.8}\ d^{-1}$)	16.8	12	14
Feed conversion (-)	1.5	1.9	1.6
Stocking			
Body weight (g)	5	10	2
Dry matter (%)	20	26	18.2
Protein (%)	14.2	14.1	13.7
Fat (%)	2.9	10.5	1.5
Ash (%)	2.9	1.4	3
Harvesting			
Body weight (g)	500	150	300
Dry matter (%)	28.5	42	28.9
Protein (%)	17.9	15	15.6
Fat (%)	6.6	25	10.8
Ash (%)	4	2	2.5

a) Hogendoorn, 1983 ; Heinsbroek (unpublished)
b) Zohar & Viola, 1983; Degani et al, 1986 ; Heinsbroek (unpublished)
c) Huisman, 1976; From & Rasmussen, 1984

The results of these calculations of waste production and growth are given in table 3 for dry matter, nitrogen and COD. The distribution of COD is calculated according to the results of Henken et al (1986), which indicate that feed and faeces have a COD:dm ratio of 1.4 and fish of 1.6 . The remaining COD is further partly oxydized in the respiration of the fish.

From table 3 it can be seen that the amount of waste produced does not differ very much between fish species.

The amount of wastes actually discharged into the environment depends on the production system (recirculation vs flow-through) and on whether there is additional treatment of the effluent.

Table 3. Distribution of feed dry matter, nitrogen and COD over waste and fish production (values are in grammes per kg feed, percentages in parentheses)

	Dry matter	Nitrogen	COD
Feed[a]	900	76.8	1260
African catfish[b]			
Faecal loss	405 (45)	26.9 (35)	567 (45)
settleable	225 (25)	20 (26)	315 (25)
non-settleable	180 (20)	6.9 (9)	252 (20)
Respiration			255 (20)
Non-faecal loss	303 (34)	30.6 (40)	131 (10)
Growth	192 (21)	19.3 (25)	307 (24)
European eel[c]			
Faecal loss	315 (35)	23 (30)	441 (35)
settleable	180 (20)	16.9 (22)	252 (20)
non-settleable	135 (15)	6.1 (8)	189 (15)
Respiration			409 (32)
Non-faecal loss	360 (40)	40.7 (53)	50 (4)
Growth	225 (25)	13.1 (17)	360 (29)
Rainbow trout[d]			
Faecal loss	360 (40)	26.9 (35)	504 (40)
settleable	216 (24)	19.2 (25)	302 (24)
non-settleable	144 (16)	7.7 (10)	202 (16)
Respiration			308 (24)
Non-faecal loss	357 (40)	34.1 (44)	155 (12)
Growth	183 (20)	15.8 (21)	293 (23)

a) Trouvit (Trouw & Co. B.V., Putten, The Netherlands)
b) Hogendoorn, 1983; Henken et al, 1985; Heinsbroek (unpublished)
c) Spahnhof & Kuhne, 1977; Nielsen & Jurgensen, 1983; Eding, 1985
d) Windell et al, 1978; Butz & Vens-Cappell, 1982; From & Rasmussen, 1984; Bergheim et al, 1984; Clark et al, 1985; Philips & Beveridge, 1986

DISCHARGE OF WASTE

The discharge of waste into open water in the Netherlands falls under the Surface Water Pollution Act (Wet Verontreiniging Oppervlaktewateren, WVO). Discharges are regulated by permits and charges (fees) according to the principle "the polluter pays".

Table 4. Waste production and discharge of intensively cultured African catfish, European eel and rainbow trout in the Netherlands in 1986

	African catfish	European eel	rainbow trout
Waste produced (i.e. kg feed^{-1})	7.1	5.8	6.9
Waste discharged (i.e. kg feed^{-1})	3.2	2.6	6.9
Waste discharged after physical treatment of effluent (i.e. kg feed^{-1})	0.2	0.2	4.0
Fish production (tonnes year^{-1})	250 - 300	100	250
Feed consumption (tonnes year^{-1})	375 - 450	190	400
Total waste discharged (i.e. year^{-1})[a]	3920 - 3860	1350	7560
Effluent fee (Hfl kg fish prod^{-1})[b]	0.65	0.68	1.51
Total waste discharged after physical treatment of effluent (i.e. year^{-1})[a]	205 - 247	104	4380
Effluent fee (Hfl kg fish prod^{-1})[b]	0.04	0.05	0.88

a N.B. i.e. is expressed here on a yearly basis
b based on a fee per i.e. of Hfl 50.- (fees vary from Hfl 38.- to Hfl 90.-)

The unit used is the population equivalent (inwoner equivalent, i.e.) which is the amount of ultimate oxygen demand one person discharges per day:

$$i.e. = (COD + 4.57\ N_{kj}) / 136$$

were N_{kj} is the Kjeldahl-nitrogen and COD and N_{kj} are expressed in grammes per day.

Table 4 gives the waste produced and discharged for the intensive culture of the African catfish, European eel and rainbow trout in the Netherlands. The amount of waste produced per tonne of fish produced per year is comparable to that of approx. 30 persons. From table 4 it can also be seen that intensive fish culture in recirculation systems discharges less than half the amount of waste discharged in a flow-through system, due to the fact that in a recirculation system virtually all suspended and dissolved wastes are oxydized in the biological filter.

Physical treatment (e.g. settling of the effluent) further reduces the waste discharged to about 3 - 4 % of the waste produced in a recirculation system and to about 65 % in a flow-through system.

From the above it is concluded that the culture system and the management thereof are the major factors determining the amount of waste discharged.

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REPORT ON SUSPENDED SOLIDS FROM FISH FARMS IN NORWAY

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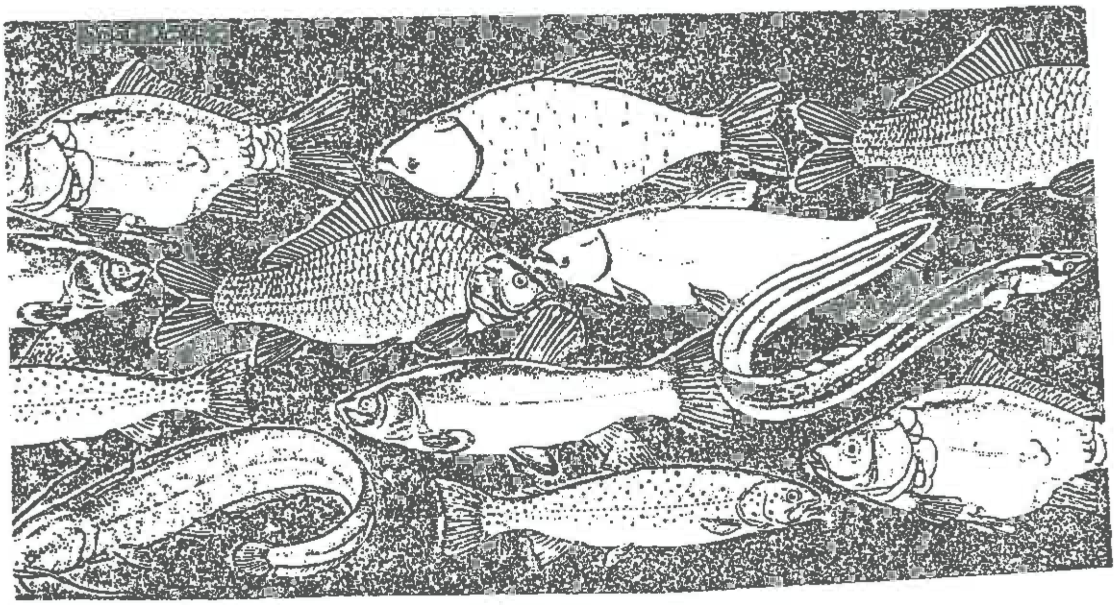


