HARVESTING POLLUTED WATERS

Waste Heat and Nutrient-Loaded Effluents in the Aquaculture

Edited by O. Devik
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Preface

Waste heat from thermal power generation and waste minerals from domestic sewage are polluting rivers and coastal waters. It would thus be an important step forward if these *pollutants* could be made productive in aquaculture. The proposal to call a meeting of experts on *Waste Heat and Nutrient-Loaded Effluents in Aquaculture* came from Dr. Ole Devik.

His proposal was accepted and sponsored by the Special Program Panel on Eco-Sciences, a subsidiary body of the NATO Science Committee. NATO has extensive programs in the scientific and environmental fields, and I would like to take this opportunity to give you a short outline of these programs.

Collaboration and consultation between member countries of the Alliance have been of major concern to the North Atlantic Treaty Organization ever since it was established. In the mid-fifties a serious attempt was made to implement the collaboration in nonmilitary fields, and a report* from a committee of foreign ministers–Lester B. Pearson (Canada), Gaetano Martino (Italy), and Halvard Lange (Norway)–named scientific and technological cooperation as especially important. As a consequence of this report, a position as science adviser to the secretary-general of NATO (later changed to Assistant Secretary-General for Scientific and Environmental Affairs) and a science committee composed of one highly qualified scientist from each of the member countries of the Alliance was established in 1958.

The NATO science programs have changed during the years, but their predominant characteristics have remained an emphasis on cooperation and catalysis and a capacity for rapid response to new developments. Each of the programs has been conscientiously designed and deliberately implemented to improve the exchange of information. Over 50,000 individuals–of which some thousands come from countries outside the Alliance, including some hundreds

*Report of the Committee of Three: Non-Military Co-operation in NATO, NATO Information Service, B-1110 Brussels.

from Eastern Europe—have directly participated in these programs. The following programs have been in operation during 1973–74:*

The Senior Scientists Program. This is a small program awarding a few science lectureships, visiting professorships, and/or senior fellowships to outstanding scientists.

The Science Fellowships Program. This program, administered by the different member countries, awards about 600 NATO science fellowships each year. The program has allowed about 10,000 scientists to study for one year each in a foreign country.

The Advanced Study Institute Program. An ASI is primarily a high-level teaching activity at which a carefully defined subject is treated in considerable depth in a systematic and coherently structured program. About 50 institutes are supported each year.

The Research Grants Program. The main purpose of this program is to stimulate scientific research carried out in collaboration among scientists in the member countries of the Alliance. Grants are renewable for up to three years and 50 to 100 new grants are awarded each year.

The Science Committee Conference Program. The main purpose of these research evaluation conferences is to identify particularly fruitful areas for future research. The recommendations are directed both to those having a responsibility for selecting and supporting research programs and to the Science Committee itself. One or two conferences are held each year.

The Special Science Programs. In addition to the general and more permanent programs listed above, the Science Committee has frequently identified specialized scientific areas as deserving special encouragement or preferential support for limited periods. In 1974 there were special programs on: air-sea interaction; ecosciences, human factors; marine sciences; radiometeorology, stress corrosion cracking; and systems science.

The Science Committee Programs are guided by panels of scientists from the member countries and support is given to all fields of science, with emphasis on fundamental aspects rather than applications. Results from research projects are published in the literature, and scientific proceedings from ASIs and conferences are published in most cases.

I would also like to mention the Committee on the Challenges of Modern Society which, since 1969, has started and coordinated pilot studies in:† disaster assistance; environment and regional planning; road safety; air pollution; inland water pollution; advanced health care; coastal water pollution; advanced waste water treatment; urban transportation; disposal of hazardous substances; solar energy and geothermal energy.

Dr. A. Rannestad

*More information on the NATO science programs may be found in the booklet *Scientific Co-operation in NATO* or the book *NATO and SCIENCE, An Account of the Activities of the NATO Science Committee 1958-72*, NATO, Scientific Affairs Division, B-1110 Brussels.

†More information on the CCMS pilot studies may be found in the booklet *Man's Environment and the Atlantic Alliance*, NATO Information Service, B-1110 Brussels.

