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Remark:
The WHO regional office for Europe, Copenhagen, presented for additional information the paper prepared by L. LANDNER (Stockholm/Schweden, 1976) "Eutrophication of lakes - its causes, effects and means of control with emphasis on lake rehabilitation. WHO Long-Term Programme in Envir. Poll. Control EURO 3130.

COMPLEX C: MEASURES AGAINST MASS GROWTH OF AQUATIC WEEDS AND PHYTOPLANKTON

General Report

by

J. AGUIRRE MARTINEZ

Center for Research and Training in Water Quality Control, Ministry of Water Resources, Mexico, D. F.

Mexico

I. Introduction

The bulk of the papers included in this report deal with control measures for aquatic weeds and phytoplankton. The rest of the papers are concerned with the effects of aquatic weeds and phytoplankton. The rest of the papers are concerned with the effects of aquatic weeds, phytoplankton, fertilizers and pesticides on the aquatic environment. Hence, it can be seen that aquatic weed control is a major problem throughout the countries that submitted papers to Complex C of this symposium.

The control of mass growths of aquatic weeds and phytoplankton involves the establishment of a vast research programme to determine:

a) the magnitude of the problem,
b) the types of organisms responsible for the problem,
c) the pertinent ecological characteristics of the problem organisms,
d) the most probable causes of the particular problem organism and its effect on the environment,
e) the applicable control methods and
f) the probable effects of these measures on the environment.

All of these topics are approached in some degree in the papers presented to this complex and are discussed further in the body of this report.

Since the papers fall into either one of two broad topics:

1) causes and effects of aquatic weeds on the environment and
2) aquatic weed control measures,

the discussion will be divided into these two main topics leading up to some general conclusions and recommendations that can be drawn from the information presented herein.

II. Causes and effects on the environments

The causes and effects of aquatic weeds and phytoplankton on the environment constitute, for all practical purposes, the main elements giving rise to the need for their effective control. Hyperfertilization of water is generally accepted as the primary cause for excessive growths of aquatic plants. This also leads to eutrophication of the water and all the environmental changes associated with it. This section analyses some of the more important causes of hyperfertilization and its effects.

A. Nutrients and eutrophication

Hyperfertilization of water-ways, ponds and lakes is normally caused by the excessive inflow of nutrients, which, combined with the proper environmental conditions, gives rise to eutrophication. The primary nutrients involved in explosive growths of aquatic weeds and phytoplankton blooms are generally conceded to be nitrogen and phosphorus, although other nutrients, such as inorganic carbon, sulphur and some metallic cations, may be the limiting factor of growth, in a specific situation.

The sources of nutrients are many and varied, originating mainly from human activities such as domestic sewage, industrial waste waters and agricultural return flows. High non-point nutrient loads are normally present on receiving streams flowing through farmlands, contributing large quantities of nitrogen and phosphorus that are washed out of the exposed agricultural soil.

Increasing quantities of fertilizers applied to the fields for increased yields are finding their way into the water-ways. KORIATH (1976) reports on the experience of five years of tests on nitrogen dislocation and removal through the application of chemical fertilizers as compared with liquid manure. He found that by far the greatest part of the washed out nitrogen comes from the reserve of organically bound nitrogen in the soil. The liquid manure, applied at rates up to 320 kg N/ha, led to removal rates similar to the inorganic fertilizer, although it was established that the removal rates depended upon other factors such as rainfall, the amount of seepage water, the soil texture, type of crop, the amount and time of application of the liquid manure. The objectives of KORIATH's study were to establish recommendations for the application of manure to agricultural soils so that eutrophying effects on the receiving waters would be kept to a minimum and at the same time obtain increased yields in the agricultural production of food.

Since the nitrate ion has the greatest mobility of the different forms of nitrogen, it is in this form that it is generally lost from the soil. The average of five years of tests showed wash-out rates of 8.8 to 16.7 kg N/ha . year (KORIATH, 1976) with different soil textures. In the special case of loess black earth the wash-out rate reached only 0.9 kg N/ha . year. It should be pointed out, however, that only 10.5 to 15 % of the total washed-out nitrogen was attributable to fertilizer nitrogen and the rest came directly from the soil. In a series of tests performed on the wash-out rate of fertilizer-nitrogen, it was established at between 1.8 and 2.5 kg N/ha or from 1.5 to 2.1 % of the total nitrogen applied.

KORIATH (1976) also compared nitrogen losses from different types of crops under various fertilizer application conditions. He observed that the application of liquid manure at the rate of 320 kg N/ha produced an increase in the nitrogen losses of about 11 kg N/ha . year over the non-manured controls; whereas, the same application rates of liquid manure, along with straw manure in one case and intercropping manure in another, gave normal and reduced (30 and 18 kg N/ha) nitrogen wash-out rates, respectively. It was derived from the study that nitrogen wash-out is dependent upon the period and amount of liquid manure applied, type of crop, amount of rainfall, quantity of seepage and soil texture. This led to a recommendation prohibiting the application of liquid manure to sites with a groundwater table level of less than

0.4 m and not to exceed a rate of 250 kg N/ha . year where the groundwater table is between 0.4 and 1.0 m below the surface.

Eutrophication becomes a most serious problem when it invades a water supply reservoir due primarily to the increased mechanical loading on the filtration plants for the production of potable water. HÖHNE (1976) reports on the experience of algal mass developments in two different reservoirs, one eutrophic and the other oligotrophic, respectively Saidenbach and Neunzehnhain, both near Karl-Marx-Stadt.

In the case of these two reservoirs phosphorus is the production limiting nutrient for algal mass development. The mean orthophosphate content of the influent to the reservoirs is 21.9 and 1.7 ug/l P (PO_4) respectively for Saidenbach and Neunzehnhain and the total annual imports from the corresponding drainage areas are in a ratio of 88 : 1, respectively. The effective load on the Saidenbach reservoir is about 11.4 times higher than on Neunzehnhain, which gives rise to a difference in the maxima of plankton volume for each reservoir on the order of 400 : 1. The biomass produced by Asterionella formosa in April 1976 within the surface layer of the Saidenbach reservoir amounted to 2.5 g/m^3 dry weight. It was also observed that in the oligotrophic Neunzehnhain reservoir only a very slight change in the planktonic structure occurs, whereas in the Saidenbach reservoir the seasonal planktonic changes are characterized, both qualitatively and quantitatively, by extreme phases of development which are often distinctly separated from each other.

Apparently, a rapid decrease of the soluble phosphate and a reduction of the available light due to self-shadowing are responsible for the emergence of massive growths of Asterionella formosa, since it is able to continue reproduction for some time with a steady reduction of the cell phosphate. The rapid decrease of orthophosphate, in part, can be attributed to the storage capacity of diatoms, the phosphate demand being largely met by remineralized phosphate and resulting in no phosphate accumulation within the pelagic region of the reservoir. This process, in the eutrophic Saidenbach reservoir, takes place at a high nutrient level, resulting in the production of a large biomass. When thermal stratification sets in, the ecological conditions for the large planktonic forms, such as Asterionella formosa, become less favourable due to lack of turbulence and the rate of sedimentation exceeding the rate of growth. The epilimnion becomes poor in nutrients and the production rich spring is followed by a summer period with a relatively low rate of production. An indication of the relatively high degree of eutrophication in this reservoir is the occurrence of the blue-green alga Anabaena flos-aquae in considerable quantities (up to 4000 colonies/l) before summer sets in (August).

Some of the more important causes for planktonic mass development in an eutrophic reservoir and the resulting impairment of the raw water quality are summarized below (HÖHNE, 1976):

Causes

1. inflow of the growth limiting nutrients (C, N, P);
2. seasonal distribution of the nutrient inflow;
3. depth of stratification of the inflowing water and the depth of light penetration;
4. the ratio of the quantities of supplied nutrients (C:N:P);
5. extent of recirculation of nutrients through the "intra-biocenotic cycle" with respect to density and composition of phytoplankton production; and
6. the effect of lowering the reservoir water level and internal standing waves on the reincorporation of nutrients to the main water body from the bottom deposits.

Impairment

1. shorter but more frequent filter runs in water treatment processes;
2. bad taste and odour of the treated water; and
3. variations in the chemical composition of the raw water through biochemical decomposition processes.

From the above, it can be surmised that the algal mass developments, occuring in the eutrophic Saidenbach reservoir, impair water utilization and increase water treatment costs.

It is important to note that the main concept of water protection against eutrophy is based on a balance of biogenic compounds. MAŃCZAK and SZYMAŃSKA (1976) suggest that this balance might be evaluated with the following relationship that consider the inputs and outputs of biogenic compounds from the water body:

$$L_s + L_w + L_o + L_d + L_a - L_{od} - L_z = L_p$$

where

L_s - biogenic load of sewage origin,
L_w - biogenic load wash-out of the soil,
L_o - biogenic load from atmospheric fall-out,
L_d - biogenic load from natural inflow,
L_a - biogenic load of authochtonous origin,
L_{od}- biogenic load flowing out of the reservoir,
L_z - biogenic load being reduced within the reservoir,
L_p - biogenic load retained in the reservoir.

To define the amount of biogenic compounds to be removed from the water flowing into the reservoir, the permissible load (L_{dop}) must be estimated from allowable concentration of the given nutrient in water of the reservoir.

Forest fertiligation was mentioned as an important source of nutrients in Poland and it was suggested that this practice be limited whenever it could give rise to the eutrophication of a nearby body of water. A similar situation has been experiences in the GDR where large livestock growing activities have been transfered from the Saidenbach river basin to other areas less critical, in order to protect the water quality of the Saidenbach reservoir. This is a most novel solution to a problem of utmost importance for the preservation of the water supply system of Karl-Marx-Stadt and surrounding communities. This brings to light that the application of water pollution control measures, in accordance with the prevailing local situation is a task requiring the coordination of agricultural, water management and environmental protection policies.

B. Dissolved oxygen balance

The dissolved oxygen balance in a body of water is possibly the most important factor in determining its state of health. When significant amounts of photosynthesis take place within the water, a diurnal cycle is established, with a net gain of oxygen during daylight (O_2 production) and a net consumption of oxygen during the night (respiration). This situation becomes critical in slow flowing waters which are rich in macrophytes (JORGA and WEISE, 1976), since the low mean rate of flow maintains atmospheric oxygenation at a low level.

JORGA and WEISE studied the lower course of the Kleine Elster, which is rich in plant nutrients and abundant biomass development. They observed biomass development levels between 100 to 1200 g/m^2 (dry weight) depending upon the season, with the lowest values appearing during autumn and the highest in the summer. The submerged macrophytes belonged mostly to Potamogeton spp, Elodea canadensis and Ranunculus aquatilis.

High biomass developments cause high nocturnal respiration losses, especially at relatively high summer water temperatures. This gives rise to high oxygen depletion rates at the end of the nocturnal respiration period, resulting in critical dissolved oxygen levels. JORGA and WEISE established that a biomass in excess of 250 g/m^2 (dry weight) could lead to this type of situation, where self-shading and increased spatial competition cause higher respiration rates and thus impair photosynthetic reoxygenation.

Removal of the "weed congestion" is advisable as a measure of environmental protection; however, the vegetable matter cut by machines or sprayed with herbicides must be removed from the water body immediately, since its microbial decomposition would constitute a significant loading on the oxygen resources of the stream. Utilization of the harvested weeds, as soil conditioner or fodder, seems highly attractive.

C. Pesticides: Toxic water pollutants

The increased use of chemical substances to control a variety of pests (weeds, viral, bacterial and fungal pathogens and animal pest) in agriculture as well as in other human activities, has introduced these pesticides (insecticides and herbicides) into the environment where they eventually find their way, through the hydrologic cycle, into most water courses of the world. TSCHEU-SCHLÜTER (1976) reports on some of the restrictions established in the German Democratic Republic on the use of these substances so that water pollution by pesticides may be kept to an acceptable minimum.

The restrictions set on the use of pesticides are concerned primarily with those substances that have unfavourable side effects, such as long persistance and accumulation in the tissues of warm-blooded animals; whereas less persistant insecticides and those that are readily eliminated from animal tissue will continue to be available.

In the GDR (TSCHEU-SCHLÜTER) herbicides are used quite extensively to keep irrigation and drainage ditches free of aquatic vegetation. Before any of these substances can be used in a freshwater environment they must be classified according to the criteria given in the Catalogue of Water Pollutants (1975), which pays particular attention to potential carcinogenic effects and acute or chronic toxicity to warm-blooded animals. Preparations containing compounds such as chlorinated hydrocarbons which are highly toxic to fish, accumulated in tissue and relatively non-biodegradable, are not admitted for use.

TSCHEU-SCHLÜTER reports on the findings of several long-term studies on the adverse side effects of different herbicides on fish. Sublethal concentrations of Dalapon, 2,4-D and Diuron can decrease the RNA content, cause lesions to nerve cells, delay hatching of eggs, slow down growth rates, enlarge livers and many other degenerative tissue changes.

The lethal concentrations for Dalapon (LC_{50}) to warm-blooded animals were found to be about 9000 mg/kg and for fish from about 7000 to more than 10000 ppm. Mixtures of Dalapon with 2,4-DP, MCPA or CMPP are somewhat more dangerous with respect to the acute oral toxicity to warm-blooded animals with LC_{50} values between 800 and 1000 mg/kg, and LC_{50} values of 300 to 500 ppm, at application rates of about 0.5 g/m^2, for fish toxicity (KRAMER and SCHMALAND, 1976).

The most widely used chemical algicide is copper sulphate, which is of moderately acute toxicity to warm-blooded animals, but highly toxic to algae and between strongly and extremely poisonous to fish. The upper permissible copper sulphate concentration in fish ponds, excepting trout lakes, is set at 0.5 mg/l. Other algicides, such as the organic triazines and urea derivatives, are powerful photosynthetic poisons, of low toxicity to warm-blooded animals; however, they are quite difficult to degrade biologically, resulting in the residue remaining active over a prolonged period of time (TSCHEU-SCHLÜTER, 1976).

In summary, it should be recognized that the active ingredients of the pesticidal formulations are water pollutants and their selection for a particular job must be made so as to keep the toxicological risk at a minimum.

III. Weed control

Increased hyperfertilization and the resulting eutrophication have given rise to the universal presence of aquatic weeds in streams, canals, ponds and lakes all over the world. Small quantities of aquatic plants have a useful ecological role; however, explosive growths of vegetation impair the usefulness, causing problems of: increased water losses due to evapo-transpiration, health hazards, impaired flow in channels and, in general, hazards to power generation, navigation and water sports. Aquatic plants are important to a well-balanced ecosystem, if they are not allowed to grow excessively, since they play an important part in the plant-animal food chain.

A. General aspects

In order to approach aquatic weed control on a rational basis it is necessary to determine the extent of the problem through a well-organized survey. The survey must locate the infested areas, predominant plants and extent of the infestation. In most cases, reported by MOURSI (1976) and BISWAS (1976), the predominant organism was water hyacinth (Eichhornia crassipes), a free floating plant or some type of rooted plant such as Hydrilla spp. or

Potamogeton spp. The infestation of aquatic weeds in Egypt's (MOURSI, 1976) irrigation and drainage canals covers about 80 % of 50,000 km, of these water-ways; as well as 4,000 ha of lake surface covered with water hyacinth in the northern part of the country. The situation in India (BISWAS, 1976) is also quite werious with nearly 40 % of the cultivable waters (80,000 ha) in West Bengal, Bihar, Orissa and Assam and 20 to 25 % of the rest of the country infested by aquatic weeds.

After the survey has established the magnitude of the problem the best possible solutions must be chosen according to the economic considerations and technology available. The methods most commonly used in aquatic weed control fall into one of three general categories: physical, chemical and biological.