1. PRODUCTION AND POLICY

1.1. Production

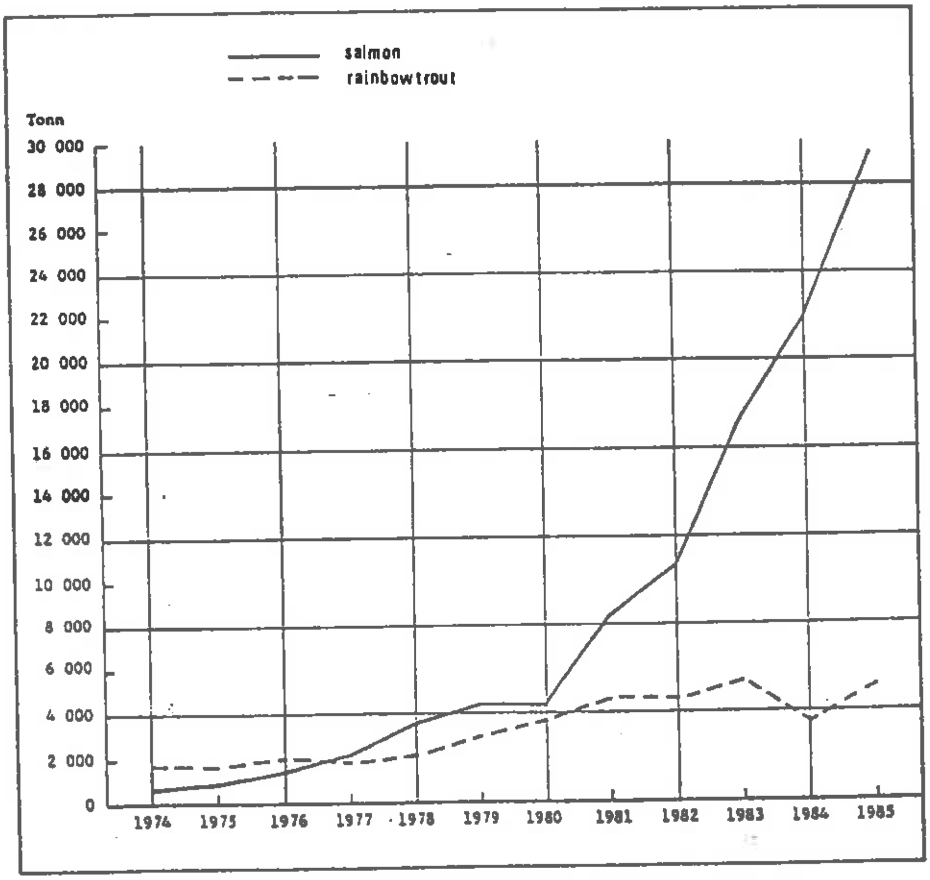


Fig 1. The slaughtered amount of salmon and rainbowtrout in Norway in the period 1973 -1985

The escalation of the fishfarming industry in Norway in the last years is demonstrated in fig 1.The figures for 1985 give a total of about 32000 tons (28000 tons of salmon and 4000 tons of rainbowtrout) For 1986 there is a total of about 50.000 tons.1987 has been a year o rest with 52.000 tons,but there is expected a greater increase in 1988 and 1989.

Until this day 720 fishfarm permissions are given with a total capacity of about 5 mill.m^3.This will give 100.000 tons provided a density of 20 kg/m^3.600 of these are in business.In addition there are registered 565 hatcheries with a capacity of 153 mill.smolts pr. year.

Just a very little share of the farming of fish is taken place in fresh water,something between 500 and 1000 tons pr.anno.Still fresh water is an essential ressource for fishfarming in Norway;all hatcheries depend on it.

1.2.General legislation and government policy in effluent qestions

For establishing/extension of a fishfarm it is necessary to obtain permissions according to several laws and from different authorities. The "main" law is the Law of fishbreeding.This law reads that permission cannot be granted if there is a risk of water pollution, spreading of fish diseases or if the welfare of the community requires so.Other important laws are the Pollution act and the Fish disease act concerning freshwater fish.

If one wants to change/regulate the waterlevel in a lake or change the waterflow in a river you need a permission according to the Watercourse act.

It is the County Governor's environmental protection department in each of Norway's 18 counties who gives permissions to fishfarms according to the Pollution act.He also evaluates the impact on wildlife and freshwater fish,recreation areas and nature conservation.The County Governor is in these matters responsible to the Ministry of Environment.
The Norwegian State Pollution Control Authority (SPCA) works with technical matters and gives advice to the Ministry of Environment and the County Governors.

The establishing/extension of fishfarms discharging to freshwater recipients is very restricted in Norway.In many areas it is practically impossible.The main reasons to this are in the fields of pollution and the impact on wild fish (salmonides).

Fishfarming -using fodder- causes a considerable loading of organic matter,nutrients and in some cases therapeutic agents.The possibilities to reduce the loadings from fish farms are in practice still small.The authorities in Norway seek in general to reduce the pollution impacts on the watercourses as much as possible and have carried out a program for reducing outlets from industry and communities.Establishing a fish farm will contribute to the total pollutional load on the watercourse and counteract the effect of the actions already done to reduce pollution.The following example illustrate this:

A fish farm is established in a watercourse where the general aim of the authorities is to reduce P-contrbution to a certain level not obtained yet.With a production of 10 tons of fish a year the farm will contribute with at least 100 kg P/year.It is possible to compensate this extra contribution by improving municipal treatment plants and sewage systems.This will in many areas demand an investment of 1-2 mill NOK and a cost of 0,2-0,4 mill NOK pr year. Community expenses will be as much as 20-40 NOK (3-6 $) pr kg fish produced.At the same time there are along the Norwegian coast in salt water a great number of sites well suited for the farming of salmonides without causing pollution problems.
Because of this,the pollution authorities have been restrictive in regard to establish fishfarms in or with outlet to fresh water.

As mentioned before does the fishfarming of salmonides also have an impact on wild species.The fish farm can spread diseases to the wild fish,escaped fish can compete with wild fish or if spawning,cause "genetic" pollution.

As a result of this,fish farms in fresh water can only be established in:

-water courses without any eutriphication problems and with large recipient capacity.

-small lakes near the coast and without interests which can be effected

and only in:

-water courses without a stock of wild salmonides of any importance.

1.3.Trends of development of fishfarming activities in Norway

- Further development of the cage technique towards more robust constructions thus pemitting the farms to move to more open waters with better exchange of water (and less pollution problems).
- Land-based fishfarms,both with and without recirculation.
- Closed constructions at sea utilizing deep water with more suitable temperatures and less germs.
- Sea-ranching
- Fjord-ranching.The fishes which are kept in the free watervolume are trained to take food by sound signals.
- Ecological manipulation of the environment outside the freshwater farms to improve the breeding conditions inside the cages.
- Rearing of other species; halibut,cod,catfish,eel,turbot,crab, mussels etc,in freshwater,crayfish.
- improving the technique of purification of effluents.

2.LOADING OF SUSPENDID SOLIDS.

In the last 3-4 years there have not come reports showing values differing much from the figures given in our report of March 83 to EIFAC.

Most interesting is the development of a computer model by Anders Stigebrandt, a Swedish oceanographer. The model is reported by the Norwegian Institute for Water Research (NIVA) and will be tested in 1987 and 1988.

The modell is based on the metabolism processe in fish and describes the fish' appetite, feedmelting, respiration, growth and execretion as a function of temperature and fish size. For a given feed (fat, carbohydrate and proteincontent can be varied) the modell gives a.o.:

1. Oxygendemand
2. Loading of dissolved N and P
3. N and P in excrements
4. N and P in spillfeed
5. Ultimate Oxygen Demand (UOD) in excrements and spilled feed.

The modell is developed in particular for net cages, but can also be used for landbased fishfarms.