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Waste Heat and Nutrient-Loaded Effluents in the Aquaculture: The Setting of the Problem

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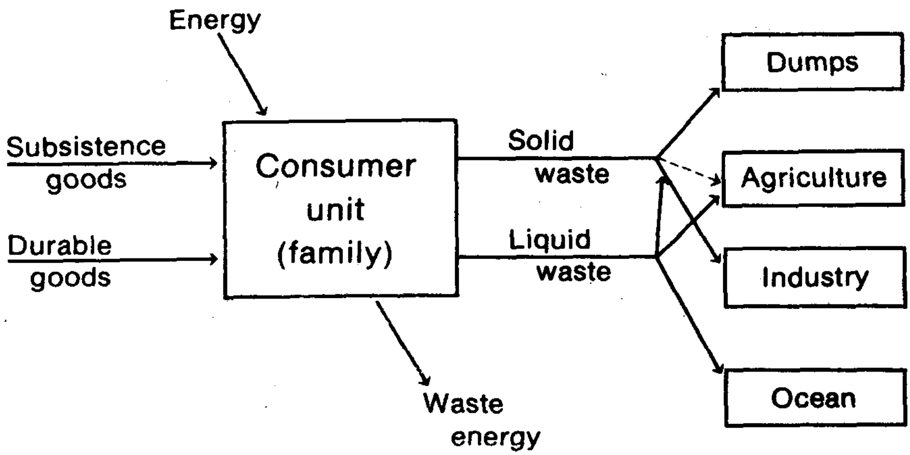
INTRODUCTION

The obvious point of departure for our discussions is the concern about the way we are managing our resources. We can approach this problem from various angles, ranging from the trustful one that "God looks after those that look after themselves," to the downright pessimistic one that foresees a collapse of the human existence in the near future because we are overexploiting our resources in a way that will leave us to choke in our own waste.

We may begin our discussion with the statement that most of our resources are limited, but that the limits are still largely unknown, and that we still can stretch the approach to the limits with a combination of a judicious use of the resources and our own ingenuity.

I would prefer to describe our situation in terms of a simplified flowsheet (see page 2). In the center of the diagram is placed the unit group of the community, commonly the family, but it may also be any small group that fulfills his own needs and wishes. The family group will function when given a certain quantity of resources. The resources will exhibit a great variety in quantity and kind in the various parts of the world.

The flowsheet indicates a distinction between input in the form of energy, subsistence goods (food and clothing), and durable goods. To a certain degree, the distinction between energy and matter is arbitrary, but the distinction is an



expression of the classification of the resources as to those that are not renewable and those that have to be recycled, whether we want it or not.

THE OBJECTIVE OF THE WORKSHOP

In this meeting the intention is to assess the possibility that we can achieve improvements in the present efficiency of recycling of materials through a judicious use of the photosynthetic process in combination with the heat produced in the course of the electricity generation.

We are dealing with output from the community in the form of liquid and solid waste which may be subdivided into domestic and industrial waste. The waste will consist of a mixture of organic and inorganic material, which will be broken down by microorganisms of various kinds so that the products of metabolism can be assimilated in the growth cycle of animals and plants. We may define a separate pathway for the various elemental components; in the diagram they are symbolized by the arrows designated agriculture and industry.

We may observe that the pathways as indicated are not closed; there is always a certain fraction of each elemental component that is drained off to the ocean. In other words, recirculation implies terrestrial cycles. The ocean may be regarded as a large sink, and once the components are absorbed in this sink, the cost of reclamation will as a rule be excessive.

GUIDELINES FOR THE RECIRCULATION

We can cite several guidelines for the optimum recirculation of the various elemental components.

1. In a recirculation, it is most economical to work in systems in which the concentration of the component is relatively large.
2. Reclamation in terrestrially based systems gives the best efficiency.
3. Restoration of materials to terrestrial use will improve the recycling efficiency.
4. In terms of quantity, the most important components to recycle will be PO_4, fixed N, K, possibly SiO_2.

For the domestic effluents, which have a relatively large concentration of fixed N, PO_4, K, and SiO_2, the most effective recycling schedule will probably include a treatment to remove in the form of sludge a major part of the mineral nutrient components, followed by the use of the runoff water for aquaculture in some form.