B. Physical control

Manual methods of controlling aquatic weeds have been widely employed; although, they are mainly applicable to small watercourses where sprays may drift and endanger agricultural crops. Labor costs for manual removal of weeds are relatively inexpensive, yet the workers are not always available in sufficient number and are subject to certain health hazards from direct contact with the weeds (MOURSI, 1976).

The utilization of machines, in substitution of hand labour, also has many disadvantages. Among these are: risk of incomplete coverage of the infested area, re-infestation by seeds or vegetative fragments left behind, and mainly, the required machines are very expensive with high operation and maintenance costs.

Mechanical, as well as manual, methods of control do not have a very lasting effect due to the way the aquatic plants reproduce themselves through seeds and vegetative fragments; and, therefore, the treatment must be repeated frequently.

C. Chemical control

Chemical control methods are the most successful, but also the most expensive, with the drawback that the chemical residues cause water pollution problems, such as: toxicity to other organisms and as fertilizers once they loose their initial toxicity. Also, in order to maintain adequate control, the applications must be repeated periodically and indefinately, which requires expert supervision in handling the chemicals and avoiding overdoses in any one area. Depending upon the specific environmental situation for a particular area, the removal of the dead weeds may be necessary and can become difficult and costly at times.

KRAMER and SCHMALAND (1976) report of the introduction of chemical weed control in 1967 in the GDR and by 1970, 12,000 km of water-ways being treated with this method. Then in 1975, chemical bottom treatment was applied to 10,000 km and chemical slope treatment to 30,000 km. Great care is taken in the selection of chemical preparations, so that the aspects of water quality protection are not interfered with.

The primary active consituent of most of the preparations used in the GDR (KRAMER and SCHMALAND) is Dalapon; chosen for this purpose mainly because of its largely unobjectionable toxicity to warm-blooded animals and fish. Mixtures of Dalapon with 2,4-DP, MCPA or CMPP are used on dicotyledonous species. A safety factor of 250, estimated as the quotient of the LC_{50} divided by the resultant concentration of herbicide applied to a body of water 30 cm deep, is always maintained against the possibility of deleterious effects.

Gramoxone and Reglone, rapidly removed by sorption from water are considered most suitable for short-time inoculations for controlling submerged macrophytes, resulting in a temporary loading of the ecosystem for only thirty minutes or so.

The application of chemical substances in slope treatment is considerably much less expensive than bottom treatment, since the plants are more directly accessible to the herbicidal action. The side effects of these agents are quite similar to those of Dalapon, with the possible exception of 2,4-D+2,4,5-T (Selest), that is used only in situations where no risk of water pollution is involved.

D. Biological control

Recently, biological control methods have evolved that promise long-term effects at a lesser cost. Biological control methods utilize living organisms that either eat the weed (fish) or are host-specific natural enemies of it (insects). An attempt has also been made to control certain environmental factors that control aquatic weed growth, such as deep water, steep shoreline slopes, cold water and low nutrient content.

Several animals feed on aquatic plants among which the manatee (JORGA and WEISE, 1976) and several species of fish can be sited as feeding exclusively on some of the aquatic weeds that cause so many problems. JÄHNICHEN (1976) and BARTHELMES (1976) report on experiences with grasscarp and silvercarp, respectively. Several insects have also been found that are host-specific parasites of some of the more troublesome aquatic weeds: Neochetina spp. (attacks water hyacinth) and a semi-aquatic grasshopper Paulinia acuminata (attacks water fern) are some examples (BISWAS, 1976).

Perhaps of the biological control methods available, the utilization of herbivorous fish has been the most sought after solution and, thus, the most studied. JÄHNICHEN (1976) reports on the experience in the GDR, since 1967, of the successful application of grasscarp (Ctenopharyngodon idella) for controlling excessive aquatic plant growths. A number of factors are required for the proper acclimation of the grasscarp fry to conditions prevalent in the GDR, such as:

1. adequate water quality,
2. water temperatures above 15^{o}C,
3. water depths of at least 0.30 m with some parts 1 m and deeper,
4. exclusion of waters with single species colonization of plants,
5. fish of a minimum age of two years,
6. mean stocking rate of 200 kg/ha, and
7. suitable barriers to prevent fish migration.

After its breeding stage, C. idella are able to feed on filamentous algae and macrophytes; and it was known that once acclimated, they are able to consume large quantities of aquatic and land plants in water temperatures similar to those of their native regions of 22 to 26°C. Because of the cold climate conditions prevailing in the GDR, doubt existed as to whether the fish would adapt to these conditions. Once the basic problems of acclimation in the GDR were solved, it was necessary to determine if the most common aquatic weeds would be consumed in water temperatures of 16 to 22°C. Detailed studies revealed that this was possible with Typha, Phragmites, Carex, Juncus and others. The only exceptions were Stratiotes aloides and Ranunculus spp. (poisonous), while Nymphaeaceae are consumed only under extreme conditions. Thus, it was concluded that the development of excessive aquatic plant stocks could be restricted or prevented effectively with grasscarp (C. idella) (JÄHNICHEN, 1976).

E. Phytoplankton control

Fish can also be used successfully to control phytoplankton. The introduction of silvercarp (Hypophthalmichthys molitrix) in the GDR was reported by BARTHELMES (1976), where climatic conditions permit stocking rates of about 10,000 organisms/ha. At this stocking rate an increase in fish mass was observed of about 1 ton/ha, which makes possible the elimination of 0.5 to 1.5 g/m^2 . year of phosphorus, if the carp are harvested. If the pond is not thermally stratified, a high nutrient regeneration takes place from the sedimented silvercarp excrement balls at stocking rates of 3,000 organisms/ha, which can increase the phytoplankton biomass in the absence of adequate numbers of zooplankton. In the case of a healthy zooplankton population, observed at stocking rates of 2,000 organisms/ha and possibly higher, reductions in the algae biomass are atteined; on the other hand, at stocking rates of about 12,000 organisms/ha there is a strong suppression of the zooplankton population, with a correspondingly strong development of phytoplankton. However, the large algal species are replaced by smaller algae below 5 to 10 µm in size. This phenomenon can be effective in controlling blue-green algae blooms.

Two distinct effects can be distinguished in the control of massive algal growths with silvercarp (H. molitrix):

1. direct effects through consuption of the plankton, sedimentation of excrement balls and regeneration of nutrients; and
2. indirect effect through nutrient accumulation in the fish flesh and harvesting of the fish.

The direct and indirect effects of the silvercarp depend upon the stocking rate and whether the pond or lake is stratified or not (BARTHELMES, 1976).

The elimination of nutrients through their accumulation in fish flesh has reduced possibilities, since normally this amounts to an extraction of about 0.5 to 1.5 g P/m^2 . year, where as the phosphorus input through natural inflows may reach values on the order of 10 g P/m^2 . year.

However, the accumulation of nutrients in silvercarp can be included within a comprehensive water management plan for nutrient control in highly eutrophic waters. The utilization of the carp could be used in coordination with other nutrient extraction activities, such as partial removal of bottom muds and diversion of hypolimnic water (BARTHELMES, 1976).

BARTHELMES (GDR) pointed out in discussion that the ecological conditions prevailing in different parts of the world require that the acclimation of grass carp will have to be studied very carefully for each situation that is looking at the utilization of herbivorous fish for the elimination of aquatic weed problems. KAJAK (Poland) has mentioned that the experience in his country in introducing carp for the improvement of water quality has been very favourable at stocking rates of 100 g/m^3 (5 ton/ha) of silver carp. Finally, JÄHNICHEN and BARTHELMES (GDR) have presented some of the most prominent results of their experiences in the breeding rearing and transportation of H. molitrix, C. idella and A. nobilis, all phytophagous fish used in their country for aquatic weed control, after the proper acclimation procedures. Great care must be taken in the handling of these fish since they do not reproduce naturally in the conditions prevalent in the GDR. After the fish reach maturity they are transfered to the breeding plants, with water temperatures of 23 to 26°C, where they are artificially induced to ovulate. The eggs are cared for until they hatch and once they are actively feeding they are sold to pond farms for further rearing.

F. Eutrophication control through bioproductivity

Nutrient control is a major factor condusive to successful eutrophication prevention in ponds, lakes and reservoirs. KALISZ (1976) suggests the use of algal ponds for the removal of nutrients from biologically treated sewage and VELICHKO et al. (1976) report on the bioproductivity of shallow water in reservoirs and how it can be used to limit eutrophication.

Algal ponds are recognized as an inexpensive means of rough biological treatment for sewage and, where needed, as a means of reducing the bacterial content of the treated effluent. However, they may also be utilized in the removal of the macronutrients: nitrogen and phosphorus. A process such as this works only if harvesting of the algal mass has been provided for before the effluent is discharged to the receiving stream. Otherwise, the algae will become a massive nutrient load upon the receiving stream as they die and the algal cells begin to lyse.

Treated sewage is a rich environment for algal growth, where a few species with a high number of individuals predominate. The maximum concentration of algae observed by KALISZ was of about 4,700,000 cells/ml.

Field studies were carried out on both fully treated and partially treated sewage. The observed reduction of nitrogen in the effluent was higher for the ponds fed on partially treated sewage, resulting in a two-fold increase of the organic nitrogen content within the algal cells. Reduction of phosphorus was highest in ponds with the most intense algal growth (KALISZ, 1976).

In laboratory experiements with monocultures of algae, the reduction in nitrogen and phosphorus in the treated sewage was compared to the increase in dry mass of algae. Scenedesmus obliquus presented the highest reduction of nitrogen and phosphorus in relation to the increase in algae dry mass. The average reduction in nitrogen was roughly equal to the percentage increase of this element in the algal mass. Phosphorus reduction, however, was higher, probably due to its precipitation at the high pH values attained during intense algal growth.

In order for this scheme to work, an efficient means of removing the algae from the pond effluent must be found. Various techniques were tried, such as algicides, but these were found to be troublesome and expensive. However, the algae are a rich source of carbohydrates, proteins, lipids and vitamins, and form the basic food source for such invertebrates as rotifers and crustaceans, which in turn become the food source for fish. So why not convert the algal protein into fish protein and harvest it as such, instead of trying to harvest the algae directly? Proper management of algal ponds with cultures of plankton crustaceans or plant feeding fish can effect removal of nitrogen and phosphorus from sewage and at the same time work as tertiary treatment plants (KALISZ, 1976).

Nutrients washed out of agricultural areas enter the shallow shore zones of reservoirs and give rise to serious eutrophication problems. The shallow waters of reservoirs, like the littoral water of other regions, are highly productive, uniting rich feeding places for fish and an extremely favourable water quality (VELICHKO et al., 1976). Natural eutrophication depends upon the characteristics of the area flooded, the absence of flow, the hydrological regime, protection from weather and wave action, the amount of runoff during the year and an intensive growth of plants and animals. VELICHKO et al. compare two reservoirs in the Dniepr, one mesotrophic and the other eutrophic.

The shallow water areas of these reservoirs become almost entirely overgrown with macrophytes. The phytoperiphyton reach maximum values of 15.4 to 296.8 g/kg raw mass of plants. The water has a high content of nutrients: NH_4 from 0.808 to 0.937 mg/l, NO_3 from 0.124 to 0.141 mg/l and PO_4 from 0.113 to 0.124 mg/l. The increase of these nutrients in the shallow water areas speeds up during the spring floods. In the summer, when runoff is very slight, shoreline activities, such as cattle grazing and water sports, contribute noticeable amounts of nitrogen and phosphorus.

Eutrophic shallow waters are characterized by relatively low concentrations of phytophilic invertebrates in the benthos. These areas become highly saprobic (α-mesosaprobic zone), which leads to the absence of oxyphilic invertebrates. The negative influence of eutrophication on shallow water can be suppressed to a large extent by a series of corrective measures, such as the direct removal of nutrients through aquatic plant harvesting and elimination of the vegetation all along the shore zone (VELICHKO et al., 1976).

It is possible and necessary to remove nutrients from the shallow water by eliminating the surplus of macrophytes, since they are important in raising the productivity of the shallow water only up to a certain limit. The increase in biomass of the invertebrates and of dissolved oxygen in water with cattails and reeds reaches its maximum values at from 30 to 50 % overgrowth, with the biomass of cattails from 4 to 5 kg/m^2 and that of reeds up to 2 kg/m^2. An increase in the level of biomass of these macrophytes leads to the occurrence of α-mesosaprobic rotifers and saprobic nematodes, which indicate a development of decay processes. With biomass concentrations of 4 kg/m^2 for submerged thickets and a projected covering of 80 to 90 %, a high biomass of zooplankton can be found. In moderate developments of filamentous algae (up to 6 kg/m^2) water purification processes predominate; at biomass levels exceeding 6 kg/m^2 pollution processes take over (VELICHKO et al.).

With the removal of the aquatic plants from the shallow water areas a considerable quantity of nutrients is withdrawn along with the vegetable mass. Common reeds contain, at 40 ton/ha , from 600 to 650 kg/ha of nitrogen, 20.0 to 25.0 kg/ha of phosphorus and 400 kg/ha of potash. Filamentous algae, in the reservoir as a whole, can represent from 20 to 30 tons of nitrogen and about 3 tons of phosphorus. Thus the removal of macrophytes and filamentous algae can be an extremely important means of regulation of the content of nutrients in lakes and reservoirs.

G. Integrated control

In general, no single method of control will give a perfect solution to the problem of aquatic weeds, but all methods compliment each other, depending upon the nature and magnitude of infestation. Complete eradication of aquatic weeds is undesirable, since they have positive as well as negative effects. The normal role of the aquatic vegetation should be understood before extensive control measures are initiated. As such, an integrated approach needs to be evolved and employed so as not to cause ecological disturbances nor create pollutional problems. The ecosystem as a whole must be studied including the process, interaction and transfer rates of different organisms, as well as organisms and their environment (BISWAS, 1976, MOURSI, 1976).

H. Utilization of aquatic weeds

One of the major handicaps in the eradication of aquatic weeds is the cost factor. Hence, weed control programmes should include the recovcry of the costs involved, possibly through the utilization of the extracted plants, as such, or in processed form for some gainful purpose. Aquatic weeds are green plants that contain valuable nutrients, protein and carbohydrates. Unfortunately, the large amount of water in the plants dilutes their nutritional content and adds to the cost of their handling and processing; however, they cost nothing to grow (BISWAS, 1976).

In Egypt (MOURSI, 1976) studies are underway to develop rational programmes for the utilization of water hyacinth, as an initial phase, because it grows in large uniform stands and is relatively easy to harvest from the water surface. These studies include the following topics:

1. development of ways and means, either manual or mechanical, of harvesting the weeds;
2. development of efficient and economical processes for handling, dehydrating, reducing the volume and transporting the harvested plants;
3. development of potential uses of the water hyacinth for improving the soil, either as green manure or compost; and
4. determine the feasibility of utilizing the plant as live-

stock feed, either fresh, artificially dried or processed.

Subaquatic plants are also considered useful as compost for improving soil fertility or for fodder, as silage or pellets, with the exception of the poisonous Ranunculus spp. (JORGA and WEISE, 1976). Preparation of manure by composting water hyacinth shows that it is nearly twice as rich as town compost and four times as that of farmyard manure, with respect to the main plant nutrients, nitrogen and phosphorus (BISWAS, 1976). Its potential as an animal feed supplement is also quite attractive considering that it can be a more effective means of exploiting solar energy, since laboratory experiments have shown that it is possible to grow as much as 0.75 tons/ha . day of algae while the yield for food crops is limited to merely 7.5 tons/ha . year (BISWAS, 1976).

Considering the vast amounts of aquatic plants throughout the world as raw materials instead of weeds, it may be concluded that it is definately feasible to obtain certain economic returns from the utilization of the harvested plants, that will allow the eradication process to become self-financing or maybe even turn in a profit.

IV. Conclusions and recommendations

The analysis of the presented papers reporting on experiences in different parts of the world relating to measures against mass growth of aquatic weeds and phytoplankton has led to the following conclusions and recommendations.