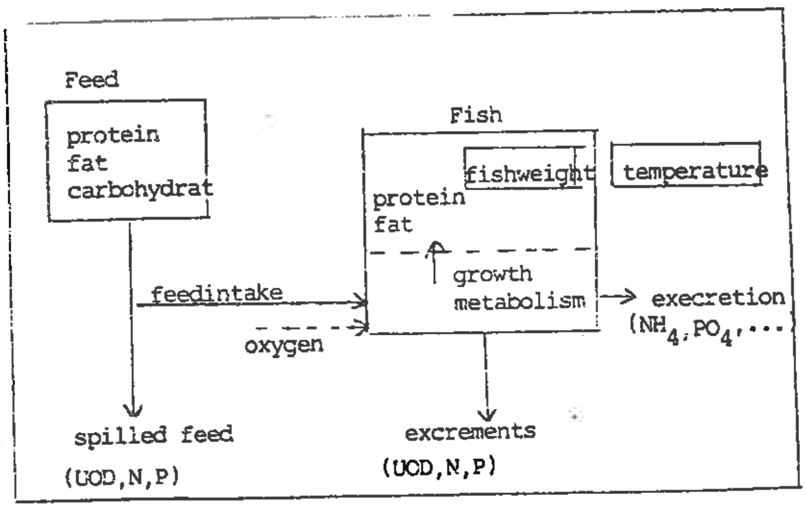


fig 2. Outline of the fishmodell

Feed is eaten by the fish (feedintake) or settles (spillfeed). As the fish grows, protein and fat are deposited. For metabolism the fish uses oxygen which is taken from the water. The fish excretes NH_4 and PO_4 (dissolved) to the water. Excrements and spilled feed with its content of UOD, N and P settles on the bottom. All these processes vary with fish size and temperature.

The use of the modell is demonstrated in an example (appendix I)

3.REMOVAL OF SOLIDS

In 1985-86 the Hordaland County Environmental Administration carried out a study of current methods for treatment of discharge from fish farms.The report called "Methods for reducing pollution from fish farms" was published in december 86.It is a survey of the different methods mainly used in Norway,Sweden,Finland and Denmark.

Exept for the technique of removal of sediment under fish-cages,most of the development of the purification treatment techniques take place outside Norway.The reason why our contribution is modest may be the following:
Our long and diversified coast provides excellent possibilities for aquaculture.This advantage means that the demand for location sites can be met in seawater or in freshwater in the vicinity of the sea. Our policy has therefor been more or less not to allow fishfarming in inland waters where the pollution problems are greatest.When choosing sites at the coast,great care has been taken to seek locations in streamy water,with good exchange of water and sufficient depth under the pens.The impact of pollution from fish farms is thus reduced or often even eleminated.The consequence of this has been a lack of incentive to dvelop techniques for purification treatment of waste from fishfarms.However,something has been done and the need for these techniques are nevertheless also present in Norway too.

Returning to the report mentioned above,the summary says:

"The paper is a study of current methods of treatment for discharge from fishfarms.The study is based on liteature,visits to fishfarms and contact with specialists in the fishfarming business.
Most often the discharge is fresh and because of that will efficient mechanical treatment reduce the discharge og organic matter and nutrients in a very cost-efficient way.Traditional biological and chemical treatment methods are too complicated and expensive for traditional fish farms without recirculation.Controlled assimilation of the discharge in limited parts of recipients would be o good method from an ecological point of view.However,it is too complicated yet.

Sludge disposal is still an unsolved problem.This will prevent an effective overall solution at least for some years.We have little experience with the methods described.Because of that it is important to support the opinions given in the report with examples of experience and development of new products."

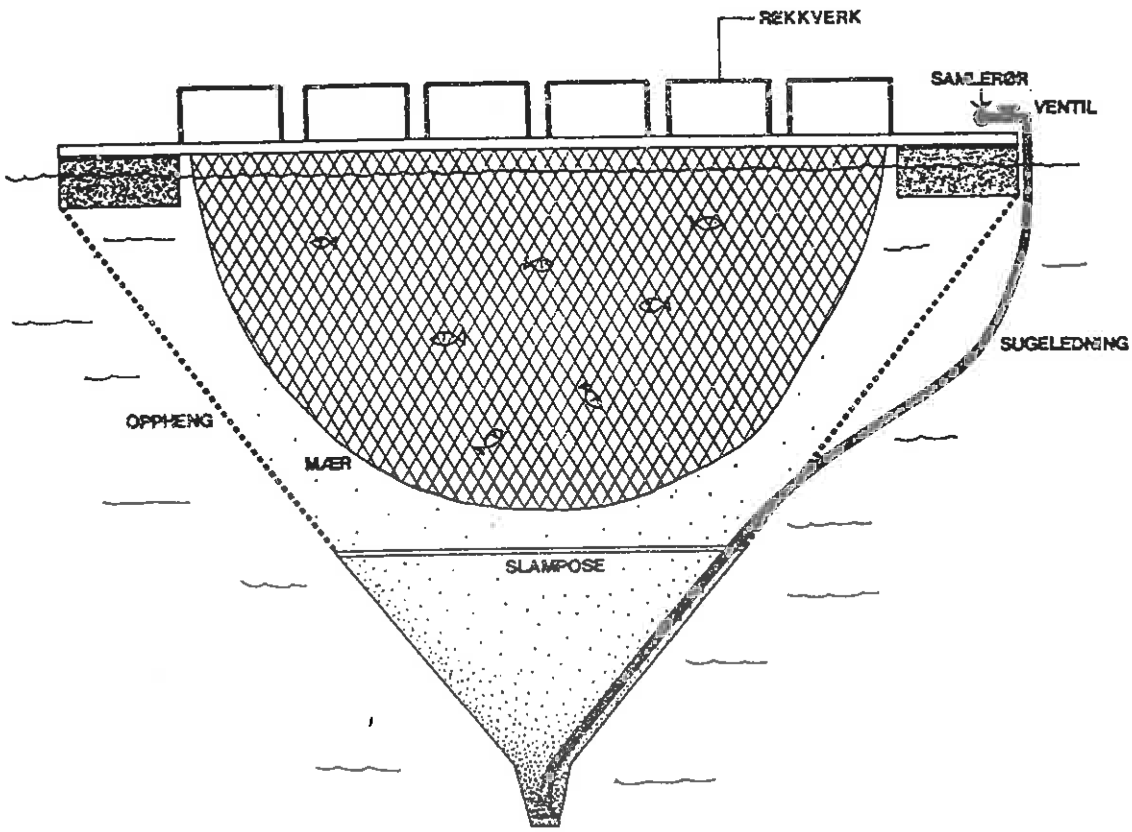
The authorities advices or demands to a fish-farm applicant will be:

a. Find a location site where you won't have pollution problems.

b. Minimize feeding waste and/or instal devices for removal of solids

As to b. the following techniques are for the time being available in Norway:

1. **Sludge pocket under the pens**



f:g 3. **Sludge pocket under a fish pen**

Manner of operation

Spillfeed and excrements sediment in the pocket which is placed under the pen. Sludge is pumped away with intervals varying from 15 minutes to once a day. With sludgeremoval once a day, a farm with a penvolume of 8000 m^3 (ca 250 tons fish/year) had ta handle 15-20 m^3 sludge a day. The dry matter content varies from 0.1 - 10 %, depending on the frequency of sludgeremoval. The cost is about 300.000 NOK (50.000 $) for a 8000 m^3 farm.

Advantages: - Simple system

Draw-backs: - Expensive method and poor purification efficiency when the sludge has to be treated. Today there exist no realistic methods for treating the sludge.

Conclusion: - Little experience yet. Usefull when the sludge can be disposed wihout treatment, f.ex pumping to a good recipient nearby.

2. Filtration.

Triangle-filter

A kind of sieve cloth filter developed in Sweden.Tried out in Saltviken Fiskodling in Barsebeck in Sweden.The last year some filters have been installed in Norway.The operation experience so far is good.

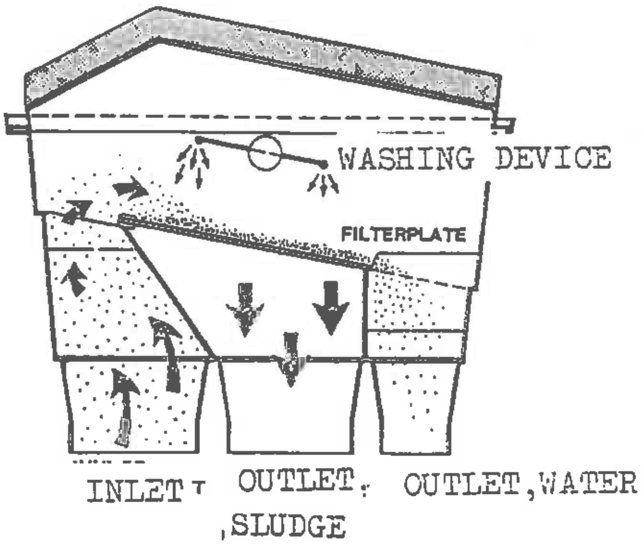


fig 4. The triangle filter

Manner of operation:

The water is led upwards in the rear of the construction,over a tilted filter-cloth where particles greater than the openings of the pores (f.inst. 60 µm) will settle.The particles will slide off due to a washing device and gravitation and are collected in a sludge pocket.
The purification efficiency during the tests in Sweden was about 80-95 % for SS and 70-80 % for tot-P.The content of dry matter in the sludge was 0,8-1%.
The price of a filterunit with a capacity of 2.400 l/min was about 6.000 $ in 1984.