AQUACULTURE IN THE RECIRCULATION CONTEXT

The aquaculture will have its main value in the utilization of mineral nutrients in the runoff, which has a concentration of mineral nutrients too low to be reclaimed economically by other methods. From the point of view of the recycling of minerals, aquaculture methods may be ranked according to the fraction of matter returned to the terrestrial use.

The ranking will then reflect the number of links in the food chain. We may then rank the crop utilization in this order: (1) direct food use, (2) use in terrestrial animal husbandry, (3) use in marine animal husbandry or *ranching*, and (4) fish farming with intensive feeding. This ranking does not take into account the economy of the activity, which will be determined by such factors as the acceptability of the food produced, efficiency of the conversion of the feed, or investment costs.

The recent development of aquaculture reflects the influence of these factors. In our part of the world, we have seen that the age-old technique of raising such freshwater fish as carp in fish ponds has been supplemented by fish farming. Here, relatively high priced fish—such as salmon, rainbow trout, catfish, or sole—are produced from feed based on cheap protein, made from fish, or derived from suitable vegetable sources. These methods have been highly successful, and it now seems likely that the production of shrimp in large ponds will be commercially interesting.

The development in England to produce sole in ponds heated by cooling water from power plants utilizing atomic energy is in this context particularly interesting; it demonstrates the importance of additional heat to shorten the growth cycle of the fish.

I understand that the initial experiments also included alternative projects to utilize the primary production as a basis for the production of food animals. The results of these experiments, however, were not encouraging; they indicated that such an approach was not commercially attractive at the time. Since that time, an ever increasing research activity in fields related to aquaculture has provided us with additional data. We can point to investigations into the influence of various factors governing the rate of primary productivity, both in the oceans and in eutrophied areas. We have also made good progress in the mathematical modeling of such systems, and it therefore seems an opportune moment to ask whether these new experiences and research results may be utilized to achieve progress in the efforts to employ culture methods to control the productivity of selected areas.

The utilization of waste heat is of importance, because a moderate rise in the temperature will increase the turnover rate of the metabolic processes and lead to an increase in productivity. Besides, with the large amounts of heat available, the probability is that an increase in the productivity over large areas may make systems commercially attractive, even if under ordinary circumstances they are uneconomic.

The topics of the meeting have been chosen with these possibilities in mind, with the hope that the lectures will serve as starting points for discussions that should help to evaluate where we will meet the problems.

SIMILARITIES BETWEEN AGRICULTURE AND AQUACULTURE

It goes without saying that aquaculture and agriculture employ vastly different techniques, and that the commercially successful aquaculture owes little to the methods and principles of agriculture. All the same, it is worthwhile to ask whether these principles and methods are applicable. At any rate, I myself have found that a formulation of the principles serves as a useful frame of reference.

1. The area or volume under cultivation should be established and delimited physically and legally.
2. Physical and legal control should be established of the area or volume under cultivation..

3. Control over the exchange of matter (living or dead) between the ambient and the volume under cultivation should be effected.
4. Conditioning of the nutrient level by the addition of fertilizer or manure should be employed.
5. Control of species composition by the inoculation or implantation of key species and the weeding out of others should be maintained.

Using these principles, we may identify the various problems we have to solve.

DELIMITATION OF AREA OR VOLUME

The problems of delimitations of the volume under cultivation increase with the physical size and will be strongly influenced by the topography of the shore and the seabed. Grossly speaking, with coastal conditions as in Norway, aquaculture will comprise the exploitation of the euphotic layers, and the need is then to fence off the upper layers. The area for a production unit will be of the same order of magnitude that we find in the country's agriculture. In Norway, for example, the ordinary size farms have areas under cultivation from 100,000 m^2 upward, and we would expect similar areas to be indicated for aquacultural activities based upon the use of the primary production. We may compare this area to that of a standard supertanker.

PHYSICAL AND LEGAL CONTROL

The physical control of the volume will be dependent upon the local conditions and the construction of the fences, and will pose problems similar to the task of delimitation of the volume. I hope we will get an idea of the magnitude of these problems and how they can be tackled during the later discussions.