A. Conclusions

1. Aquatic weed infestations in the waters of a great many countries of the world are becoming a very serious problem.
2. Due to the importance of aquatic vegetation in a well-balanced ecosystem, it is necessary to establish the ecological role of these plants before they are completely eradicated from a body of water.

3. The utilization of aquatic weeds as soil conditioners or fodder can be an attractive way of defraying the costs of their control.
4. An integrated approach to the control of aquatic weeds is the best all around solution, since a combination of methods can give better results than any one method alone.
5. Mechanical, as well as manual, methods of control do not have a very lasting effect due to the way the aquatic plants reproduce themselves through seeds and vegetative fragments, which necessitates frequent repetition of the treatment.
6. Chemical control methods are the most succesful, expensive and dangerous to use due to the water pollution problems that they may originate, if great care is not taken in their use.
7. Very effective biological control methods that employ weed eating fish or host-specific insects are being studied in several countries.
8. It should be recognized that the active ingredients of pesticidal formulations are water pollutants and their selection for aquatic weed control should be made in such a manner so as to keep the toxicological risk of their application at a minimum.
9. It was established that nitrogen removal rates depend on factors such as amount of rainfall, amount of seepage water, soil texture, type of crop, amount, time, and method of application of the type of fertilizer and by far the greatest part of the washed-out nitrogen comes from the reserves of organically bound nitrogen in the soil.
10. Proper management of algal ponds with cultures of plankton crustaceans or plant feeding fish can effect successful removal of nutrients from sewage and at the same time work as tertiary treatment plants.
11. The removal of macrophytes and filamentous algae can be an extremely important means of regulation of the nutrient content of lakes and reservoirs.

B. Recommendations

In summary it should be emphasized that three points are of primary importance in the prevention and rehabilitation of eutrophic bodies of water, which include:

a) location and definition of the nutrient (biogenic compounds) sources in order to adapt the most suitable solution or combination there of;
b) integrated control measures are generally more successful than the application anyone individual method; and
c) the industrialization of the aquatic plant mass for soil conditioner or livestock feed can be an effective means of defraying the costs involved in the application of the different control measures.

1. Before an aquatic weed or phytoplankton control programme is established, an integral research project must be undertaken to determine:
   a) the magnitude and extent of the infestation,
   b) the types of plants that are involved,
   c) the ecological role of the plants in the infested zone,
   d) the most probable causes of effects of the infestation,
   e) feasible control methods and
   f) the most probable effects of these control measures on the environment.
2. The application of liquid manures to sites with a groundwater table level less than 0.4 m below the surface should be prohibited, and should not exceed the rate of 250 kg N/h . year where the groundwater table is between 0.4 and 1.0 m below the surface.
3. The biomass of aquatic weeds should not be allowed to exceed 250 g/m^2 (dry weight) since it could lead to critical dissolved oxygen levels resulting from impaired photosynthetic reoxygenation.
4. The use of pesticides that have unfavourable side effects, such as long persistance, high toxicity and accumulation in the tissues of warm-blooded animals should be greatly restricted.

Since chemical control methods are the most practical at the present, these give rise to very severe water pollution problems, necessitating great care in their use. The example of the GDR, in regulating the use of herbicidal preparations, is one to be followed by all that are concerned with the effects of these chemicals on the environment. In other parts of the world, the use of the chlorinated hydrocarbons is either restricted or prohibited entirely, however the application rates of other formulations are only considered as recommendations which quite often are exceeded many times over by the farmers in an effort to obtain increased protection for their crops. The application of these herbicides and pesticides in general should be closely regulated in order to avoid the occurrance of water pollution problems from the use of these substances.

5. The successful application of grass carp (C. idella) for controlling excessive aquatic plants, requires that a number of conditions be met, mainly: adequate water quality, water temperature above 15°C, minimum water depth of 0.30 m, minimum fish age of two years and a mean stocking rate of 200 kg/ha . year.
6. The accumulation of nutrients in fish flesh should not be considered a primary means of nutrient removal, since this normally would amount to the extraction of quantities (0.5 to 1.5 g P/m^2 . year) far below the input from natural inflows (on the order of 10 g P/m^2 . year), but should be included in a comprehensive water management plan for nutrient control in highly eutrophic waters.
7. Algal ponds may be used successfully in the removal of nutrients, only when efficient harvesting of the algal population has been provided for before the effluent is discharged to a receiving stream.
8. An integrated weed control programme needs to be evolved and employed so as not to cause ecological disturbances nor create pollutional problems, considering the ecosystem as a whole.
9. Weed control programmes should include the recovery of

the costs involved through the utilization of the extracted plants, as such or in processed form for some gainful purpose.

10. Since water hyacinth compost shows promise as a rich fertilizer, containing more nutrients than town compost and farmyard manure, it should be studied further as a main plant nutrient supplier, as well as a potential animal feed supplement.

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ON THE EFFECT OF HYPOPHTHALMICHTHYS MOLITRIX IN THE ECOSYSTEMS POND AND LAKE

D. BARTHELMES
Institut für Binnenfischerei, Berlin
German Democratic Republic

Summary

The climatic conditions in the GDR are permitting stocking rates of the silver carp (Hypophthalmichthys molitrix) of about 1o ooo specimen / ha. In a pond being normally explored with carps with this stocking rate was attained the hitherto utmost silver carp increment of about 1 t/ha besides the carp yield. Therefore in ponds and shallow lakes the highest possible carry-out of P with silver carps can attain 0,5 ... 1,5 g/m^2. In case of lacking temperature strata and with a corresponding high nutriment regeneration from the sedimented silver carp excrements at stocking rates of 3ooo sp/ha and in absence of higher stocks of filtrating zooplankton comes to pass the augmentation of the phytoplankton - biomass. In case of a rich zooplankton expanding which still has been observed at 2ooo si/ha and possibly still goes on at higher stocking rates reductions of the algae - biomass are possible too. On the contrary silver carp stocking rates of about 12ooo sp/ha obviously are already strong suppressing the zooplankton. Therefore at such high stocking rates under pond conditions a strong development of phytoplankton is to be observed. In such cases the large species of algae disappear and they are replaced by small species with sizes below 5 - 1o μm. This effect can be used for the combatation of blue-green algae water blooms. At these high stocking rates in ponds a reduction of the algae biomass is only possible, if the algae are already saturated with nutriment. Beyond it in stratified lakes the sedimentation of the nutriments being contained in the silver carp excrements can become effective in cases of a lower nutriment supply over the inflows. Therefore there are several points of

view, speaking for the inclusion of silver carps into reorganization plans for enclosed, strong eutrophic waters in the GDR.

Under the point of view of the combatation of algae mass developments two fields of effects of the silver carps (Hypophthalmichthys molitrix) can be distinguished:

1. direct effects by feeding away of plankton, sedimentation of excrement balls and by regeneration of nutriments,
2. indirect effects by nutriment accumulation in the fish body and taking out these nutriments from the water in catching the fishes.

The direct and the indirect effects of the silver carps depend on the possible stocking rate. Moreover at the direct effect by sedimentation and nutriment regeneration it is mentionable, if a pond or a stratified lake is under consideration.

The hitherto investigations about the combatation of algae mass developments by silver carps have been carried out in small carp ponds and in the laboratory. The stocking rates were 17oo si_{sp}/ha, 3ooo si_2/ha, 1o ooo si_3/ha, 12 ooo si_2/ha, 15 ooo si_3/ha. The investigations are still to be extended upon intermediate stocking rates and in order to secure the results to a great extend they have to be repeated.

According to the theoretical expectations the possible stocking rate is essentially higher than that of fish species feeding small animals. Under the climatic conditions of the GDR the increment per specimen si_{2-3} at stocking rates below 1ooo sp/ha is about 2oo - 25o g (JAENICHEN 1969). Beyond stocking rates of about 3ooo si_2/ha these "normal values" are decreasing. With a stocking of 12 ooo si_2/ha still about a third of the normal value could be attained. The hitherto utmost increment per area was attained in a normally managed carp pond with a stocking of 1o ooo si_3/ha. It was about 1 t/ha. In shallow lakes with a trophogenic zone possibly 2 - 3 times higher yields can be expected. However then the increment per specimen is only about

1oo g. Possibly this implies additional problems for the fishery production technology. However the possibility of very high increasings of the production of marketable fishes by means of silver carps is opening also at the climatic conditions of the GDR. A silver carp yield of 1 t/ha is identical with a P - carry-out of o,5 g/m^2 a year. As mentioned above in certain circumstances in shallow lakes with a depth of 2 - 3 m this value could be higher by the factor 2 - 3. A nutriment export of this amount is not yet sufficient for a nutriment pauperization of strong eutrophic waters. The P - import of many waters in the GDR often is essentially higher and for instance attains values in the order of 1o' g/m^2 a year. In contrary it could be useful to include the management with silver carps into comprehensive reorganization plans for enclosed high eutrophic waters, also for an advantageous formation of the nutriment balance. Other kinds of a nutriment carry-out (f. i. partial moving away of the mud, diversion of hypolimnic water) could be completed by this way with a simultaneous gaining of high class fish flesh. However the direct effects of the silver carps being far extending independent of the effect of the fishes at the nutriment balance of the water have to be respected too.

According to the hitherto investigations the direct effects also become visible from about 3000 si_2/ha. In ponds with high stocks of one - summer - aged carps with an additional stocking of 3000 si_2/ha the phytoplankton amounts and also the plankton primary production are higher than in test ponds without silver carps. Similar observations have been made in Poland too (WOLNY and GRYGIEREK, 1972). The cause for the encouragement of the phytoplankton under these conditions is of two kinds. Firstly in the instratified ponds the nutriments set free from the deposited silver carp excrements are very well accessible to the phytoplankton. Secondly the macro-filtrators of the zooplankton, in particular Daphnia longispina, are decimated till to those insignificance by strong stocks of common carps. Hence a decisive regulation factor of the phytoplankton developments falls off. In ponds without a higher stock of common carps was proved, that also if the zooplankton stock is high silver carps hardly feed it. In an experiment with 1700 si_{sp}/ha f.i. strong stocks of cladocera and rotatoria appeared. They prevented a vegetation colouring or water bloom, although it had been tried to produce these effects by fertilizing and pumping - in of water being rich of phytoplankton from a pond situated besides. In a strongly fertilized pond of the same kind that contended 850 si_{sp}/ha at the time of the investigation in August a Daphnia clear water stage developed. These observations about a lacking or a small influence of the silver carps upon the zooplankton coincide with those of other autors. In our experiments the silver carps only then fed larger amounts of zooplankton, if it was no more plenty vital after a passage through a pump. Therefore as a working hypothesis we suppose, that the zooplankton to a great extent can escape living from the mouthes of the choiceless feeding silver carps. However at a charging of 12000 si_2/ha the zooplankton was evidently weakly developed (see figure 1). Therefore at this high stocking rate due to the very frequent fish mouth passages possibly the zooplankters are by and by hurted and yet filtered out. It is still to be found out, at which stocking rate this effect upon the zooplankton opens. From the hitherto observations only results, that this critical stocking rate undoubtly will lie between 2000 and 12000 si_2/ha. Below the critical stocking rate the zooplankters can be additionally used at the decimation of the phytoplankton, if the population density of the other fish species is controlled in a corresponding manner. In accordance with the examples mentioned this can be very effective in carp ponds too and can lead to a considerable reduction of the phytoplankton. The effects of the zooplankton and of the silver carps insofar are completing one another, as the decimation now happens beginning from both ends of the phytoplankton size spektrum. The zooplankton decimates the phytoplankton from a bacterium's size up to about 30 μm. In contrary the silver carps are filtrating the coarse zooplankters completely choiceless. Their effectivity range extends downwards till to the phytoplankters of about 10 μm of size. Consequently at a combinated use of zooplankton and silver carps the production of phytoplankton can evade no more into such size ranges being secure before eating losses as it often happens at the separate acting of both filtrator groups. In case of Daphnia mass developments f. i. blue-green algae blooms from large forms like Aphanizomenon and Microcystis often can be observed. However at a strong stocking rate silver carps with a weak zooplankton development those smaller nanoplankters are combinatorically furthered which cannot be filtred out by the fishes. This state has been observed in experiments with silver carp stocking rates of 10 000 and 12 000 si/ha in carp ponds. At the same time in both cases an Aphanizomenon development was put aside respectively suppressed. The removal of water blooms forming algae by silver carps was observed in small experiments too. That opens practical employment possibilities for the silver carps in waters with water blooms. However here has to be clarified too, from which stocking rate the effective removal of the water florescence algae begins. Under certain circumstances already stocking rates below 10000 si/ha are sufficient for this purpose. Undoubtly advantageous for a combatation of the water blooms is the circumstance, that as a rule these algae appear in the midsummer at maximum temperatures, when the nutriment requirement of the fishes has it's maximum too. Furthermore is the specific activity of the blue-green algae lower than that of other algae groups (FINDENEGG 1971). Possibly even there are stocking rate ranges, in which the combatation of the blue-green algae is suitable for a combination with the saving of the zooplankton. That has still to be examined in corresponding experiments.

At stocking rates of 10 000 si_2/ha and beyond under conditions of a very good nutriment regeneration like in an carp pond a mass development of nanoplankton will be the final state, because the zooplankton is lacking. A certain reduction of the algae biomass is connected with this state, if the production is restricted by the light and no more by the nutriments. In stratified lakes at such high stocking rates as a pecularity the nutriment settling would have to be respected. At the feeding rates that appear in midsummer according to estimative calculations a noticeable nutriment pauperization of the epilimnion can appear by the sedimentation of the silver carp excrements. Thus states would be thinkable, at which within a few days all the seston mass having been filtred out would be transported into the hypolimnion. In cases of a small nutriment import by the influx this effect of the silver carps could attain practical value too for the diminuation of algae masses (BARTHELMES, in print).

<u>Abbrevations:</u>

m	metre	µm	micrometers
ha	hectar (= 10 000 m^2)	sp	specimen
g	gram	t	ton (= 1000 kg)
kg	kilogram	a	year
si	silver carps		
si_2	silver carps, two years aged		
si_{sp}	silver carps being spawners.		