Advantages :
- High purification efficiency as to removal of particles,organic matter and phosphorus.
- Cheap when compared to its hydraulic capacity.

Draw-backs : (1984)
- The pumping system washing the filters may break, daily supervision is required
- The particles should not be smashed before reaching the filter.The water way should not exceed 30 m and no hydraulic jumps.
- Dewatering the sludge is necessary.
- Algae growth on the filter cloth (clogging).

Conclusion :
- Very promising

3. Swirl Concentrator/separator

This device has been used and tested especially in Denmark and Finland.There are different versions.In Norway Aqua-Care A/S in Bergen,is producing the one depicted in fig 5.

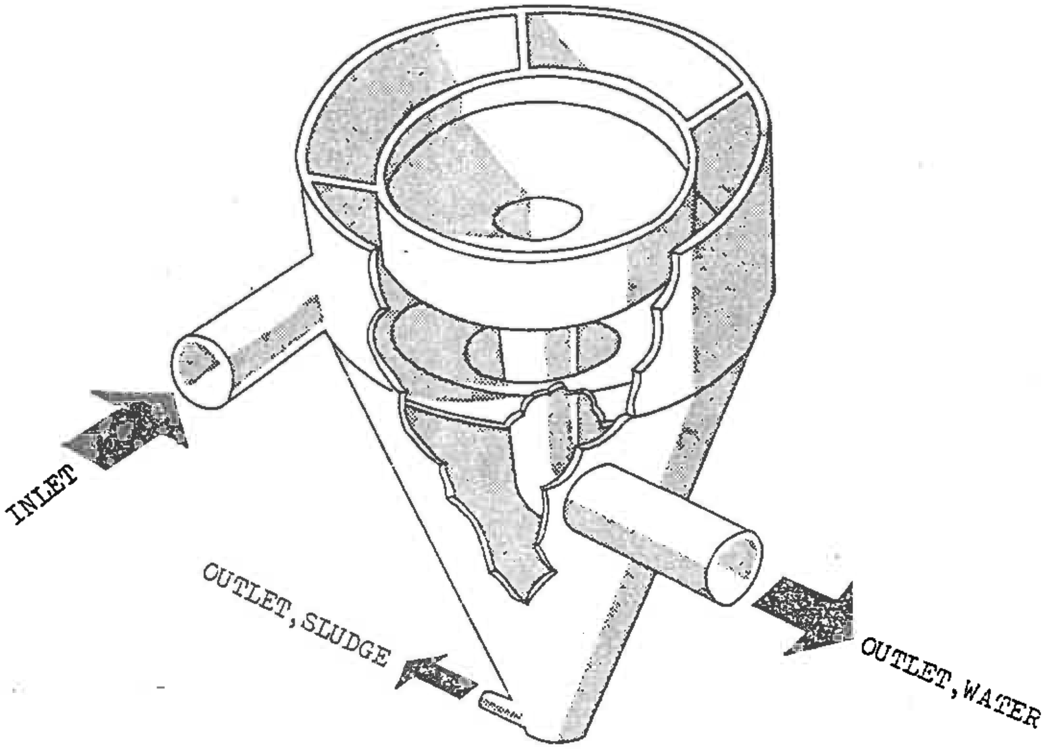


fig 5. The Swirl Separator

Manner of operation:

The water is led in a tangential direction into the bottom of a cylinder and drawn off at the top.As the water circulates in the cylinder,the velocity decreases radially towards the center where the particles are permitted to sediment and can be sucked off from the center at the bottom.
The purification efficiency is about 60-80 % for SS and 30-50% for tot-P.

Advantages:
- Perhaps the cheapest device,considering its hydraulic capacity
- None moving parts

Draw-backs:
- Very dependant on a gentle water stream (no hydraulic jumps)
- Moderate purification efficiency
- Algae growth,must be cleaned 1-2 times each week

Conclusion:
- Promising,further development needed.

4. SLUDGE DISPOSAL/UTILISATION

The number of treatment units for fishfarm effluents being very limited yet there has not been established a system for the handling of the sludge.The biggest problem is the very low content of dry matter in the sludge from most treatment systems.This will most often make it necessary with expensive dewatering treatment of the sludge.

As soon as this problem is solved,the sludge can be used as a fertilizer,eventually after being stabilized by a composting process.A research project on the matter of composting waste from fishfarming will be ready in early 1988.The possibility of the use of sludge in the compost process will be looked on.

5. CURRENT RESEARCH AND RESEARCH NEEDS

5.1. Current research

The following items are under research and reports will be ready from 1988:

- Antibiotics
    - degradation in sediments
      effects of antibiotics on biological activity and microflora in sediments
    - development of resistant bacteria living in fish,sediments and water
    - antibiotics/degradationproducts in wild fish and shell

- Waste from fishfarming,that means dead fish,waste from slaughtering algaegrowth on pens

- Chemicals used in fishfarming

- Effects of fishfarming in salt water

- Computer modell for loadings from fishfarms

5.2. Research needs

The environmental effects of fishfarming will be integrated in each field of a large researchprogram which is planned for the coming years.These fields are:

- Production plant and maintainance conditions (environment,pollution)

- Feed/feedresources (environment,pollution)

- Disease/health,therapeutic agents environment

- Breeding/genetics

- New species

-Sea/fjord-ranching

-Economy,production,distribution,market

Especially important from an environmental point of view are the following topics:

- -Antibiotics and chemicals
- -Better feed/feeding
- -Development of better purification treatment systems,standards for these and rutines for operation
- -Development of recipientsurveyprograms
- -Eutriphicationmodells for marine recipients

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REPORT ON SUSPENDED SOLIDS FROM LAND-BASED FISH FARMS IN SWEDEN

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1 INTRODUCTION

Sweden has today approximately 1000 fish farms and 600 of these are land-based and 400 net-cage cultures.

The total production of fish 1986 was 3000-4000 tons.

The main production is rainbow trout with an average weight of 1-3 kg and they are cultured in net cages.

Most of the land-based fish farms are very small with a production of less than 10 tons per year in average.

The main purposes of fish cultivation in land-based farms are

A. for production of fish fry to reinforce the natural supply,

B. to offset damage to natural fish populations caused by construction of hydroelectric power stations and similar installations,

C. to introduce new species,

D. to produce fry for aquaculture.

Permits for fish farms are given by the National Board of Fisheries according to the Fisheries act and by County Councils according to the Environmental Protection Act.

The Fisheries Act concerns mainly the prevention of an introduction of new species into areas where natural stock is considered of special value. According to this act it is also important to prevent the introduction of diseases to valuable natural stocks.

The Environmental Protection Act requires a policy of prevention of interference with the environment as far as is practically and economically feasible. Any assessment of what is practically and economically feasible is based on an individual evaluation of each case performed by the County Council.

Localization of a fish farm is based upon an area utilization plan of the local water resources. The size of the fish farm is limited by the capacity of the receiving body of water to accept nutrients without damage to the environment.

The reaction of lakes to an increased input of phosphorus will depend on the annual nutrient salt load and the hydraulic load. The nutrient salt load is expressed in terms of the quantity of phosphorus per surface area unit: the hydraulic load is expressed in terms of catchment runoff per surface area unit. A diagram has been drawn up using these figures and based on the relationship identified between dose and responsein different types of lakes. Using the diagram, it is possible to make an assessment of the effect of different levels of phosphorus load on a specific lake as shown in Figure 1. The limits between different levels of load set out in the diagram represent the dividing line between loads that will result in nutrient-deficient (oligotrophic) lakes and loads that cause nutrient-rich (eutrophic) lakes. This diagram can be used to obtain an approximate estimate of the existing margins in a lake to accept an increased phosphorus load. See the example in Figure 1.