The legal control of the volume will be difficult as long as there exist only a few legal guidelines that can be applied. The rights of ownership are ill defined—which is only too reasonable, considering that aquaculture is a fairly new activity. During the planning of the program, it was considered whether a discussion of these problems should be included. The feeling was, however, that it is still somewhat premature to enter into a discussion on these aspects; it is better first to obtain more specific information regarding the feasibility of large-scale aquaculture and the specific problems such an activity will create.

CONTROL OF THE EXCHANGE OF MATTER WITH THE AMBIENT

A prerequisite for the aquaculture is to be able to exercise a certain control over the exchange of water between the volume under cultivation and the ambient. The objective should be to add the necessary nutrients at the same rate as they are assimilated and ultimately removed by cropping. We will probably need to know in more detail the interrelationships between the organisms cultivated, the nutrient level, and other factors such as light, temperature, and weather conditions. There will also be a need to monitor the changes, and we may imagine rather complex modeling of the systems, at least in an initial period. The ultimate aim is to eliminate as far as possible the need for such auxiliaries, and to try to get the control routines integrated into the know-how of the operators.

CONDITIONING OF THE NUTRIENT LEVEL

A consequence of the control of the exchange of matter is that we may be able to regulate the nutrient level within certain limits. It is convenient to consider the nutrient level separately, because the requirements will differ according to the organisms we intend to cultivate. We might also expect that selective control of one or more nutrients will facilitate the cultivation of chosen species.

There is obviously a lack of and need for characteristic growth data for the various species of interest, and this state of affairs will always exist, simply because improvement in the knowledge raises the need for supplementary data. To reach technical solutions, we have to seek pertinent information where it is available, and we hope that there is sufficient information to be found so that we can define the proper nutrient condition and point out the key factors for any one species.

As an added complication, we encounter the desire to utilize domestic effluents, which may be expected to contain both mineral nutrients and positive growth factors as well as inhibitors. Industrial effluents should not be considered in the first run, because of the added risk of harmful constituents that may be present, in spite of treatment of the effluent.

For the domestic effluent it seems realistic to assume that it has been through a certain amount of treatment which has removed the majority of the organic constituents, but that it still has a significant concentration of mineral nutrients and more or less known growth factors. We have a profusion of data that can be utilized in this context, but it is pertinent to ask what additional information is needed, and particularly what the consequences are for the public health when domestic effluent is extensively used.

CONTROL OF THE SPECIES COMPOSITION

The selection of species is, of course, dependent upon what kind of crop one intends to raise. At present, bivalve production seems the most imminent; only at a later stage may direct harvesting of the crop be practicable. Here we meet problems of inoculation and preconditioning of the selected species; one may raise the question whether genetic selection procedures are practicable. It is of importance to define the conditions for sufficient inoculum to secure the existence and growth of the desired organisms in a system that is as poorly controlled as those we are considering.

Furthermore, each specific use of the primary production will raise separate problems. In the production of bivalves, for example, a high temperature during the winter will lead to a high maintenance metabolism, and the animals may starve to death. Should we cool the system, or should we add suitable food during the dark months of the year, when the photosynthesis is negligible?

We may also mention the interrelation between grazers and the primary production, and among the grazers themselves. In the case of bivalves on a raft, for example, one may ask whether a heavy population of bivalves will squeeze out other grazers, with less interest for aquaculture.

I find then, that the dominant question is how we can make use of a eutrophied system, either in the aquacultural context, or as a ranching unit. Such a system could at least in principle be made to behave as a normal ecosystem, but with a higher level of productivity. This level may be raised even higher by the application of heat.

We may also expect that to the extent that organic materials sediment out of the system, there will result a gradient in nutrients, which will eventually lead to the accumulation of life proliferating on the system that is created.

These questions are not new; we find rather that they are asked again and again. In the course of time, some drop out when a sufficiently satisfactory answer has been reached, or when the question has been made obsolete by research results, but then new questions are raised.

No doubt, some of these questions will get an answer during our workshop, and additional questions will be raised. My hope is that we can use the deliberations here to define where the main problems are for the moment, and also to define a line of attack.