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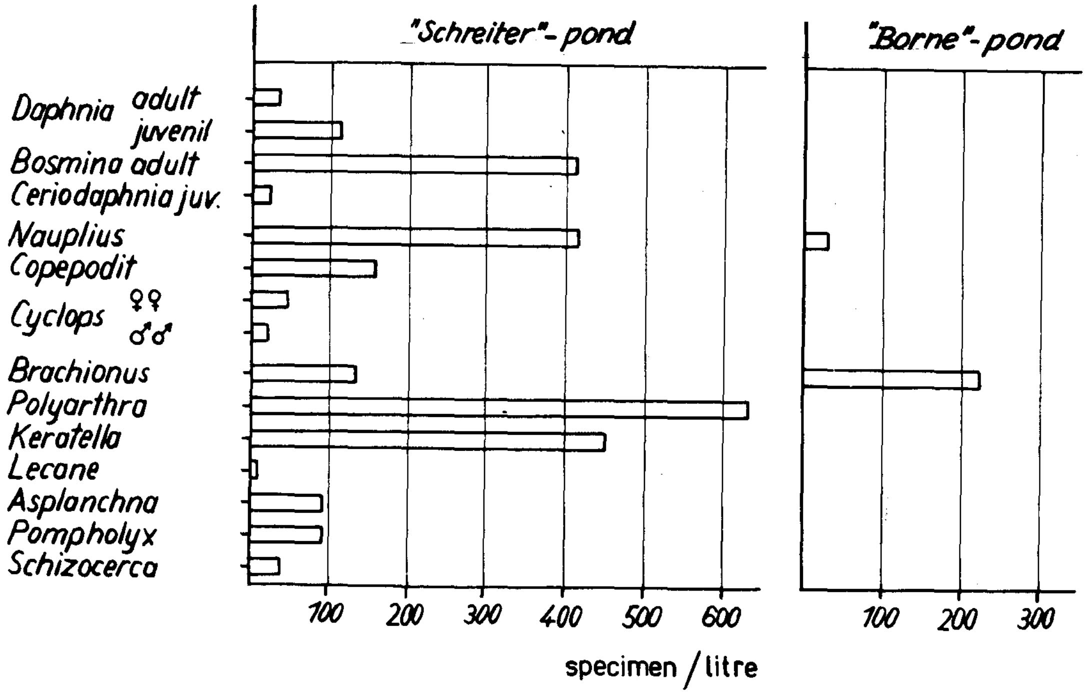

Fig. 1: Zooplankton stocks each in a carp pond without ("Schreiter"-pond) and with 12 000 si_2/ha ("Borne"-pond) in June until September 1974

COMBAT AGAINST MACROPHYTES BY CTENOPHARYNGODON IDELLA

H. JÄHNICHEN
Institut für Binnenfischerei, Berlin
German Democratic Republic

Summary

In 1966 for the first time fry of the grass carp (Ctenopharyngodon idella) was imported from the Soviet Union into the GDR. After it's breeding stage this species of fishes take as food filamentous algae (Cladophora, Spirogyra) and macrophyta. On the one hand the feeding on these plants makes accessible an ecolocigal niche of our waters which hitherto was not directly used, on the other hand in suitable waters it hampers any excessive growth of plants. With the aid of extending experiments and observations in different objects since 1967 the effectivity of C. idella in the combatation of aquatic plants could be proved. As premises for the successful application are concerned:

1. a sufficient water quality,
2. water temperatures being higher than 15 ... 16°C,
3. water depths of at least o,3o m with positions of 1 m and deeper,
4. exclusion of waters with single-species-colonization, for instance by Stratiotes aloides, Ranunculus sp. or with an abundant development of Nymphaeaceae,
5. objects which are suitable to prevent any migration of fishes,
6. fishes with a minimum age of two years,
7. mean stocking rate of 2oo kg/ha, which is to be reduced or raised due to the extent of the plant stock.

At present about 15o ha of water currents are being stocked with C. idella. Any further extension of the biological cleaning (of submerged plants) is actually atill restricted because of the shortage of fishes.

The first experiments on the acclimatization of the grass carp (Ctenopharyngodon idella) in the GDR were opened in 1965 and were continued in an increased degree when at the first time mentionable amounts of fry (5oo ooo specimen), 3 days aged and being capable of swimming and feeding were imported from the Soviet Union [19, 2o, 21] .

From the literature it was known to us, that after it's breeding stage this species of fishes is feeding itself on filamentous algae and macrophytes [2, 3, 21 and others] . Therefore it was the goal of the acclimatization in the GDR to make accessible with the aid of this fish species an ecological niche of our waters and thus to contribute to an increasing production without any expenditure in additional forage means. At the same time these fishes should contribute to the purpose to keep away any excessive growth of plants from the production waters and pond farms. The application of this fish species in the biological cleaning was not only a matter of interest in the fishery, but everywhere else, where an excessive arising of plants is disturbing the biological balance and thus hampers the natural production process, as f. i. in water storages, canals and in other water currents.

The water currents in the GDR are to be cleaned of submerged plants several times a year because of the strong plant growing. The expends for this aim are very high. Especially the water currents with small bottom latitudes are causing considerable difficulties, as here all the cleaning actions must be carried out manually. Therefore an effective combatation of the aquatic plants by C. idella could have a high economic advantage.

It is known from many publications, that the acclimatized C. idella make away with large amounts of aquatic and land plants with water temperatures being similar to those in their native country, i.e. water temperatures of 22 - 26° C [1, 2, 3, 5, 17, 18, 22] . Because such high temperatures under the climatic conditions of the GDR at the most will be reached in ponds during a short time, while in water currents the temperatures rise only few above 20 °C, it was the basic question, if under these conditions an effective biological cleaning would be possible.

After having solved positively the first basic problems of the acclimatization in the pond farms of the GDR as there are the hibernation and the breeding [13, 19, 2o] , we investigated the question, how far the aquatic plants, which occur most frequently in the GDR, are taken as food in water temperatures beginning from 16 °C [4]. After that we have examinated the effectivity of C. idella upon the aquatic plant - stocks in ponds and in different types of water currents (in canals, water streets and land - reclamation ditches) [5, 6, 7, 8, 9, 1o, 11].

Since 1967 comprehensive results of experiments and practical experiences could be gathered. Here the most important results are to be communicated.

From the forage experiments and nourishment investigations it was evident, that already in an age of 2 - 3 weeks and with a total length of 1,5 - 2 cm the fry begins to take vegetable food, above all filamentous algae. After that preponderantly fine tender submerged plants being in their youth stage are fed. According to the further growth of the fishes their food spectrum expands itself. In August / September the one - summer - aged fishes, having a mass of 15 - 25 g a specimen, are already devouring all aquatic plants being accessible to them. Only those plants are not yet taken which cannot be caught by the little fish mouthes because of the size of their stalks and leafs. Land plants can be taken as forage for the one - summer-aged fishes. The fishes take the forage from the water surface. Lemna stocks are cleared too, r espectively in the case of a high fish stocking they are far extending annihilated.

In the second summer in the GDR the C. idella in square are growing up to 2oo - 4oo g. Already in this phase they feed tall and hard macrophytes as there are Thypha, Phragmites, Carex, Juncus and others. Exeeptiones not being fed are Stratiotes aloides and Ranunculus sp., while Nymphaeaceae are fed only under extreme conditions. In ponds the fishes are already successfully used on the combatation of aquatic plants. In accordance to the stoutness of the plant supplies up to 1ooo specimen each ha are used and even more in extreme cases. By this means completely overgrown waters could be got back for the production of carps.

At present we can confirm, that the expensive mechanical combatation of the aquatic plants in ponds, having been commonly used years ago, could be replaced with a high economic advantage by the biological procedure with the aid of C. idella.

Since 1968 we have tested in different water currents (canals, land reclamation ditches, water streets) if those are suitable to the biological cleaning by means of C. idella [5, 6, 8, 9, 1o, 12], after we had found out by profound investigations about the taking as food of macrophyta in water temperatures of 16 - 22 °C, that the fishes with a high effect take the aquatic plants which are most frequent in the GDR [4]. By this we could clear up the basic question mentioned above and conclude, that by the application of C. idella the development of excessive plant stocks can be restricted or prevented. At a successful combatation of the aquatic plants however the following premises have to be fulfilled.

Water quality: The water has to correspond with the demands of a fish water. Especially is to take care of waste water influences and oxygen content. The oxygen content shall not decrease to values less than 3 mg O_2/l.

Water temperatures: If in the summer months the maximum values do not attain 15 - 16 °C on an effective plant combatation cannot be counted.

Water depth: The grass carps consequently avoided the shallow tracts of the above stream currents. As they are shy and very timid animals these parts of waters do not offer any hiding possibilities to them. It is known, that grass carps flee into deep water positions, if they are disturbed in any way. Also because of the security against robbery shallow water currents on principle are to be excluded of the charging with grass carps. Therefore only such waters are suitable for a biological cleaning whose water depths don't sink below o,3o m, whereas tracts with a depth of 1 m or deeper should be present. At the same time this offers the guarantee for a secure hibernation in the water currents.

Vegetation: Water currents with a single - species colonization, for instance by Stratiotes aloides, Ranunculus sp. or Nymphaeaceae are to exclude of the biological cleaning by C. idella and first of all they should be estimated by a specialist.

Lattice works: The migration of the grass carps from ponds is sufficiently known. On water currents we have gathered similar experiences. Therefore at human being's judgement the blocking has to be absolutely secure, because hereby depends any success of the biological cleaning. The experiments carried out up to now have shown, that a blocking device which is to be constructed anew, causes relative high expenses in procuring and attandance and at the very end it offers no guarantee for a secure lattice system. Because at the biological cleaning blocking devices will be necessary in future too as a rule already existing dam constructions (weirs) come into question, where only suitable bar lattices are put in. By this means complete water systems are secured against a migration of fishes. The lattices at present most commonly used are bar lattices with bar distances between 4 and 5 cm according to the sizes of the used fishes. The small bar distances are causing the effect, that larger drift - goods are stopped. Therefore the lattices must be cleaned dayly. The necessity of a stable and secure lattice blocking is considerably restricting the comprehensive application of grass carps in larger central water currents, if there are no possibilities for the drawing-in of lattices.

This question caused the intention to investigate the possibility of an application of electric fish repulsers. A positive result would be a contribution to a still further extent of the biological cleaning.

Stocking rate: At the stocking should be taken into account, that in water currents the water temperatures in square are by 3 - 5 °C lower than in ponds [5] . At the other hand many water currents have a pike population (Esox lucius), so that little C. idella would be strongly exposed to danger. Therefore the fishes should be at least 2 years aged and should have a mass of 2oo - 25o g a specimen.

By the experience that could be gathered in the last years the foundation for a new combatation procedure of unwished aquatic plants in water currents was performed. The large scale experiments having been carried out up to 1973 corresponding to proposed criteria successfully passed and were connected with a high economic advantage. In 1972 a trass of water currents of total 33o km with a square bottom latitude of 3 m was held free of aquatic plants by C. idella. In such cases up to 5o m^2 ground sheet are held free of aquatic plants by 1 kg C. idella. In 1973 and 1974 the biological cleaning was not mentionally extended because due to the problems in the breeding no fishes were available. But in autumn 1975 a new stocking could be realized, so that 1976 about 15o ha are held free of any excessive plant growing. In accordance to a square bottom latitude of 3 m this is a water trass of about 5oo km. By the stabilization of the artifical augment and breeding of C. idella [7, 11] at present in the fresh water fishery they complete the stipulations for covering the demand for biological cleaning. At present the total demand for a first stocking is about 2oo t, i.e. about o,57 - 1,o million of two-years aged C. idella. With this not yet all suitable water currents and water systems are included. We think, that the biological cleaning can be successfully used all over there, where as to the temperature are existing better or similar conditions as in the GDR. This could already be proved by corresponding experiments [14, 15, 16, 2o, 23, 24] .

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BIOMASS DEVELOPMENT OF SUBMERSED MACROPHYTES IN EUTROPHIC SLOW FLOWING WATERS AND ITS EFFECTS ON THE WATER OXYGEN BALANCE

W. JORGA +) and G. WEISE ++)

+) VEB Projektierung Wasserwirtschaft, Bad Liebenwerda

++) Technische Universität Dresden, Sektion Wasserwesen, Dresden

German Democratic Republic

Flowing waters which are rich in macrophytes show a pronounced day and year rhythm of their oxygen balance, which does not exist in such a degree in heterotrophic stretches of flow. For clarifying causal relationships between the biomass development of submerse macrophytes and the oxygen balance, the Kleine Elster in the Cottbus district (GDR), an in its lower course considerably weeded receiving water of the lowland plain, was selected for being investigated, since due to the low mean rate of flow (0.15 m/s to 0.20 m/s) the atmospheric oxygenation remains low and therefore variations of the oxygen balance should be mainly conditioned biogenic.

Dynamics of the biomass development

If sufficient nutrients are available, as it is true for the receiving water investigated, the biomass development mainly depends on the light available. In the lower course, which is rich in plant nutrients, in spring the biomass development, reaches maxima of about 300 g/m^2 (dry weight). In summer even values of > 600 g/m^2 (maximum values > 1200 g/m^2!) are obtained. As expected, when they drop in autumn, the biomass development decreases to values of ≈ 100 g/m^2. An extra-ordinarily high degree of biomass development in spring is observed with eutraphentic species (dispersed mainly in eutrophic waters) as Potamogeton pectinatus. In the summer aspects Potamogeton species (P. pectinatus, P. natans, P. crispus) are dominant besides Elodea canadensis and Ranunculus aquatilis. Ceratophyllum demersum, Callitriche and Ranunculus species winter as well as Elodea canadensis. Here the light available and the waste water load are the main limiting factors.

Biomass development and its relations to the water oxygen balance

In order to determine relationships between the biomass development of the subaquatic flora and the oxygen balance in flowing waters, synchronously determinations of the oxygen content were performed at the plant sampling stations in the river area of the Kleine Elster (WINKLER method, electrochemical oxygen measurements with membrane-covered electrodes). The influence of macrophytes becomes particularly evident when a heterotrophic stretch of flow is compared with an autotrophic one. Such conditions could be studied also in the Kleine Elster. In the heterotrophic stretch of flow, caused by mass inflows of waste water, in the growing season (April-September) oxygen saturation values of < 20 % were found, which drop to < 5 % (about 0.5 mg/l O_2) in the summer months of August and September in an extreme case. After the digestion of the putrescible substances contained in waste water mineral nutrients are liberated to a high degree, which promote the biomass development of submerse aquatic plants. Under conditions that again are autotrophic we have found oxygen concentrations which already in the morning hours had exceeded the 75 % saturation limit. Here should be underlined, however, that in the early morning hours extremely low oxygen values are observed.

Fundamentally, high biomass values cause high nocturnal respiration values at summerly water temperatures.

With regard to photosynthesis negative feedback phenomena become effective with a biomass development of ≥ 250 g (dry weight) $\cdot$ m^{-2}. Here should be mentioned self-shading and increasing spatial competition, which simultaneously impair the net assimilation and thus the photosynthetic water oxygenation. Up to the biomass limit value mentioned the photosynthetic oxygen production of subaquatic plants l i n e a r l y varies as the light available.

The photosynthesis of submerse macrophytes can also be determined by infrared gas-analytical investigations from the CO_2 consumption (IRGA methods). By the installation of the IRGA measuring unit in a mobile laboratory there can be made effective the advantages inherent in this highly sensitive measuring technique. On the basis of continuously ascertained CO_2 corversion, the production performance can be determined.

Conclusions

If the limit value of 250 g (dry weight) • m^{-2} is exceeded, a high nocturnal oxygen deficit results in slow flowing waters due to the respiration of macrophytes. If the light available is unfavourable, also in the daytime the photosynthetic oxygenation can be highly restricted. In dense standing crops of plants we have found by means of simple underwater light measurements (selenium photocells immersed in the underwater plant standing crops) that the relative light supply (light supply at the measuring point as referred to the intensity at the surface of water) decreases down to < 5 %. In this case, on days with cloudy weather, which often bring rain, hardly any photosynthetic "gain" is achieved. On the basis of their investigations in the very weedy lowland river Ivel (Great Britain) OWENS and coworkers found out that on cloudy summer days 70 % of the oxygen consumed every day in the water is lost by respiration processes of the higher aquatic plants.

The oxygen depletion by macrophyte respiration is more important when the atmospheric oxygenation remains low at an only low rate of flow of the water. This, however, is the direct result of the decrease of the rate of flow due to the biomass development. Since after continuous rainfall, waterlogging and flooding of agricultural acreages are possible, the removal of the "weed congestion" is advisable as a measure of environmental protection. In normal years in the lower course of the Kleine Elster, which is particularly rich in macrophytes, the first removal of weeds per year has to be carried out in May already. This action is performed mechanically. The following removals of weeds are carried out in the months of June to September. The vegetable matter removed by machines must be immediately removed from the receiving water, since its dying down in the water and the subsequent microbial decomposition would constitute further considerable loadings. The maximum biomass value of > 500 g (dry weight)

$\cdot m^{-2}$ determined by us in the Kleine Elster corresponds to a biomass of > 50 t/ha. In fact, during removals of weed (3 cuttings of weed within the growing season) in the Kleine Elster (lower course) 60 tons of vegetable mass were removed per ha receiving water. In many allotment gardens in the Bad Liebenwerda county already the vegetable matter obtained from the recipient by removals of weeds is used as compost manure very successfully. Also with respect to agriculture, the utilization of this high-quality humus manure appears us as a contribution to the stabilization and improvement of soil fertility. Also the use of harvested subaquatic plants, with the exception of the poisonous Ranunculus species (THOMAS 1975), as fodder (perhaps as silage or pellets) should be studied as soon as possible, the more so as in the Cottbus district already first success has been made with such a utilization.