It is inadvisable to locate fish farming cages in eutrophic lakes, as they may worsen the situation in the lake, e.g. algal growth.

The phosphorus input to running water from a fish farm should not be allowed to exceed 50 % of the natural background content of the waterway.

2. LOADING OF SUSPENDED SOLIDS

Because of the Swedish policy of using nutrient input, in fresh water phosphorus input, as a limiting factor for fish farm localization the Swedish research on environmental impact from fish farm effluents has not been focused on suspended solids. This fact makes data on suspended solids scarce.

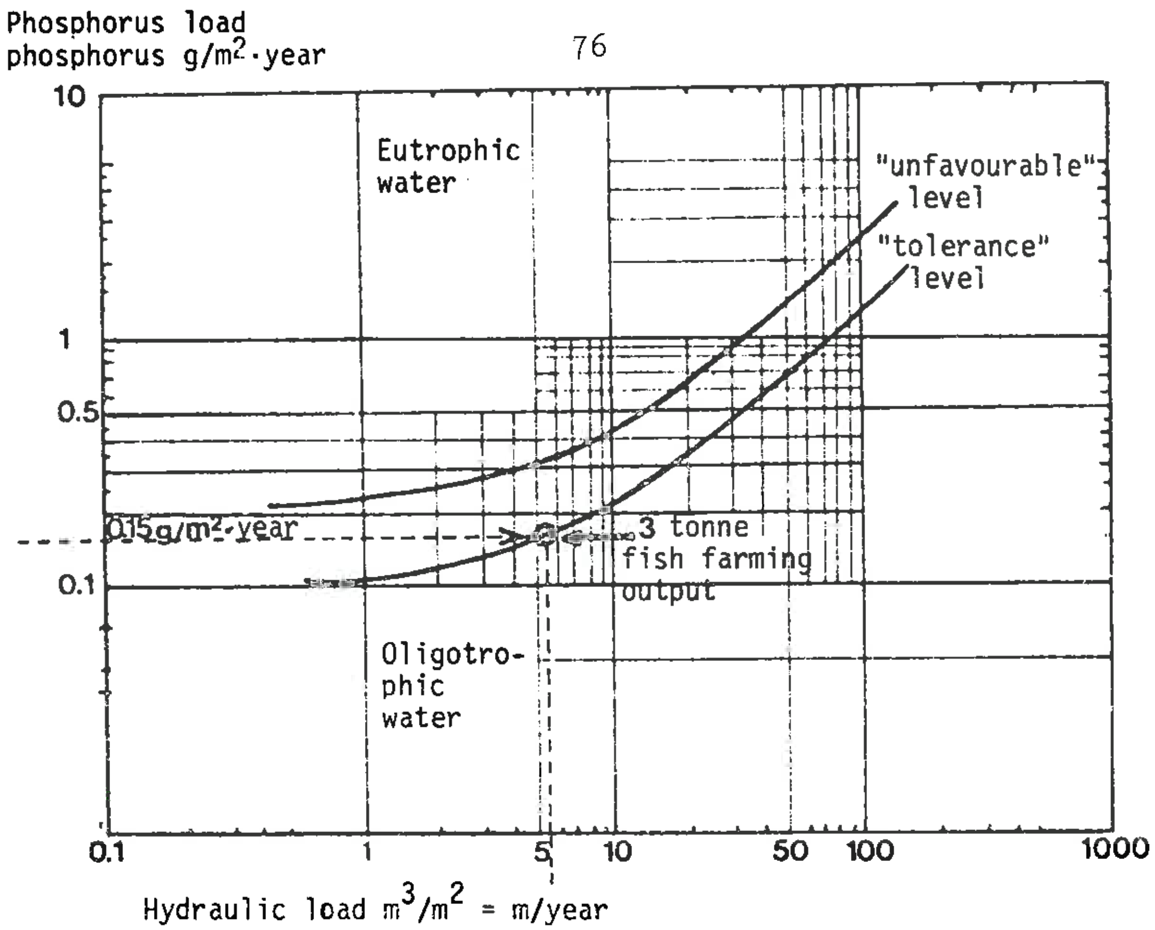

Fig. 1. Diagram for assessing the threat of eutrophication.

The following computations illustrate how the diagram should be used:

Lake area (A) is 45 hectares.

Catchment area runoff (Q) = 2.4 million m^3/year.

Hydraulic load $\frac{Q}{A}$ = 5.3 m the input value on the x-axis.

Phosphorus content of catchment runoff (P_f) = 9.4 ug/l.

Natural background load $\frac{P_t \times Q}{A}$ = 0.05 g/m^2/year.

Amount of phosphorus discharged from farming 3 tonnes of fish (P_o) = 15 kg P/tonne fish x 3 = 45 kg.

The load from an output of 3 tonnes of fish and the background load are 0.10 + 0.05 = 0.15 g/m^2 year, which is the input value on the y-axis.

This example shows that the lake is capable of supporting a farming output of 3 tonnes of fish, although this will eat up the entire existing load margin.

3 REMOVAL OF SOLIDS

During the last years there has been an active development of equipment going on for effluent water treatment at landbased fish farms. The technical development has been focused upon different types of filtering equipment that has produced excellent results referring to removal of both suspended solids (85-90 % removal) and phoshporus (60-80 % removal).

The experience from different farms shows that a short retention time in the farm is very important for an efficient removal of phosphorus. This depends on that phosphorus, mainly bound to suspended solids, easily dissolves into the water and that this process depends on water temperature and the composition of the fish-food. Recent research shows that the mobility of phosphorus in fish-foods and fecal faeces from rainbow trout varies greatly in magnitude between different fish-foods. The easy soluble part of phosphorus in fecal faeces varies between 16-51 % which shows the importance of the composition of fish feeds for the total result in the effort to reduce the nutrient load on the receiving body of water.

The food coefficient (f.c.) is also important to know in an evaluation of the treatment efficiency. The degree of treatment of nitrogen compounds indicates the f.c. In fish foods nitrogen is bound in organic fractions. Excreation of nitrogen compounds from fish consists of 60-80 % of the dissolved fractions of nitrogen. This fact makes a nitrogen removal of more than 10-25 % an indication of overfeeding and of an overestimated reduction of suspended solids and phosphorus. Consequently, a good treatment efficiency due to a high f.c. leads to a higher phosphorus input to the receiving body of water.

Time controlled feeding gives an intermittent load to the equipment for water treatment. This puts special demands on the sampling-techniques used in research.

4 SLUDGE UTILIZATION

The use of filtering techniques gives a sludge with a content of dry matter that varies between less than 1 % up to 10-20 % depending on filtering technology.

Sludge with a low dry matter content must be refiltered or settled and treated with chemical precipitation.

The nutrient content of the sludge varies between 19-35 g N/kg dry matter and 13-23 g P/kg dry matter depending on retention time f.c. etc in the fishfarm.

The sludge is spread on land and used as fertilizer for agricultural purposes.

5 CURRENT RESEARCH AND RESEARCH NEEDS

In Sweden no research is done or will be done in the near future within the field of environmental impact specific to land-based fish farms. On the other hand extensive general research is going on concerning dose and response of nutrients in fresh water and the marine environment. Technical development and evaluation of new effluent treatment techniques for fish culture will continue.

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REPORT ON SUSPENDED SOLIDS FROM LAND-BASED FISH FARMS IN THE UNITED KINGDOM

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1. INTRODUCTION

1.1 Production levels

Production by United Kingdom fish farms continues to increase, particularly of salmon in cages moored in inlets from the sea ('sea lochs') in Scotland and its offshore islands. Rainbow trout production was estimated to be 10 000 tonnes in 1986, according to the Ministry of Agriculture, Fisheries and Food (MAFF). This is virtually the same production as reported by Lewis (1984). The Scottish contribution to this 1982 figure was 1918 t but it had risen to 2082 t by 1984 (Department of Agriculture and Fisheries for Scotland 1985). Of the 2082 t 45% were produced in freshwater cages (at 17 sites) and only 4% in seawater cages (at 8 sites).

Salmon production in 1984 was 3912 t, mostly in cages, at 46 freshwater and 83 seawater sites (Banks 1985). In 1986 MAFF estimate that 10 500 tonnes of salmon were produced. With just 500 tonnes of sea trout and sea-based rainbow trout and 250 tonnes of brown trout this gives the 1986 estimated total farm-production of salmonid fish of 21 250 tonnes.

The 1987 forecast for Great Britain (to which perhaps 500 t of rainbow trout for Northern Ireland should be added) is 14 000 t of salmon, 950 t of large trout and 11 750 t of portion-sized trout (Federation Européene de la Salmoniculture 1987), a total of 26 700 t.

1.2 Conditions of consents to discharge fish-farm effluents

Details vary from country to country within the United Kingdom but under the general framework of environmental protection legislation a consent to discharge a fish farm effluent may be issued.

The consent conditions may include specific maximum values or maximum changes permitted for the following:

- Biochemical oxygen demand (nitrification suppressed)
- Total suspended solids
- Total ammonia
- Turbidity
- Malachite Green
- Copper compounds
- pH
- Colour
- Free chlorine
- Cationic detergent
- Formaldehyde
- Phenolic compounds

Often the consent requires that the following should be absent:

Antibiotics	Visible Oil	Fungal growth in the receiving water

Dissolved oxygen minima may also be specified. There are other requirements concerning abstraction rates and the screening of influent and effluent streams to prevent the entry of wild fish or the escape of farm fish.

1.3 Advice to fish farmers

The National Farmers' Union of England and Wales, in consultation with the Ministry of Agriculture, Fisheries and Food, the Department of the Environment and representatives of the water industry have prepared the following guidelines and codes of practice for fish farmers:

NFU Code of Good Husbandry for Farmers Rearing Fish for the Table and Restocking Markets

Guidelines for the Safe Use of Chemicals on Fish Farms

A quarterly newsletter, 'Trout News', began publication in 1987. It is produced by the MAFF Directorate of Fisheries Research at Lowestoft and contains articles, letters and news relevant to the British trout farming industry.

This brief report addresses the main item of business on the agenda of the EIFAC Working Party 'suspended solids from land-based farms' but the Appendices include notes relevant to other agenda items.

2. LOADING OF SUSPENDED SOLIDS

No information on the nature of suspended solids in relation to the different types of fish-farming activities is presented here.

In a previous survey of fish-farm effluents in the United Kingdom (Solbé 1982) data were gathered and presented to EIFAC. A questionnaire survey of up to 69% of the UK's fish farms in fresh water was undertaken. The results are summarised below and compared with data collected in 1987 for the years following the questionnaire survey.

Information was collected on the concentrations of suspended solids in water supply, effluent and receiving water. With an estimate of the water-flow through the farm and the rate of production of fish on the farm it is possible to calculate approximate values for:

mass net output of solids and
output of solids per tonne of fish produced.

These data are set out in Table A2.1.

The sampling regime employed seems to be reasonably comparable nationally. Samples were generally taken in 'working hours' (the time being recorded) at the inlet and outlet within a few minutes of one another. Samples were filtered (GF/C papers typically) and dried at 105 °C.

Although the sample sizes differ it is possible to draw tentative conclusions from a comparison of data from the two periods.

(i) Most fish farms continue to discharge effluents containing 4-18 mg solids/litre although the average nett increase in concentration is only 2.2 mg/l.

(ii) Maximum concentrations of solids observed in effluents continue, in rare instances, to be extremely high. The ratio maximum conc : average conc was less than 4 in 31 of the 47 farms in the 1987 data set but exceeded 6 in seven farms.

Table A2.1 Suspended solids from land-based fish farms

	1980	1981-1987
Geometric mean and (range) of average concentrations in effluent (mg/l)	6.3 (0-47) 68 farms	8.5 (1.8-22) 47 farms
Geometric mean and (range) of maximum concentrations in effluent (mg/l)	20.6 (3-333) 54 farms	28.3 (5-282) 47 farms
Increase in concentration in rivers downstream of farm (mg/l) 2.1	5.0 58 farms	12 farms
Mean and (range) of average increase as water passed through farm (mg/l)	4.4 (-16-31) 64 farms	2.2 (-19-11) 54 farms
	1980	1981-1987
Average nett mass outflow from farms (tonnes/year)	73.4 36 farms	52.4 20 farms
Average production of fish in farms giving nett mass outflow data (tonnes/year)	54.2	96.1
Nett mass outflow per tonne of fish produced (tonnes)	1.35	0.55

(iii) In the twelve farms for which such data were available, concentrations of solids in the rivers downstream showed changes ranging from a decrease of 7 mg/l to an increase of

28 mg/l but the average change was an increase of 5 mg/l, much higher than in 1980 (but see iv).

(iv) The encouraging news is that average nett mass outflows per tonne of fish seem to have markedly decreased. In 1980 for 36 farms the figure was 1350 kg dry solids discharged per tonne of fish produced while in 1987, for 20 farms, the corresponding figure was 546 kg. There could be many criticisms of conclusions drawn from these figures - the farms used were not necessarily part of both surveys (the data are anonymous so there is no way of checking); fish production levels may have been pessimistically quoted in 1980 and/or optimistically in 1987 (properly validated production figures seem to be difficult, if not impossible, to find nationally); sampling of the water passing through the farms is prone to a number of errors.

One particular point was noted in one case - that the samples, 'grabbed' from the mid-stream near-surface flow, may have missed the solids that had already settled lower in the water column and were moving along the bed of the effluent channel. If this was a significant occurrence it could lead to an under-estimate of solids discharged from fish farms. There is also a general awareness of the dependence of suspended solids concentrations on the particular activity on the farm at the time of sampling.

However, the trend is in the right direction and the efforts of fish food manufacturers and fish farmers to use less polluting foods may be meeting with some success.

3. REMOVAL OF SOLIDS

The majority of UK fish farms do not yet seem to be equipped with effluent treatment systems. In 1980 about 17 per cent of farms used settlement ponds. In four farms monitoring data were available, and these showed reductions of 0.5 mg BOD/l, 2-7 mg suspended solids/l and 0.05-0.19 mg NH_3-N/l from the use of ponds. In the 1987 survey one farm equipped with a settlement lagoon discharged only 166 kg/t of fish produced compared with the national average of 546 kg/t.

From the 1980 survey data it was estimated from the regression BOD on SS that 13% of the weight of suspended solids might be expressed as BOD. Simply calculating the nett outflow concentrations of other characteristics as percentages of nett solids outflow gave the following

BOD	37% of weight of solids
NH_3	6%
NO_3	6%
P	0.7%

but these weights will contain dissolved material.

More recently Phillips <u>et al</u> (1986) made an 85 day study of a rainbow trout cage unit. For each tonne of fish produced 292 kg of dry matter was trapped below the cage and this waste contained 96 kg C, 10.5 kg N and 10.3 kg P. In addition, the waste soluble carbon, nitrogen and phosphorus per tonne of fish weighed 305, 64 and 9.8 kg respectively. The solids were therefore a more important source of phosphorus (51.2% of the phosphorus lost was in solid form). The phosphorus in solid form accounted for 3.5% of the total weight of dry solids, rather more than the 0.7% suggested by the questionnaire survey data of 1980.

4. SLUDGE UTILISATION

No information is available for the UK at present but the practice of utilising sewage sludge on agricultural land (at no cost to the farmer) is widespread and experiments on its use in forestry are under way. The 10 000 tonnes of land-based fish-farm production appears capable of producing 5000 to 13 000 tonnes of dry solid (perhaps 100 000 to 260 000 tonnes of wet sludge) annually and there may be useful outlets near fish farms. It does not seem likely that wet sludge would become a saleable commodity in the UK.

5. CURRENT RESEARCH AND RESEARCH NEEDS

Research appropriate to the management of land-based fish farms is carried out by Government Departments (MAFF and DAFS), Universities, Agricultural Colleges and the water industry. Topics covered include: fish breeding and the production of mono-sex stock; diet; diseases, their treatment and prevention; effluent treatment and pollution prevention. It should be possible to collate these various studies to give a national picture.