Among the methods for the control of an excessive biomass of aquatic plants the biological method is the most significant. Higher aquatic plants can be primarily utilized only by few groups of animals. Since the application of herbicides is not possible everywhere for reasons of environmental protection, only real primary consumers come into consideration for preventing a mass development of the aquatic flora: the east Asian herbivorous grass carp Ctenopharyngodon idella, the common swan (Cygnus olor), phytophagous apteral insects, sea cows (Manatidae) in tropical and subtropical regions. By using the grass carp in weedy lowland rivers costs of the mechanical removal of weeds as well as labour necessary for it can be saved, if the using of these carp is not made impossible by masses of poisonous Ranunculus species, because they are not eaten (JÄHNICHEN 1973). "The removals of weeds necessary in the GDR every year in central watercourses over a length of about 26,000 km and an area of about 14,000 ha (inclusive of necessary repeated weed removals in many stretches and areas) for guaranteeing a flood drainage without any damage, taking into account an average cost of about 0.15 M/m^2 clearly show that each possible reduction of the expenditure for removal of weeds would result in a high economic benefit" (FIEDLER 1973).

This aspect of the economic expenditure must be taken into account for all necessary regulation measures for waters in the future. In eutrophic flow waters oftenly a shading effect by riparious woody plants constitutes the best prophylaxis for limiting the biomass formation. Thus, by an increased growing of bank-protecting woody plants in the lowland every possible reduction of the expenditure for the removal of weeds would result in a high economic gain.

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CONSIDERATIONS ON THE INFLUENCE OF FISH ON THE FUNCTIONING OF LAKE ECOSYSTEM AND RESULTING WATER QUALITY+)

Z. KAJAK

Polish Academy of Sciences, Institute of Ecology, Department of Hydrobiology, Dziekanów Leśny near Warsaw

Poland

Summary

Silver carp, removing macrophytoplankton (a competitor of nannoplankton) and zooplankton - a consumer of nannoplankton, should stimulate the development of the latter. On the other hand, removal of matter from epilimnion with sedimenting faeces makes the water poorer; so does the decrease of zooplankton abundance and resulting decrease in excretion of matter to water. In stratified lakes, and the environments with low mud-water exchange, all this should result in the decrease of the trophic status of the water during stagnation period; more data are needed to allow predictions for longer periods. Several times decrease of phytoplankton biomass and the decrease of Cyanophyceae dominance was obtained in 6 m^2, 1.5 m deep plankton-tight enclosures with natural lake bottom, at 18 g/M^3 of phytoplankton and 30 g/m^3 of silver carp (KAJAK et al., 1975). However in shallow environments, especially those with common carp, phytoplankton is significantly stimulated even at very high densities - up to 213 g/m^3 of silver carp (JANUSZKO 1976, OPUSZYŃSKI, 1976). This is undoubtedly due to the increased rate of decomposition and circulation of matter; they result from promoting forms with shorter turnover time in plankton by silver carp and fertilization of bottom deposits by this fish. The shallowness of the environment combined with the thorough stirring of mud by common carp results in rapid release of matter from the bottom deposits to water.

Selectivity of particular groups of seston and of particular phytoplankton species by silver carp, and the modifications of physio-chemical conditions due to its activity, result in change of dominant species. Although blue-greens do not form desirable food, and other groups of algae are preferred, blue-greens abun-

+) Paper received after completing the General Report complex C dance and dominance often diminishes under the influence of silver carp.

An improvement of water purity can be also obtained, in certain conditions by other fish, e.g. common carp, through other mechanisms, like grazing on bigger zooplankton an increasing water turbidity.

The goal of this paper is to consider the possible ways of the influence of fish, first of all silver carp, on the phytoplankton in pelagial of lakes, and resulting water purity. There seem to be 3 main ways of the influence of fish on an ecosystem:

1. exploitation of food organisms, and thus decreasing their biomass, and changing quantitative relations. This in turn modifies the impact of the organisms exploited by fish, on the other components, connected with them.

2. Excretion of all kinds, influencing the chemistry of the environments and the decomposition processes.

3. Other ways of modifying the ecosystem, like stirring the mud, and thus increasing the amount of abioseston in water, changing the light and other physico-chemical conditions for phytoplankton photosynthesis etc.

Silver carp grows well not only in ponds, but also in moderately eutrophic lakes in temperate zone (OPUSZYŃSKI 1964, WOLNY 1970, BRYLIŃSKI, KRZYWOSZ, BIAŁOKOZ 1976). Although phytoplankton is usually the main component of food of silver carp, both zooplankton and detritus are often dominant (BORUCKII 1973, KAJAK et al. 1977, LUBEZNOV 1974, OPUSZYŃSKI 1964, SIRENKO et al. 1973, VOVK 1974). The percentage of phyto- and zooplankton in the guts in relation to their percentage in the water varies in various environments (fig. 1). The contribution of detritus is greater when the plankton is scarce. The growth of silver carp seems to be good, while it feeds on detritus (OMAROV and LAZAREVA 1974). This is very encouraging showing the possibility of growing the silver carp even in environments periodically or permanently poor in plankton.

Within phytoplankton blue greens are often avoided (but eaten, especially when very abundant and dominant) and diatoms are preferred (KAJAK et al. 1977, OMAROV and LAZAREVA 1974, SIRENKO et al. 1973, VOVK 1974). However the selectivity of particular groups and species of phytoplankton, as well as main food components (phytoplankton, detritus, zooplankton) is very changeable and it is difficult to see the general pattern at the present state of our knowledge.

Feeding on bigger phytoplankton the silver carp does not compete with herbivorous zooplankton, which feeds on smaller particles. On the contrary, removing bigger phytoplankton, which competes with the smaller one, the silver carp can improve the conditions for small phytoplankton and stimulate its development.

Taking besides into account that zooplankton is in lake water usually many times less abundant than the phytoplankton, whilst in the fish guts of silver carp only several times less abundant (KAJAK et al. 1977) and that turnover rate is rather higher for macrophytoplankton than for zooplankton, one can conclude that the pressure of the silver carp on the zooplankton is much stronger than on the phytoplankton. This makes the situation for small phytoplankton even more favorable, because not only its competitor (macrophytoplankton), but also its consumer (zooplankton) are diminished.

The selective feeding of zooplankton by silver carp is at present controversial. MALCMAN (1970) suggests selective feeding on bigger forms, GRYGIEREK (1973) - the opposite, and KAJAK et al. (1975) did not find serious influence of silver carp on the composition of zooplankton.

The abundance and composition of phytoplankton, resulting from the selective feeding of silver carp will of course depend on the intensity and selectivity of the exploitation of phyto- and zooplankton, on the abundance and quantitative relations within and between this groups, and on the environmental conditions.

Assuming rather high (as compared to natural fish stock in lakes) density of silver carp - 500 kg/ha what makes 10 g/m^3 within the 5 m epilimnion layer), 20 % daily ration of silver carp (BORUCKII1973, OMAROV and LAZAREVA 1974), and 40 g/m^3 of phytoplankton in lake water, we obtain 5 % daily removal of phytoplankton biomass. It is doubtful that this would decrease the biomass of phytoplankton.

Very strong decrease of the biomass of phytoplankton was obtained at the daily removal of at least 33 % of phytoplankton in experimental 6 m^2 enclosures with no other fish in a lake at 1.5 m depth (fig. 2) (KAJAK et al. 1975); it must be stressed however that the biomass of phytoplankton in the control was at that time comparatively low (18 mg/l). Zooplankton biomass decreased even stronger than phytoplankton one. Very low zooplankton biomass and resulting low release of nutrients in water were one of the reasons of low phytoplankton biomass. There was not clear change in a pattern of dominance within zooplankton except increasing share of nauplii. On the other hand there was very clear and positive change in dominance within phytoplankton - decrease of Cyanophyta and increase in Pyrrophyta and nannoplankton. Both the decrease in biomass and the described change of dominance were very desirable from water purity point of view. In fish ponds with common carp, at higher phytoplankton biomass (34 mg/l) and lower rate of its removal by silver carp - about 16 % daily at the beginning of the season, and more than 20 %, at the end of the season, the biomass of phytoplankton was only slightly - about 10 % decreased (JANUSZKO 1974), and this could result either directly on indirectly from the silver carp activity.

Assuming that at high - 40 g/m^3 phytoplankton biomass the removal of 50 % of it (that is 20 g/m^3) would efficiently decrease the bloom, one should introduce 100 g/m^3, that is 5,000 kg/ha of silver carp at the 5 m deep epilimnion. If 20 % removal of algal bloom is sufficient to diminish it, 2.5 times smaller fish stock would be sufficient; on the other hand, at 100 g/m^3 algal bloom, happening in polytrophic lakes, 2.5 times higher fish stock, that is again 5 t/ha should be applied to remove 20 % of algae biomass. That high stock of fish is unusual in natural water bodies but not impossible to apply for silver carp, taking into account its feeding plasticity and the possibility of feeding on detritus.

In the fish ponds with carp, even twice higher stock of silver carp (213 g/m^3 at the end of the season) phytoplankton was stimulated, not reduced (OPUSZYŃSKI 1976, JANUSZKO 1976).

The difference between silver carp influence in the enclosures without other fish (in the lake) and in the fish ponds with common carp, will be discussed further.

Filtratory zooplankton can be also important in a removal of phytoplankton. In highly eutrophic environments the biomass of the filtratory zooplankton reaches about 40 g/m^3, being similar to the high one of silver carp, mentioned above. The food ration of filtratory zooplankton is about 100-200 % of its biomass (HILLBRICHT-ILKOWSKA 1976), that is about 10 times higher than the food ration of silver carp. This means that the removal of some amount of zooplankton by silver carp, results in very significant decrease in the impact on small phytoplankton, what can stimulate its development, advantageous from the water purity point of view. But due to very complicated relationships within planctonic community, including feeding, competition, excretion to the environment etc. it is impossible at present to predict the results of both removal of phytoplankton, and the removal of zooplankton by silver carp. Moreover changes in bottom deposits will influence those in plankton.

Some of the above mentioned results (KAJAK et al. 1975) suggest, that very heavy pressure on phytoplankton, can in certain circumstances efficiently improve the water purity, at least for some period of time.

The feaces of silver carp sink rahter rapidly (1-3 m/sec.)-(BARTHELMES 1975), so they get out of the epilimnion before significant decomposition and nutrient release. Data by KAJAK et al. (1975) agree with that - in comparatively stagnant environment, the nutrients were thus removed from circulation for months.

In the water bodies with clear-cut thermocline, the nutrients would thus certainly not come back to circulation at least during whole stagnation period.

The situation is probably quite different in the environments (e.g. fish ponds) where the bottom is permanently and strongly stirred by benthophagous fish. This can stimulate both the decomposition of feaces, and the return of nutrients to water.

The feaces of filtratory zooplankton, due to their more liquid composition, return to circulation quickly.

Within other than discussed above, ways of modifying the ecosystem and purifying water, I shall mention only the succesful attempt of introducing carp to shallow eutrophic lake. By both changing the zooplankton dominance structure, and stirring the mud, this fish significantly decreased the biomass of phytoplankton and the value of primary production (KAJAK and ZAWISZA 1975).

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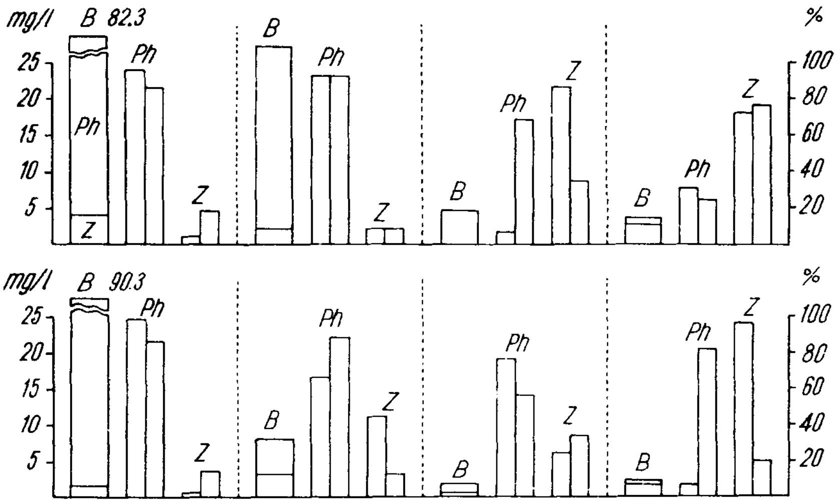

Fig. 1: Biomass of plankton (B) in environment and share of phytoplankton (Ph) and zooplankton (Z) in total plankton biomass in environment (left column in pair) and in guts (right in pair) of silver carp.
Upper part - 2 m^2 net cages, 15 VIII 1974; from the left: lakes Czarna Kuta, Mikołajskie, Guber.
Lower part - 6 m^2 enclosures; from the left: lakes Czarna Kuta, 10 IX 1974; Warniak, 19 VII 1973; 16 IX 1973; 10 IX 1974 (after KAJAK et al. 1977, modified).

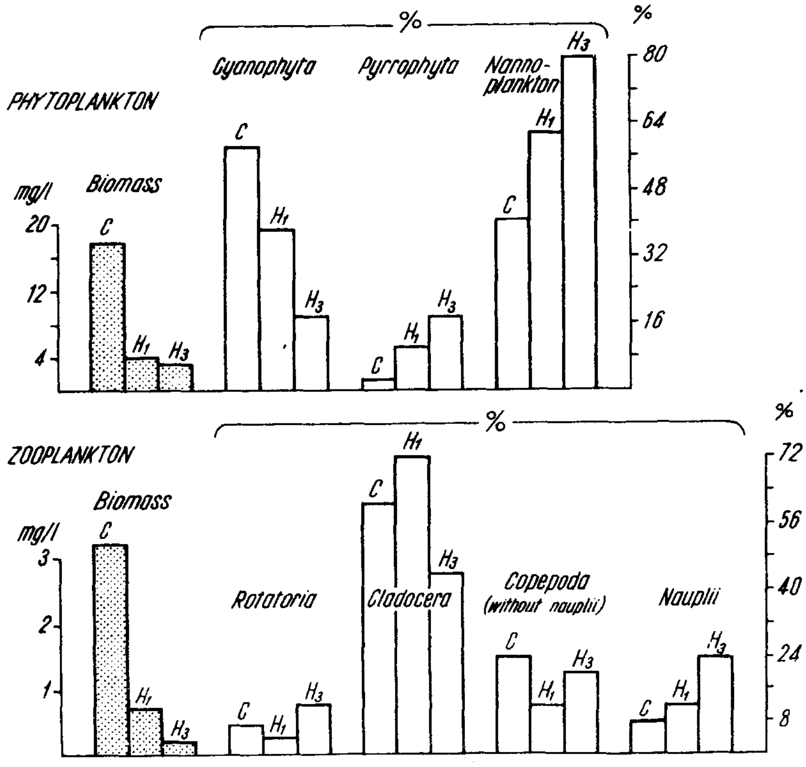

Fig. 2: Biomass of silver carp in plankton-tight enclosures: C - control - without fish, H_1 - with 1 specimen of silver carp per 1 m^3 (30 g/m^3), H_3 - with 3 specimens of silver carp per 1 m^3 (90 g/m^3). Average for the period July 5. - September 13. 1973 (after KAJAK et al. 1975 modified).

ALGAL PONDS AS A EUTROPHICATION PROTECTION

L. KALISZ
Instytut Kształtowania Środowiska, Warszawa
Poland

Summary

The paper presents results of research concerning the significance of algae in the removal of nitrogen and phosphorus from sewage. The investigated ponds worked as tertiary treatment plants.

An acceleration of the eutrophication process of surface waters is observed in last years, resulting from rapidly increasing amount of sewage and its concentration. This results in considerable and unwanted changes of surface waters.

The generally applied methods of biological sewage treatment, as activated sludge and trickling filters, allow to process the sewage to the level required by low. However, sewage waters already treated still contain certain amounts or organic substances. These accumulate in water bodies receiving the effluents and thus accelerate the eutrophication of such water bodies.

The investigation of the removal of mineral substances from sewage, down to the level prohibiting the mass development of algae, are carried out in many countries. This aims at the protection of surface waters against eutrophication.

The investigations are directed towards the utilization of physico-chemical and biological methods. The application of algal ponds, where a process of further biological treatment with parallel elimination of nitrogen and phosphorus take place belong to the latter group of methods.

The investigations on technical scale, carried out in many countries, supported the usefulness of this method and potential possibility of its application, especially in regions with relatively mild climate.

The sewage treated biologically is an especially convenient environment for the development of algae. This results in an intense green colour of water in biological ponds due to the algal development there in vegetation season. The phytoplankton in such ponds consists of few species with high numbers of particular populations. Euglenophyta, Chlorophyta, mainly Chlorococcales and Volvocales dominate there, and Bacillariophyceae to the smaller degree. Maximum number of phytoplankton algae in biological ponds comes up to 4,700,000 cells per 1 ml, showing their importance in the pond biocenosis.

The development of algae is closely related with the presence of nitrogen and phosphorus, the basic mineral components for algal metabolism. The lack or low concentrations of these components causes the inhibition or clear limitation of algal development. The ammonia salts, nitrites, nitrates can be utilized as sources of nitrogen. Also some organic nitrogen compounds as e.g. urea can be utilized. As the source of phosphorus the orthophosphates are assimilated in the easiest way. Also, some algae can utilize directly certain forms of organic phosphorus compounds.

The laboratory and field studies were run in the Institute of the Environment Formation for the estimation of the significance of algae in the removal of nitrogen and phosphorus from the sewage (1), (2). The field studies were run on sewage after full biological treatment, with low content of ammonia and organic nitrogen and with large content of nitrate nitrogen. The investigations were also carried out with sewage after partial biological treatment, with nitrogen mainly as ammonia nitrogen and organic one, with very low content of nitrites and nitrates. The phosphorus content varied, being on the average 1.2 mg PO_4/l after the full treatment, and 1.5 to 7.0 mg/l after the partial treatment.

The field studies in ponds showed a reduction of easily assimilated by algae forms of nitrogen (ammonia nitrogen, nitrites and nitrates). The reduction of these forms of nitrogen was lower in ponds with sewage after the full biological treatment, and higher in ponds with sewage only after the partial treatment. At the same time there was observed a twofold increase of the organic nitrogen within the algal cells in the period of mass development of algae. The organic nitrogen in other periods was reduced.

About the phosphorus it can be told generally that its amount was reduced in both cases of low and high loads in sewage flowing into the ponds. The reduction of phosphorus was the highest in ponds with the most intense development of algae.

For the more detailed studies of algal removal of nitrogen and phosphorus from sewage, and for the elimination of factors disturbing these processes in the natural conditions in ponds, a laboratory experiment was made on monocultures of algae isolated from ponds.

During the experiment the intensity of algal development was estimated as changes of the dry mass of algae. It should be pointed out that there is 2-10 % of nitrogen (6.5 % in the case of Chlorella, and 2.2-7.65 % in the case of Scenedesmus) and 1-2 % of phosphorus in dry mass of algae. Thus with the more intense development of algae larger amounts of phosphorus and nitrogen are assimilated from the environment by algae. The reduction of the amount of nitrogen and phosphorus in sewage was compared with the increase of the dry mass of algae. Different reduction of both these nutrients was observed in particular monocultures. The highest reduction of nitrogen and phosphorus in relation to the increase of algal dry mass was found for Scenedesmus obliquus. The lowest reduction of nitrogen in relation to the increase of the algal dry mass was found for Sc. quadricauda, and of phosphorus - for Chlorella vulgaris. The average reduction of nitrogen from sewage was roughly equal to the percentage contribution of this element in algal dry mass. The phosphorus reduction was higher. This resulted on one side from the assimilation of this component by algae, but it could be also due to the favourable conditions for the precipitation of phosphorus (high pH during intense algal development). In the latter case the contribution of algae was indirect.

Summing up the above it should be stated that due to the algal development a certain amount of nitrogen and phosphorus is withdrawn from the environment.

It should be underlined, that independently from the removal of nutrients from sewage, some further biological purification of sewage takes place in the algal ponds. The degree of the removal of the wasteload, expressed as BOD_5 is high especially in summer, as the result of treatment in ponds depends mainly on the temperature. The removal of the total number of bacteria is very effective, also of the coli forms. That is why the ponds acting as tertiary treatment plants are a justified element of treatment in cases of necessary high degree of sewage purification.

A totally different and serious problem connected with ponds working as tertiary treatment plants is the removal, or strictly speaking, getting out the algae. The attempted various techniques or application of algicides were found to be troublesome and expensive. On the other hand algae are a potential source of material rich in carbohydrates, proteins, lipids and vitamins (biotin, riboflavine, pantothenic acid, vitamin B_{12}). The cultures of unicellular algae are being developed for yielding the quickly growing mass of these plants, which can be a source of vitamins, dyes, sterols and other compounds, and also can be used as animal or human food. It is also known without doubt, that algal yield of plant proteins is 20-30 times higher than in the case of common crops.

It looks, however, that in our conditions we should concentrate on natural utilization of algae as a component of plankton, which is one of the components of food chains in aquatic ecosystems.

The alge form a basic food for invertebrates as rotifers and plankton crustaceans, which in turn are the food source for fish. There are also certain species of plant feeding fish, which feed directly on algae.

Thus, proper management of algal ponds with cultures of plankton crustaceans or plant feeding fish can solve the discussed problem with direct profits for man and for the protection of his biological environment.

THE USE OF HERBICIDES FOR CHEMICAL WEED CONTROL INCLUDING ALGAL CONTROL AND ITS RELATIONSHIPS TO ENVIRONMENTAL CONTROL

D. KRAMER and G. SCHMALAND
Institut für Wasserwirtschaft, Berlin
German Democratic Republic

The removal of macrophytes and algae is essential in order to maintain the functionality of many waters or serves aesthetic purposes.

Plant harvesting, i.e. the removal of macrophytes from the bottom of rivers or lakes, has a long-standing tradition in irrigation and drainage systems since it is the only way to ensure the necessary flow of water. Especially over the last two decades, the eutrophication of waters has accelerated the growth rates of aquatic plants to such an extent that more and more time and labour had to be spent on their removal. In places where, in the past, between one and two harvests a year proved satisfactory, in general between three and four harvests are required today, with the amount of weeds to be removed having increased accordingly.

The conditions on the surrounding land are such that it is impossible or uneconomic to mechanize weed cutting and removal. Until the introduction of new weed control methods, weed cutting therefore had to be carried out by hand in 70 to 80 % of the waters. With the increasing general mechanization it became impossible to recruit labour for this job. The application of biological weed control is limited to a small number of water bodies because of its water quality requirements. For this reason, this problem has been and is being solved in the GDR by the use of chemical weed control on an ever wider scale.

After many years of research we began to introduce chemical weed control on a broad scale in 1967. In 1970, 12,000 km of water courses were harvested by this method. In 1975, chemical bottom treatment was applied to 10,000 km, chemical slope treatment to as much as 30,000 km, which is 8 and 30 per cent, respectively, of the waters requiring plant harvesting.

We regard this use of herbicides in and around bodies of waters as a measure of consciously planning the human environment. This must, however, not be allowed to interfere with the interests of environmental quality protection. Therefore, such a method must be kept under continuous scientific control so that agents and techniques can be eliminated immediately should the results of the increasingly extensive toxicological tests suggest dangerous side-effects.

Consequently, the development of techniques and their control does not rest with agriculture, which is charged with the practical execution of chemical weed control, but with Water Management, so that the aspects of water quality protection can be taken into account from the very inception of a treatment technology.

In this sense, particular attention is to be placed on the selection of preparations. Table 1 shows the preparations approved in the GDR for chemical bottom treatment, i.e. the removal of emergent macrophytes, and rates of application.

Table 1

Herbicides and application rates for chemical bottom treatment

Ser. No.	Herbicide or tank mixture	Active principle	Application area	Application rate g/m^2
1	Sys 67 Omnidel + Sys 67 Prop 1)	Dalapon + 2.4-DP	V,S,T,Z	4.0 + 0.5
2	Sys 67 Omnidel-N + Sys 67 Prop 1)	Dalapon-N + 2.4-DP	V,S,T,Z	3.5 + 0.5
3	Sys 67 Omnidel + Azaplant + Sys 67 Prop 1)	Dalapon + Amitrol + 2.4-DP	V,S,T	1.7 + 0.7 + 0.3
4	Sys 67 Omnidel + Azaplant-Kombi + Sys 67 Prop 1)	Dalapon + Simasin + Amitrol + 2.5-DP	V,Z	1.7 + 1.5 + 0.3
5	Azaplant-Kombi	Amitrol + Simazin	V,Z	3.0
6	CKB 1018	Amitrol + Simazin + 2.4-D	V,S,T	3.5

Ser. No.	Herbicide or tank mixture	Active principle	Application area	Application rate g/m²
7	Gramoxone	Paraquat	V,S,T	2.5
8	Reglone	Diquat	V,S,T	2.0
9	W 6658	Simazin	Z,T	3.5

1) also MCPA or CMPP

V = recipient

S = lake

T = pond

Z = influents

- -

As will be seen from Table 1 the technique is based mainly on Dalapon which is largely unobjectionable toxicologically. It has an acute oral LC_{50} to warm-blooded animals of about 9,000 mg/kg and shows LC_{50}-values of 7,000 - >10,000 ppm to fish. For killing dicotyledonous species a mixture of Dalapon and 2.4-DP, MCPA or CMPP is used. These preparations are also very suitable with regard to their acute oral toxicity to warm-blooded animals with LC_{50}-values between 800 and 1,000 mg/kg. With LC_{50}-values between 300 and 500 ppm as related to the low application rate of about 0.5 g/m^2 they have also a low fish toxicity. This ratio of application rate to toxicity is taken as a prime criterion in selecting a preparation. In addition, the concentration is calculated which obtains on herbicide application in a 30 cm deep body of water. The safety factor is obtained as the quotient of LC_{50} divided by this concentration.

Thus all substances mentioned so far have a safety factor of 250 against deleterious effects on rivers and lakes. Amitrol which is especially suitable by its mode of action for chemical weed control, but whose toxicologic effect on humans is still subject of controversy, is now being used only in combination with other substances to ensure that only very small amounts of active principle will reach the water body. A number of restrictions on the use of these combinations, e.g. a minimum water depth, sub-critical area application or local regulations which have to be co-ordinated with water resources and health authorities (sanitary inspectorates), make sure that no detrimental side-effects will be produced by the herbicides.

Gramoxone and Reglone are rapidly removed by sorption from the water and therefore to be considered most suitable from the water toxicological point of view. In running waters use is made of short-time inoculations for controlling submerged macrophytes, resulting in only a temporary loading of the ecosystem for thirty minutes, at the most.

Table 2 lists the herbicides and application rates for chemical slope cultivation. Again SYs 67 Omnidel is used to inhibit the growth of grasses but with considerable less expenditure in time and cost than required in chemical bottom treatment. Another agent for controlling grass growth is Malzid. The preparations included in Part II of the table serve for controlling the growth of dicotyledonous weeds on the slopes.

Concerning the side effects, of these agents, these are similar to those described with reference to the preparations used for chemical bottom treatment, with the exception of the compound preparation 2.4-D + 2.4.5-T. However, its use for chemical slope cultivation is limited to such cases where no risk of water pollution is involved.

Table 2

Herbicides and application rates for chemical slope cultivation

Ser. No.	Herbicide or tank mixture	Active principle	Application rate g/m^2
Part I - basic application			
1	Sys 67 Omnidel + growth-inhibiting herbicide ...	Dalapon	0.6 application rate as in part II of this table
2	Malzid + growth-inhibiting herbicide ...	MH	1.5 application rate as in part II of this table

Ser. No.	Herbicide or tank mixture	Active principle	Application rate g/m2
Part II - growth-inhibiting herbicides			
3	Sys 67 Prop	2.4-DP	0.5
4	Sys 67 MProp	CMPP	0.5
5	Sys 67 Prop Plus	MCPA + 2.4-DP	0.5
6	Sys 67 ME	MCPA	0.3
7	Sys 67 Komadam	MCPA + 2.4-D	0.3
8	Sys 67 Ramex	MCPA + 2.4-DP	1.0
9	Sys 67 Actril C	Ioxynil + CMPP	0.8
10	Selest	2.4-D + 2.4.5-T	0.6

In the GDR, the agents, their application rates and guide-lines for use are laid down as binding in TGL - GDR Standard 24 351/01-02.

The proper application of the methods of chemical weed control is, however, not only a scientific and administrative, but also an organizational and human issue since, in the final analysis, it is not the state of knowledge but its practical application with a sense of responsibility which decides on whether or not the interests of environmental quality protection are taken into account.

It is for this reasor that along with the general introduction of this technology into practice a special system of continuous implementation has been set up, for which principal enterprises were selected from among the water maintenance enterprises of each county, in which specially interested staff members concern themselves specifically with questions relating to chemical weed control. At the same time, there exist specialized work teams for chemical weed control whose members receive regular in-service training.

These principal enterprises and the Institute of Water Management are working closely together. The carrying out of chemical weed control measures by these enterprises is directed and evaluated regularly by staff members of the Institute.

These principal enterprises on their part instruct the other maintenance units within their territory on all questions of the use of this technology, taking into account environmental considerations. Fresh scientific findings and practical experience are generalized in demonstrations and at conferences held at regular intervals.

Representatives of the principal enterprises, the Institute of Water Management and the competent state authorities form together the study groups "Chemical Weed Control" within the Chamber of Technology (KDT). This study group organizes e.g. regular training courses for all those concerned with the application of chemical weed control.

These measures taken together enabled us to build up a reliable cadre with a good understanding of the technique and a great sense of responsibility that will ensure the correct and non-detrimental application of chemical weed control in practice.

WEED CONTROL IN THE IRRIGATION AND DRAINAGE SYSTEMS OF EGYPT. THE PRESENT PROBLEM AND PROPOSED SOLUTION

H. A. MOURSI
Botany Lab., National Research Centre, Dokki, Cairo
Egypt

Summary

The outbreak of aquatic weeds in the irrigation and drainage systems of Egypt causes serious losses annually. Dense growths of the weeds on the waterways have far reaching biological, ecological, economic and hygienic hazards.

The control programmes via traditional means (chemical and mechanical) are expensive and have many disadvantages. In addition to their environmental hazards, their effect is short-lived. Yet, these are the only available means. New and innovative control approaches need to be explored.

Recently, biological means of control are receiving considerable attention especially as long-term control agents. Ecological means, through manipulation of the hydrological regime and decreasing water eutrophication so as to create unfavourable conditions for the growth of weeds deserve study. The utilization of the weeds for agricultural and industrial purposes is also a field that need to be explored. For applying such measures and setting up sound control management, adequate knowledge of biological and ecological relationships of the weeds and ecosystems concerned is needed.

In view of the above mentioned facts an integrated programme of studies is planned with the purpose of establishing bases for rational management and control of aquatic weeds in the waterways (irrigation-drainage networks).