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CONTRIBUTION ON SUSPENDED SOLIDS FROM LAND-BASED FISH-FARMS IN YOGOSLAVIA

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1. INTRODUCTION

1.1. Production Figures on Fish Farming

According to available statistics there are about 27,025 ha of carps' and 25 ha of salmonids' fish-ponds in Yogoslavia today. The following species of fish are reared in carps' fish-pond:

Carp (Cyprinus carpio L. 1758)
Grass carp (Ctenopharingodon idella Val. 1844)
Carp fish (Hypophtalmichitys molitrix Va. 1844)
Bighead (Aristichtys nobilis Rich. 1844)
Tench (Tinca tinca L. 1758)
Cat-fish (Silurus glanis L. 1758)
Pike (Esox lucius L. 1758)

According to statistical data for 1985, the participation of separate species was: carp about 70 %, plant-eating fish (grass carp, carp fish and bighead) about 26 % and other (tench, cat-fish, pike, pikeperch etc.) about 4 %.

Total production of fish on inland fish farms for 1985 was about 32,484 tons. Annual total production of fish on 26 greater carps' fish farms was approx. 29,084 tons which includes approx. 23,270 tons (80 %) of market fish and fingerling of approx. 5,817 tons (20 %).

There are no exact statistical data for existing areas of salmonids' fish farms. It is considered that there are 46 greater salmonids' fish farms occupying the area of 25 ha with the total production of about 3,400 tons of domesticate rainbow trout (Salmo irrideaus Gibb.) (Bojcic, Bunjevac, 1982).

1.2. General Legislation and Government Policy in Effluent Questions

Existing regulation of socio-economic relations within Water Authorities is not settled adequately. The influence of the Federation exists only trough the Act of Waters which concerns common waters only, satisfying interests and needs of several republics and provinces which share the same waters.

Each republic has its own book of rules for control of level and kind of waste waters' pollution. However, the problems of effluents from fresh-water fish farms have not been legally regulated yet.

New statutory resolutions, which are in preparation, will recognize the problem of water quality protection in connection with water management, technological and legislative proportions (Dordevic, 1986). The New Act on Water will anticipate river basins on which a uniform management on waters will be established. If the principle of integrity within Water Authorities is realized, together with other legal requlations, common programmes of protection against water pollution include fresh-water fish-farms, too. An initiative has commenced that in water pollution generally, a part of effluents from fish-farms must be determined.

1.3. Tends of Development in Fish-farming Activities

The development programme for fresh-water fishery in Yugoslavia up to the year 1990 foresses considerable increase in the production of fish in fish-ponds (Tables 1 and 2). It will be achieved by reconstruction of old, sub-standard fish-ponds, and by increasing the amount of such species as salmon, cat-fish, pike, pikeperch and tench and by the introduction of new technologies for rearing eels and sterlets (Development Programme up to 1990).

Table1. Scheme of fish production in carps' fish-ponds

Stated in 1985			Planned for 1990		
Area (ha)	kg/ha	total (tn)	Area (ha)	kg/ha	total (tn)
27,025	1,076	29,084	30,500	1,580	48,200

2. LOADING OF SUSPENDED SOLIDS

When talking about carps' fish-ponds, there is a wide range of sizes and types in Yugoslavia. Areas of single fish-ponds for the production of market fish varies from several dozen to several hundred hectars. In such fish-ponds semi-intensive technology is carried out.

Table 2: Scheme of fish production in salmonids' fish-ponds

Stated in 1985			Planned for 1990		
Area (ha)	kg/ha	total (tn)	Area (ha)	kg/ha	total (tn)
25	136,000	3,400	39	193,000	7,525

Fingerlings are grown in ponds which vary in size from several hundred sq. m. up t a hundred hectars. Fish-farms have close cycle production as they produce market fish and fingerlings for their own needs.

Intensive production in small carps' fish-ponds was introduced a couple of years ago. But such high production technology is being applied in the area of several dozen hectars only.

Salomonids' fish-farms can be distinquished with regards to construction, largeness and production assignment. Rearing of salmonids is carried out in earth, concrete or plastic ponds and other kinds of basins, which vary in size from several sq.m. to several hundred sq.m. Besides small salmonid fish-ponds which use a semiintensive type of production and are mainly specialized for market fish production, the majority of them were constructed using up-to-date technology for rearing both fingerlings and market fish.

During the rearing process a certain amount of supplementary fish food and fertilizer is added to the water. In carps' fish-ponds cereals (maize 58 %, wheat 10 %, rye 0.04 %, barley 19 %) and fodder mixture are used as fish food. The total amount of fish food used during the year 1985 was as follows: cereals 60,564 tons and fodder mixture 8,259 tons (Turk, 1986).

The amount of fish food used in salmonids' fish-ponds during the 1985 was approx. 8,527 tons. This was mainly industrial food with 5 - 10 % of fresh sea fish.

According to the above statistical data it follows that during the year 1985 the quantity of supplementary fish food added to carps' fish-ponds was approx. 2.24 tons/ha or 2.08/kg fish of cereals and approx 0.30 tons/ha or 0.28 kg/kg fish of fodder mixture.

Te quantity of fish-food added to salmonids' fish-ponds was approx. 341 tons/ha or approx 2.51 kg/kg of fish.

Manual fish feeding is carried out, except on several dozen hectars of carps' ponds where an intensive technology is applied. On such small areas semimechanical and mechanical fish feeding is carried out.

The total amount of fertilizers used in carps' fish-ponds is approx. 8,240 tons: 5,115 tons (80 %) of mineral fertilizers and 1,211 tons (20 %) of organic fertilizers. During 1985 the following amount of mineral fertilizers were used: nitric fertilizer 462 tons; phosphate fertilized 378 tons; lime 4,275 tons. On average it is approx. 176 kg/ha of mineral fertilizers and approx. 45 kg/ha of organic fertilizers.

Up to now, the production of suspended solids in fresh-water fish-ponds in Yugoslavia has not been analyzed. Analytical methods for determination of suspended solids in other waters are as follows:

Total solids

Ignite an evaporating dish in a muffle furnace at 105°C for 90 minutes. Cool the dish in a desiccator and weigh it. Take 100 ml of the water sample and pour into a tarred evaporating dish. Place in an oven at 90°C. Firs, evaporate to dryness and then increase the temperature to 103°C for an hour. Cool the dish with residue in desiccator and weigh. The following equation is used to calculate the total solids:

$$\text{Total solids in mg/l} = \frac{(B-A) \times 1000}{\text{sample volume in ml}}$$

B = the weight in milligrams of the evaporating dish with residue
A = the weight in milligrams of the evaporating dish

Total volatile solids

Ignite the evaporating dish and residue from the total solids analysis in a muffle furnace at 550 C for 30 minutes. After that, cool it in a desiccator and weigh. The total volatile solids concentration is calculated by means of the following equation:

$$\text{Total volatile solids in mg/l} = \frac{(B-C) \times 1000}{\text{sample volume in ml}}$$

B = the weight in milligrams of the evaporating dish with residue before ignition
C = the weight in milligrams of the evaporating dish with residue after ignition

The procedure for total dissolved solids and total volatile dissolved solids is the same as for total solids and total volatile solids, but the water sample must be filtered through a glass or paper filter before analysis (Methods, 1966).

3. REMOVAL OF SOLIDS

Up to now, systematic measurement of quality and quantity of sedimented and suspended solids in fresh-water fish-ponds has not been carried out. None of the methods for reducing and outflowing sedimented and suspended solids have been applied.

4. SLUDGE UTILIZATION

In spite of all suggestions for the removal of sludge from fish-ponds and the possibilities for its use in agriculture, none have been realized yet. There are many reasons for this which apart from the lack of adequate machinery for such methods, are mainly financial.

5. CURRENT RESEARCH AND RESEARCH NEEDS

Water quality in fresh-water fish-ponds is checked by means of physical, chemical, biological and technological indices defined from water samples and samples taken from the bottom of the pond, The following chemical and biological parameters are requlariy checked as part of the technological process: dissolved gases, minerals, consumption of oxygen from $KMnO_4$ and qualitative and quantitative composition of biocenozes. These analyses are carried out in order to determine favourable conditions of inflowing waters in fresh-water fish production. They also help to establish endogenous and antropogenous alternations in different fish-pond categories.