Introduction

The constructed series of river control schemes caused several ecological changes which encouraged the growth and spread of the water weeds in the Nile system of Egypt. Such outbreak of aquatic vegetation in the irrigation and drainage systems causes serious losses annually. Dense growths of the weeds in the waterways have far reaching biological, ecological, economic and hygienic hazards. It has created multifarious short comings to flow of irrigation water, drainage, navigation, fishing and fish production, dams, original waterways profile, hydraulic pumps, and the cultivation of many semi-aquatic crops.

The weeds cause greater losses of water by evapotranspiration. According to the Ministry of Irrigation estimates, the total water loss due to the presence of aquatic vegetation in the Egyptian canals equaled about 3.5 billion (10^9) m^3/ year The cost of one billion m^3/ year of the water amounts to 75 million Dollars.

Discussion

The most troublesome weeds in the Egyptian waterways are: *Eichhornia crassipes* and *Pistia stratiotes* (floating plants), *Ceratophyllum demersum*, *Najas* spp., *Ottelia alismoides*, *Potamogeton* spp. and *Zannichellia palustris* (submersed plants), and *Cyperus alopecuroides*, *Echinochloa stagnina*, *Nymphaea* spp., *Panicum repens*, *Polygonum serrulatum* and *Typha* spp. (ditchbank and emergent plants).

Egyptian activities to control water weeds started very early by manual means. However, during Summer 1964, the first year without flood (after the completion of the Aswan High Dam) the situation of water weeds was so serious that a crash control programme was carried out during 1965 - 1967 by Ministry of Irrigation using chemical, mechanical and manual means. The waterways were declared free. In the last few years there was enormous regrowth. The Ministry of Irrigation started another crash control programme from 1975 for three years using manual, mechanical and chemical means.

The control programme started in April 1975 by surveying weeds infestations in the watercourses. The survey is presented in Table 1.

Considering that there is about 50 000 km of man-manipulated water bodies (irrigation canals and drainage ditches) covering the Egyptian land, one can conclude from the table that about 80 % of the whole waterways (40116 km) were found infested by aquatic weeds in April 1975. Irrigation canals represent about 55 % of the total infested channels, whereas drains represent the rest. Since the total length of drains in the Egyptian system is much less than the length of irrigation canals, it can be inferred that the extent of infestation in drains is much heavier than that in the irrigation canals. The general eutrophication, due to discharge of plant nutrients that often escape from fertilized fields into adjacent ditches draining irrigated fields, contributes substantially to this heavy infestation.

Of the 40116 km of canals and drains recorded in the survey of 1975, about 12.5 % were infested by floating weeds, about 65 % by submersed aquatic weeds, and nearly 22.5 % by emergent aquatic and ditchbank weeds. The data also shows that the waterways in Upper Egypt (southern region) were free from the floating weeds. By contrast the water ways in Lower Egypt (Delta region) were heavily infested. Meanwhile, submersed weeds and to a lesser extent ditchbank weeds represent a serious problem in all regions especially Upper Egypt. It seems that the sedimentation in the High Dam reservoir of the alluvial materials (silt) carried by the Nile water makes the water more clear. This allows sufficient light penetration which ensure adequate photosynthesis, and hence vigorous growth, for submerged plant species. On the other hand, the relatively warm temperature allover the year is likely to promote growth of submerged weeds in the region of Upper Egypt all the year round.

Ministry of Irrigation survey also showed that the floating weeds (mainly water hyacinth) cover an additional area of about 40,000,000 m^2 of the northern lakes.

Table 2 presents the length of waterways that were declared free of weeds due to the crash control programme which lasted 7 months (from June to December 1975).

From the data of table 2, it is clear that the control management covered about 82.5 % of the infested area. Due to this programme, nearly all waterways infested with floating weeds were declared free. The table also shows that manual methods were principal means used for control (represent about 80 %) followed in order by chemical control measures (represent about 15 %), then mechanical means (represent about 5 %).

Chemical methods of control are among the most successful means. But such operations are costly, must be repeated regularly and indefinitely and has serious environmental consequences. The chemical control measures used in Egypt are mainly dependent on the use of the herbicides 2,4-D and acrolein. The pollution by chemicals and their residues (left after their break-down) together with the destroyed vegetation cause serious hazards to the different elements of the ecological system.

The use of mechanical methods of control in Egypt showed many disadvantages. Among these are: risk of incomplete coverage of the infested area, re-infestation by seeds or vegetative fragments left, and the need for frequent repetition of the treatment. The machines used are very expensive and the costs of their operation and maintenance are high.

Manual methods of controlling aquatic weeds have been widely employed. It is mainly applied in minor canals and areas where 2,4-D spray drift may endanger other field crops especially those of broad leaves. Labour cost for manual removal of weeds are relatively less expensive, yet the needed number of labourers are not easily available. The effectiveness of such methods leaves much to be desired. They are not encouraged for their bad hygienic consequences on labourers.

According to the reports of the Ministry of Irrigation, the total financial resources needed for the control of aquatic weeds in Egypt in the fiscal year 1975 reached 8.75 million Dollars, from which 5 million Dollars were paid in hard currency for the purchase of mechanical equipments and chemical herbicides. Budget for the programme of aquatic weed control in Egypt during the following two fiscal years 1976 and 1977 amounts to 5.75 million Dollars of which 1.9 million Dollars are in foreign currency. Thus the estimate of the total cost of the control practices in Egypt during the three years (1975 - 1977) is a staggering figure of 14.5 million Dollars.

As indicated from the recent survey of the infested waterways carried out in February 1976 and presented in Table 3, enormous regrowth was recorded in 29621 km. of the channels. This figure represents about 75 % of the infested area recorded in April 1975. Data in the same table also reveal that the situation will be worsen in the next summer especially due to the enormous infestation with submersed aquatic weeds.

The above mentioned data show that control by the mentioned means is costly and has many disadvantages in addition to their environmental hazards. Yet, there are no signs, so far, indicating that the problem can be controlled in the near future. Consequently additional control approaches are desirable.

Recently, biological means that use living organisms to attack the weeds, and ecological means that depend on or manipulation of natural environment so as to hamper or prevent weed growth are receiving considerable attention especially as long-term means of control. Aquatic weeds may be controlled by appropriate preven_tive measures that avoid creating environmental conditions conducive to growth. Possibilities also exist for the manipulation of the hydrological regime so as to make growing conditions unfavourable for the problem weed. The utilization of the weeds in agricultural and industrial purposes is also a field that needs to be explored. Such measures demand adequate knowledge of biological and ecological inter-relationships between the weeds and ecosystems concerned.

The growth of the weeds depends on a variety of interrelated factors. Of these factors are the silt content of the water and the dimensions of the channel which determine the influx of sun energy, as well as the rate of water flow which determines the rate of water aeration and plant movement. Other important factors which affect the establishment and growth of aquatic vegetation include: temperature, degree of eutrophication and availability of plant nutrients in the water, rate of vegetation decay which provides additional food andhumus, and presence of organisms and predators that affect the growth of the weed. All these and other factors must be analysed in order to develop effective methods of weed control. Such methods must be appropriate to local circumstances of climate as well as social and economic structure, since measures which have proved successful in one country may not be applicable in another. It is in these areas that research is urgently required and that synthesis of knowledge is essential.

To deal with the aquatic weed control problem on scientific bases, the Egyptian Academy of Scientific Research and Technology established a special committee (Water Weeds Research Committee) to plan, organize and supervise research programmes in this field. As a consequence of the extensive discussions carried by the Committee, the following components of a programme of studies are identified.

I. Biological, ecological and geographical studies

These studies will comprise an inventory of the weeds infesting the water bodies on geographical basis, carrying out surveys and studies on taxonomy, distribution and population dynamics. Such studies also deal with behavioural patterns and the relations between weeds and its environment. This will help to identify the scales of this problem, and will provide background information for the other series of investigations undertaken for its control.

The programme will cover the following research topics:

1. Botanical, phytogeographical, and taxonomic identification of the weeds infesting the waterways.
2. Periodical monitoring of aquatic weeds in the infested areas.
3. Studies on the life cycle of every weed: patterns, places, seasons, capacity and potentials of its propagation.
4. Studies on growth rate and chemical composition of the different weed organs during stages of their life cycle.
5. Studies on the relations between weed and the factors of climate, surrounding ecological systems, and other environmental conditions including physical and chemical properties of water.
6. Studies on the relations between different weeds and algae that exist in the same aquatic area and its reflection on the rates of growth and spreading.
7. Studies dealing with the effects of the weeds on the aquatic life (microorganisms, snails, fish and other vertebrates) as well as the effects on water quality.

II. Physiological studies on the effectiveness of the chemical herbicides used and its effects on the environment

The widespread use of synthetic organic chemicals in pest (including weeds) control is today under severe criticism of environmentalists. Consequently screening studies aiming at establishing guidelines and priorities for using chemicals in the control of aquatic weeds on grounds of effectiveness in eradication with minimum environmental hazard are urgently needed. The proposed studies will aim at clarifying the interactions between the chemical structure of the herbicide, the physiological considerations of the organisms and the surrounding environmental conditions. The studies are planned to cover the following research topics.

1. Reviewing previous studies and research results.

2. Collection of data about the different kinds of herbicides and selection of the promising and safest chemicals for use as aquatic weed killers according to its chemical and physical properties. This will cover: stability and persistance, volatility, susceptibility to chemical, physical and biological degradation, extent of adsorption on soil particles, ability to accumulate, and pathways of the degraded components into different elements of the ecological system.

3. Studies for identification of appropriate concentrations, methods, number and time of applications, necessary equipments, suitable stage of weed growth for application.

4. The periodical qualitative and quantitative estimation of effects of the tested chemical on the different morphological and physiological aspects, as well as definition of the mode of action and of pathways of such chemicals and its degraded components in the different weeds.

5. Studies on the relations between results obtained from the aforementioned investigations and climatic conditions prevailing during times of application.

6. Studies on the possibilities of mixing herbicides or adding other additives to the herbicide to increase its effectiveness and decrease its harmful side effects.

7. Technological studies towards increasing the effectiveness of the equipments used for treatment, and to minimize the harmful consequences due to its use in application of the chemicals.

8. Studies on static water undertaken in isolated places and closed areas to clarify the direct, indirect, immediate and accumulated effects due to the degradation of the chemicals at the recommended concentration used for weed eradication.

Such studies need to consider all organisms that use the polluted water including: humans, farm animals, birds, plant crops, other weeds, fish and other aquatic vertebrates, aquatic microorganisms, etc. It will also monitor physical and chemical properties of the water and its impact on purification treatments for potable supply and domestic purposes.

III. Studies on the means of biological and ecological control

The aim of these studies is to investigate possibilities of using certain species of the following organisms which are apparent natural enemies of weeds (whether native or imported) as control agents, and to define, in case of success, the pratical ways for its mass rearing and spreading:

1. Fish (grazers, mowers and soilers)
2. Harmless or less harmful weeds which practice competitive displacement
3. Insects
4. Pathogens
5. Herbivorous aquatic animals (as manatees)
6. Other aquatic herbivorous vertebrates as turtles
7. Herbivorous snails
8. Ecological factors that may counteract the existence and vital activities of harmful aquatic weeds (as growth, propagation and spreading out).

IV. Studies on the economical utilization of aquatic weeds

This part of the project attempts at determining whether it is possible to convert plants, which otherwise have to be expensively eradicated, into a product which can be used. At least in the near future much of this study will mainly consider the potential usefulness of these products in agricultural purposes. The possibilities of utilizing water hyacinth is an obvious example because it grows in large uniform stands and plants are floaters that are relatively easy to harvest. Such group of studies may comprise the following topics:

1. Development of ways and means whether manual or mechanical of harvesting and collecting aquatic weeds.
2. Development of efficient and economical means and processes for handling, dehydration, reducing the volume and transportation of aquatic weeds.
3. Studies on the potential usefulness of aquatic weeds as improving soil additives whether incorporated into the soil as green manure or after processing as compost.
4. Studies on the feasibility of utilizing the aquatic weeds in livestock diets whether fresh, artificially dried, or processed.

V. Studies on the integrated control of aquatic weeds

In general, no single method of control for aquatic weeds will give perfect solution for the problem, but all methods compliment each other. Complete eradication of aquatic weeds is undesirable since aquatic vegetation has positive as well as negative effects. The normal role of the vegetation in the water should be examined before extensive control measures are instituted.

VI. Regional coordination

This can be attained through contacts between specialists from the countries sharing the Nile basin to establish a coordinated regional strategy for aquatic weed management in the whole river system.

Table 1. Length (in km) of water-ways infested by weeds in the different parts of Egypt.
(Survey conducted in April 1975)

Geographical region	Total length	Type of water-way		Type of prevailing weeds		
		Drains	Canals	Floa-ting	Sub-mersed	Ditch-bank
1. West Delta	7254	3929	3325	1735	3975	1544
2. Middle Delta	8505	4332	4173	1061	5599	1845
3. East Delta	10147	4723	5424	1118	6642	2387
4. Middle Egypt	9269	4516	4753	1055	5515	2699
5. Upper Egypt	4941	756	4185	0	4484	457
Total	40116	18256	21860	4969	26215	8932

The data in this and other tables were collected from the reports of the Ministry of Irrigation, then tabulated, classified, summarized and interpreted according to geographical regions (see the map).

Tabel 2. Length (in km) of water-ways that declared free of weeds due to crash control programme lasted 7 months (from June to December 1975) classified according to the type of watercourse, the type of the eradicated weeds and the means used for control.

Geographical region	Total length	Type of water-way		Type of eradicated weeds				Means of control		
		Drains	Canals	Floa-ting	sub-mersed	Ditch-bank	Mix-ture	Man-ual	Mech-anical	Chem-ical
1. West Delta	3392	2095	1297	1209	2151	5	27	2163	103	676
2. Middle Delta	8971	5019	3952	2129	4862	628	1351	6217	721	2033
3. East Delta	6128	2912	3216	1624	3658	612	234	4885	197	1046
4. Middle Egypt	8377	2998	5379	968	4940	0	2469	7492	479	407
5. Upper Egypt	6412	1446	4966	3	5733	553	124	5489	123	799
Total	33280	14470	18810	5933	21344	1798	4205	26696	1623	4961

Table 3. Length (in km) of water-ways infested by weeds in the different parts of Egypt
(Survey conducted in February 1976)

Geographical region	Total length	Type of water-way		Type of prevailing weeds		
		Drains	Canals	Floa-ting	Sub-mersed	Ditch-bank
1. West Delta	3337	1602	1735	575	2432	330
2. Middle Delta	6693	2551	4142	78	6108	507
3. East Delta	6384	2431	3953	454	5022	908
4. Middle Egypt	7697	2528	5169	589	6239	869
5. Upper Egypt	5510	804	4706	0	4997	513
Total	29621	9916	19705	1696	24798	3127

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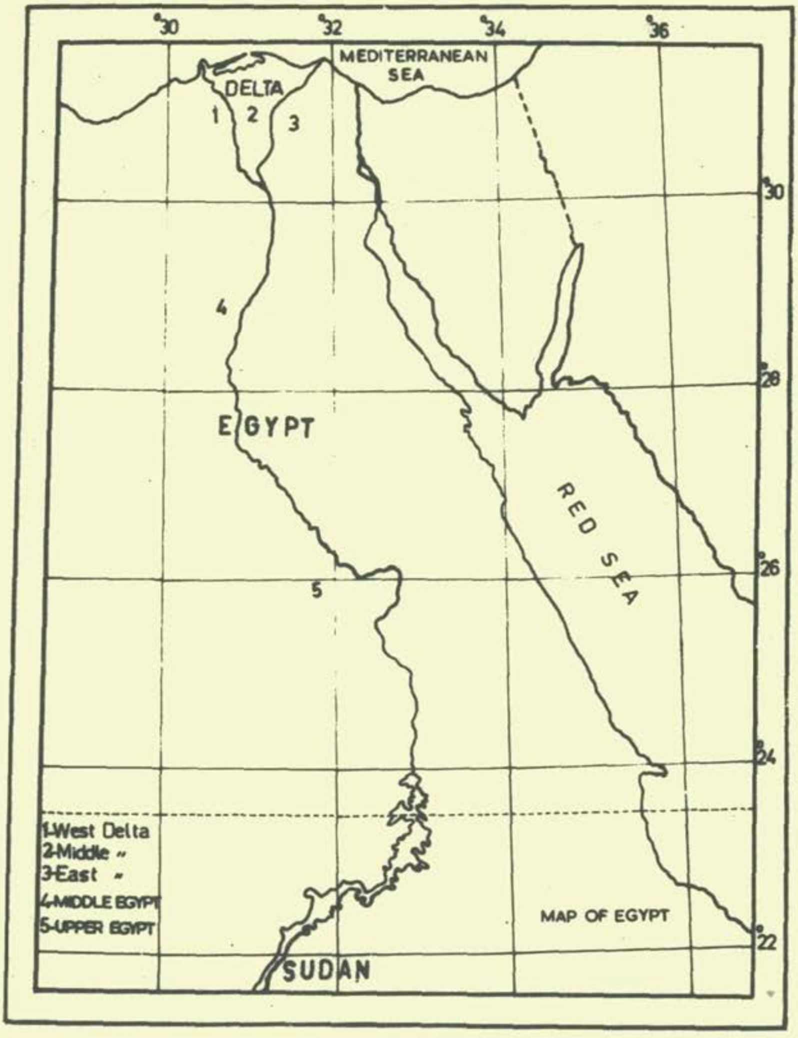
30
32
34
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MEDITERRANEAN
SEA
DELTA
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28
EGYPT
RED SEA
26
5
24
1-West Delta
2-Middle "
3-East "
4-MIDDLE EGYPT
5-UPPER EGYPT
MAP OF EGYPT
22
SUDAN

WATER TOXICOLOGICAL ASSESSMENT OF SELECTED PESTICIDES

M. TSCHEU-SCHLÜTER
Institut für Wasserwirtschaft, Berlin
German Democratic Republic

With the increasing intensification and industrialization of agricultural production growing use is being made of fertilizers, plant protectives and pesticides. These groups of chemical active substances are considered as major water pollutants in the long run.