As the water quality is gradually becoming worse, from now on fish-ponds effluents must be taken into consideration. The increase in fish production will gradually bring bigger water quality changes. To determine the level of physical and chemical water changes in fish-ponds and their impact on other ecosystems, systematic research by a team of experts must be carried out.
At the moment, we do not have approved research programmes, but according to the methods for effluent evaluation in other waters (Miloradov, 1986) the same three basic parameters will be used. They are as follows:

- suspended solids
- oxidization matters
- toxity

These three parameters were suggested at II Congress on Waters on Yugoslavia (Dular, 1986).

For the determination of suspended solids gravimetric analysis will be used.

Oxidization matters will be determined with the chemical consumption of oxygen in the stirred water sample.

For carrying out toxity tests Salmo Gairdneri is proposed but it will be necessary to take other species typical of warm water basins too.

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Appendix

Standardization of Methodology in Fish-farm Effluent Research and Monitoring

submitted by S.A. Carlsson

1. Introduction

At the ad hoc meeting of the EIFAC Working Party on Fish-farm Effluents, Aarhus, Denmark, in May 1984, it was stated during the discussions that there is an obvious need for a recommended standard methodology for investigations of fish-farm effluents to make research results more comparable.

Much of the existing literature on fish-farm effluents is less useful than it might be because of the lack of basic data. This often gives reports a limited value as basis for, for instance, development of equipment for effluent water treatment.

2. General Considerations and Recommendations

2.1 Basic Data

2.1.1 Working hypothesis should be clearly stated

2.1.2 Layout and brief data on the fish farm

2.1.3 Technical description of ponds and basins

Construction of basins and tanks, etc. Tubing. Retention time. Treatment of inflowing water.

2.1.4 Sampling sites

Location of the site and date of sampling. Examples of locations: (i) inflow; (ii) inflow after water treatment; (iii) flow before effluent water treatment; (iv) effluent flow. The sampling sites should be carefully chosen so that the samples will be representative. Observe that there is often a transport of solids over the bottom of the tubes of channels.

2.1.5 Data on fish

Species, age, size and number/amount of fish at each sampling site. Stocking density (expressed both as weight/volume and number of fish/volume). Annual production and maximum stocking density of the farm.

2.1.6 Fish food

Type and quantity, composition, content of phosphorus, nitrogen energy and metabolizable energy, food handling, e.g. dust removal. Feeding methods, schedule and frequency. EIFAC Technical Report T36, Report of the EIFAC/IUNS and ICES Working Group on Standardization of the Methodology in Fish Nutrition Research provides methods of analysis of fish food, if required.

2.1.7 Farm management

Frequency and timing of the last cleaning of the ponds or basins.

2.1.8 Diseases and unexpected situations

Data on diseases and treatment of diseases. Unexpected situations; for instance, if supersaturation is indicated, the total gas pressure should be noted.

2.2 Sampling Methods

Water samples should be taken at intervals and over a suitable period of time to provide data appropriate to the research or monitoring hypothesis.

Samples could, for example, be taken continually over a period of 24, 48, 72, etc., hours with an automatic sampler at 10-20 minutes intervals with a minimum sampling volume of 100 ml. If the sample is taken through a tube, the diameter should not influence the representativeness of the sample, i.e. the tube should not be smaller than 19 mm (3/4"). Water samples could also be taken manually with a grab-sampler from which a sub-sample is collected. Samples for analysis can, for example, be taken twice each 24-hour period to represent the feeding and non-feeding period.

The handling of the collected samples is also very important. Suspended solids from fish farms are biologically very active, which means that the sample should be cooled ($<4^{o}C$) or preserved properly.

2.3 Determinations and Methods of Analysis

2.3.1 Parameters

The samples could be analysed individually to determine the following characteristics

- pH
- alkalinity
- conductivity
- BOD_5 or BOD_7
- DO
- nitrate (NO_3-N)
- ammonia (NH_4-N)
- total nitrogen (tot-N)
- phosphate (PO_4-P)
- total phosphorus (tot-P)
- suspended solids (SS)

BOD, total nitrogen and total phosphorus should also be analysed in a filtered sample (membrane filter of 0,45 um). pH, alkalinity, conductivity, BOD, suspended solids and ammonia should be analysed within 24 hours. Samples for analysis of nitrate, total nitrogen, phosphate and total phosphorus should be preserved with sulphuric acid and cooled to less than 4°C. Filtered samples should be preserved after filtering.

Waterflow and temperature should be determined for each sampling site. As water quality could be influenced by climate, the weather conditions should be recorded.

To obtain a nutrient budget of phosphorus or nitrogen, it is also important to study the nutrient content of fish food, effluent and removed suspended solids. Such research can only be carried out in a farm with self-cleaning production units and efficient effluent treatment techniques. The reason for this is that suspended solids from fish farming are biologically very active and could cause rapid leaching of phosphorus from the solids. This could make the interpretation of the data difficult.

2.3.2 Standardized analytical methods

They are to be used according to the manual "Standard Methods for the Examination of Water and Waste Water" (APHA/AWWA/WPCF, 1985). If those are not used, for any reason, the applied method should be clearly stated.

Determination of pH

pH value is determined electrometrically at 25 ± 2°C either with a glass electrode and a reference electrode or with a combined electrode.

Determination of alkalinity

The determination is performed by titration with hydrochloric acid during vaporization of carbon dioxide. The end point is determined by indicator or pH meter at pH 5.4.

Determination of conductivity

Determination is carried out with a specific conductivity cell containing platinized electrodes. If the instrument does not compensate for different temperatures, the sample must be temperated to about 25°C.

Determination of biochemical oxygen demand (BOD) - dilution method

The concentration of dissolved oxygen is determined immediately before and after an incubation period of, usually, 5 or 7 days at 20°C. The BOD value is stated as the difference in concentration of dissolved oxygen. It is necessary to use a nitrification inhibitor, i.e. allylthio-urea (ATU).

Determination of dissolved oxygen (DO)

The method is a modified Winkler titration. The addition of divalent manganese solution to the water sample followed by an alkali-iodide-azide reagent results at last in a brown precipitation of $MnO(OH)_2$. After acidification with H_3PO_4, the precipitation is resolved; the oxidized manganese reverts to the divalent state and an equivalent amount of iodine is liberated. The iodine is then titrated with a solution of thiosulfate.

Determination of nitrate nitrogen (NO_3-N)

When the sample is run through a column containing amalgamated cadmium fillings, the nitrate is reduced to nitrite. The nitrite is determined by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylene-diamine to form an azo dye which is measured colorimetrically. A correction must be made for any nitrite initially present in the sample.

Determination of ammonia nitrogen (NH_4-N)

Ammonia reacts in alkali solution with hypochlorite and mono-chlor amine is formed. Mono-chlor amine and phenol form, in the presence of catalytic amounts of nitro-prusside ions and an excess of hypochlorite, indophenol blue. The amount of indophenol blue is measured colorimetrically.

Determination of total nitrogen (tot-N)

Organic and inorganic nitrogen compounds are digested in an alkali solution of persulfate ($K_2S_2O_8$) in an autoclave. The oxidized nitrogen is reduced to nitrite in a cadmium reduction column. The nitrite is determined colorimetrically in the same way as nitrate.

Determination of phosphate phosphorus (PO_4-P)

Orthophosphate reacts with ammonium molybdate and after reduction by ascorbic acid, a blue coloured complex is formed. The intensity of the colour is proportional to the phosphate concentration in the solution which is measured colorimetrically.

Determination of total phosphorus (tot-P)

The sample is digested in a persulfate solution ($K_2S_2O_8$) in an autoclave. The organic and inorganic phosphorus are converted to orthophosphate which is measured colorimetrically.

Determination of suspended solids (SS)

The sample is filtered through a glass microfibre filter with a retention efficiency of about 1 um (i.e. Whatman GF/A). After filtration, the filter is dried at 105°C for 1 hour and then weighted.

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