The reduction in yield of crops caused by a variety of pests (weeds, viral, bacterial and fungal pathogens and animal pests) still amounts to some 20 % of the potential yields from crop cultivation. Over half of the total loss is due to plant diseases, 30 % to animal pests and about 20 % to weeds (HEY 1969).

It is generally estimated that the use of chemical weed killers, herbicides, in agriculture will continue to increase, especially that of herbicide compounds with a broad spectrum of action. A similar increasing trend is to be observed in fungicides for controlling fungal diseases as the most widespread plant disease. On the other hand, it is intended to restrict the use of insecticides with unfavourable side-effects (e.g. long persistence, accumulation in certain tissues of warm-blooded animals); such chemical insecticides as are less persistent and readily discharged from the body of the warm-blooded animal will continue to be available.

In water management in the GDR mainly herbicides are used in and along inland water-courses to counteract silting and to ensure the flow of water in irrigation and drainage ditches, and for slope cultivation and snagging (Industrial standard: Chemical Weed Control, TGL (GDR-Standard) 24 351/01).

Before any plant protective is used in a freshwater environment it should be rated according to the criteria given in the Catalogue of Water Pollutants (1975), paying particular attention to potential carcinogenic effects and acute or chronic toxicity to warm-blooded animals. Preparations with cancer producing properties (e.g. amino triazole) as well as substances which are highly toxic to fish and warm-blooded animals and which are accumulated and non-degradable biochemically, such as chlorinated hydrocarbons, must not be admitted for use.

Long-term investigations on herbicides used for chemical aquatic weed control provided evidence of adverse side-effects on fish. SCHULZ (1971), for example, observed a significant decrease in RNA in carp subjected for a period of 28 days to sublethal concentrations (25 ppm) of the grass killer Dowpon (Dalapon). The same author (1969) detected in carp exposed to 0.1 ppm 2,4-D solutions (synthetic growth-inhibiting herbicide) for 35 days lesions of nerve cells in the lower spinal cord and often, in the cerebellum of the fishes. Polish authors pointed out that the semichronic action of 50 ppm of the 2,4-D-containing commercial product 'Pielik' will delay hatching of the carp brood, cause morphological changes, slow growth rates and finally, mass mortality of fish (KAMLER et al. 1974).

From studies carried out by KOEMAN et al. (1969) it became known that Diuron, a urea herbicide which is well suited for the chemical control of submerged water plants and algae, is hardly metabolised but stored by carp. SCHULZ (1972) found in carp from a pond treated with Diuron, apart from a tautly enlarged, dark-red liver, degenerative changes in the kidneys and inflammatory lesions in the endocardium.

One way to control undesirable overabundance of algal growth is the use of chemical algae killers, the algicides.

The most widely and longest used algicide in fresh waters is copper sulphate. It is of moderately acute toxicity to warm-blooded animals but highly toxic to algae and between strongly and extremely poisonous to fish. The upper permissible copper sulphate concentration in fish ponds, excepting trout lakes, is taken as 0.5 mg/litre (CZENSNY 1934). The copper ions are rapidly absorbed by the algae which they kill within a short time, but it must be borne in mind that especially in fish ponds the ultimate decay of the algae may cause a severe oxygen depletion in the water bodies. Excess copper ions are precipitated as copper carbonate and locked in the sediment. In lakes repeatedly treated with copper toxic quantities of Cu^{2+} may be again released with decreasing pH -value which during full circulation are carried into the epilimnion (quoted from HUTCHINSON 1957).

The herbicides include, apart from inorganic algicides, triazines and urea derivatives containing organic active principles which are powerful photosynthesis poisons with very good algicidal properties. Both groups of substances are of weak to low toxicity to warm-blooded animals, carcinogenic properties have not been reported (TEICHMANN, SCHRAMM 1975). The effective application rates for controlling algae are in the order of micrograms and fish toxicity results only in the milligram range, so that the use of these algicides involves no acute poison risk for fish populations. Once more it has to be pointed out that the urea derivative Diuron is stored by carp. - Again it applies that the use of the above-mentioned organic algicides has a strongly adverse effect on the biogenic aeration rate of the water body, lasting for several days. In drainage ditches treated with herbicides the original amount of phytoplankton was reached after about a couple of weeks, with an increase in the amount of Euglenophyceae and a reduction of the species diversity of the biocoenotical structure (HEUSS 1972).

From the point of view of water quality management triazines and urea herbicides have the disadvantage of being non-degradable or difficult to degrade by activated-sludge micro-organisms (1975 Catalogue of Water Pollutants), with the result of the residue remaining active over a prolonged period of time, including the risk of accumulation in the body of water on repeated application.

Summarising, it can be stated that an intensive and industrialised agriculture has to rely on the increased use of fertilisers and plant protectives as well as on insecticides. At the same time, these groups of active principles constitute water pollutants of relevance.

If plant protectives are to be used in water management schemes these must be recognised and approved as suitable for this purpose. (1974/75 Index of Plant Protectives.) The active principles must be considered water pollutants (1975 Catalogue of Water Pollutants) and selected so as to keep the toxicological risk as small as possible. - Sanitation of rivers and lakes by means of algicides is not possible since the destruction of the algae fails to eliminate the nutrients from the nutrient budget of the water bodies.

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APPENDIX

NOTES ON THE "CATALOGUE TOXIC SUBSTANCES IN WATER", PART ONE AND PART TWO, PUBLISHED BY THE INSTITUTE OF WATER MANAGEMENT, BERLIN 1975

As a consequence of the quantities of toxic substances which are already harming the biosphere, catalogues are now being compiled which give a first survey of the human toxic and water toxic properties of environmental chemicals. Some examples are:

ALTHAUS, H. and JUNG, K. D.: Wirkungskonzentration (gesundheits-) schädigender bzw. toxischer Stoffe in Wasser für niedere Wasserorganismen sowie kalt- und warmblütige Wirbeltiere einschließlich des Menschen bei oraler Aufnahme des Wassers oder Kontakt mit dem Wasser. Düsseldorf 1972

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TEICHMANN, B. and SCHRAMM, H.: Substanzen mit kanzerogener Wirkung. 2. Ausgabe, Berlin-Buch, 1975

Simultaneously, every effort is being made by the compilation of tolerances, value limits and the highest possible rate of concentration of toxic substances to safeguard the biosphere from intoxication.

Examples are:

Predelno dopustimye kontsentratsii vrednykh veshchestv v vode vodoyemov sanitarnobytovogo vodosnabzheniya, Moskva 1970

Water Quality Criteria, Washington 1968

Allgemeine Toleranzliste. Anordnung Nr. 2 über Rückstände von Pflanzenschutz- und Schädlingsbekämpfungsmitteln in Lebensmitteln. GBl. DDR I,Nr. 3 1974

The compilation of the catalogue toxic substances in water must be viewed in relation to this. This is the first attempt to compile a comprehensive catalogue of relevant toxic substances in water. At the same time not only the chemical-physical properties of every toxic substance, toxicity in relation to mammals and to water organisms and even value limits are included but the possibilities of detoxication by chemical decomposition or physical-chemical processes.

ASSESSMENT OF TOXIC SUBSTANCES IN WATER ACCORDING TO THE CRITERIA OF THE CATALOGUE TOXIC SUBSTANCES IN WATER

Example: Monuron

Each toxic substance is characterized according to the following 14 points:

Points 1 - 6 relate to the chemical-physical properties of the active agent or the trade product. For monuron these are as follows:

1.1. Chemical term
2. Classification of substance group
3.1. Structural formula, molecular weight
5. Water solubility
6. State of aggregation, appearance, organoleptical properties, melting point

Under point 7 the biochemical decomposition and physical-chemical possibilities of elimination from watery solution by oxidation with chlorine and ozone, through absorption by solid bodies and flocculation are set out. According to the decomposition or elimination effect a subdivision into three to five groups is made, symbolized by the letters A to E. For Monuron it has been established:

7.1. Biochemically stable, Group C
7.2. Semi-oxidation with chlorine and ozone, Group B
7.3. very good absorption in corned coal WDW_{12}, Group A
good absorption in powdered coal EPW, Group B
non-absorbable in absorbable resin

7.4. Complete lack of elimination or only very little elimination through all applied flocculants, Group C

Point 8 Toxicity effect on mammals divided into:

8.1. acute oral medial lethal dose (LD_{50}) and estimate of the level of toxicity according to the HODGE-STERNER scheme Group A to E)
8.2. semi-chronic or chronic toxicity
8.3. cancerogenous effect

For Monuron:

8.1. acute oral weak poisonous effect on rats, Group B
8.2. no effect level: 1000 ppm dogs, 1 year feeding experiment
8.3. cancerogenous effect not known (-)

Under Point 9 the hygienic and other limit values are given. For Monuron the organoleptical threshold concentrations (9.2.) and simultaneously the drinking water utilization limit value (9.3.) are given as 5 mg/l. The zero tolerance for food (9.4.) in the GDR is <0.1 mg/kg, Group A.

The acute toxicity for water organisms is in points 10.1. to 10.2. The estimation of toxicity follows under 10.1. according to the level of threshold concentration, subdivided into five groups (A to E). Monuron has a strong toxic effect on Poecilia reticulata, Group D - and a high toxic effect (Group E) on Ankistrodesmus falcatus.

Point 10.2. gives medial lethal concentrations (LC_{50}) for representative water organisms or concentrations of a 50 per cent check on propagation in algae. From these good reproducable values the suggestions for the highest tolerable concentrations for river biocoenoses of the quality 2 (ß-mesosaprob) are derived by multiplication with a factor between 0.1 and 0.01.

For Monuron, a strong photosynthetic poison, the concentration of a fifty per cent check of Ankistrodesmus as a basis was made; the result was, after multiplication of a factor of 0.1

that 25 µg/l is the highest degree of toleration (10.3.).

Point 11 follows with analytical indications and point 12 with important additional facts about the particular toxic substance in water.

Under point 13 there is a classification of the toxic substances according to the following three categories:

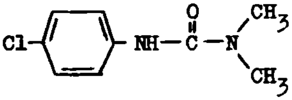
Category I: very dangerous toxic substance in water
Category II: dangerous toxic substance in water
Category III: less dangerous toxic substance in water

Due to its high toxic effect on algae monuron is placed in Category I.

Essential bibliography forms the conclusion (Point 14).

REPRODUCTION OF THE DESCRIPTION OF MONURON FROM THE CATALOGUE OF TOXIC SUBSTANCES IN WATER CATALOGUE PART I

1.1. N-(4-Chlorphenyl)-N,N-dimethylurea,
3-(p-Chlorphenyl)-1,1-dimethylurea (Monuron, CMU)
1.2.
2. Ureas, herbicides
3.1.



M : 198,67

3.2.
4.
5. 230 mg/l, 25°C
6. odourless, colourless powder
Smp. 176-177°C
7.1. C (IfW) BOD_5 adapted : 28 (IfW)
7.2. Cl_2 : B (IfW) O_3 : B (IfW)
CSV-Cr:1500(IfW) CSV-Cr(HS):1100(IfW) CSV-Mn:1050(IfW)

7.3. B (EPN) (IfW) A (WDW_{12}) (IfW)
E (ES) (IfW)

7.4. C (Al, pH 6,2) (IfW)
C (Alo, pH 7) (IfW)
C ($FeCl_3$, pH 5,5) (IfW)
C (chemical mixture pH 6,8) (IfW)

8.1. B rat (MAIER-BODE)

8.2. 2500 ppm in food increased mortality and delayed growth in two-year old male rats (MAIER-BODE)
no effect level : 1000 ppm dogs one year (MAIER-BODE)

8.3. - (TEICHMANN and SCHRAMM)

9.1.

9.2. 5 mg/l (Moscow 1970)

9.3. 5 mg/l drinking water (Moscow 1970)

9.4. A (GBl. DDR I,Nr. 3,1974)

10.1. D Poecilia reticulata (IfW)
E Ankistrodesmus falcatus (IfW)

10.2. LC_{50}/48 h: 203 mg/l Poecilia reticulata (IfW)
LC_{50}/96 h: 159 mg/l Poecilia reticulata (IfW)
IC_{50}/26 h: 106 mg/l Daphnia magna (CROSBY and TUCKER)
(IC_{50} = the concentration in which fifty per cent of the daphniae applied became immobile)
50 per cent check: 240 µg/l Ankistrodesmus falcatus (IfW)

10.3. 25 µg/l

11. ZWEIG, G.: Analytical Methods for Pesticides, Plant Growth Regulators and Food Additives, London, New York: Academic Press 1963

12. Photosynthetic poison

13. On the basis of its highly poisonous effect on water organisms the substance belongs to Category I of toxic substances in water.

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IfW = Results of investigation of the Institut of Water Management, Berlin

EUTROPHICATION OF THE SHALLOW WATER IN RESERVOIRS AND WAYS OF LIMITING IT IN CONJUNCTION WITH INCREASING THEIR BIOPRODUCTIVITY

I.M. VELICHKO, M.N. DEKHTYAR, L.A. ZHURAVLEVA, L.N. ZIMBALEVSKAYA, L.E. KOSTIKOVA, I.K. PALAMARCHUK, A.B. YAKUBOVSKI

Institut Gidrobiologii Akad. Nauk Ukrain. SSR, Kiev

Ukrainian Soviet Socialist Republic

The shallow water reservoirs, like the littoral waters of other regions, is a highly productive zone. Shallow water unites rich feeding places for fish and an extremely favourable water quality, which gives it considerable importance in the overall bioproductivity of the reservoirs. At the same time the eutrophication processes in shallow water are very intensive, this generally having the effect of reducing its bioproductivity, particularly as regards the consumers, which makes it essential to implement a complex of ameliorative measures.

The degree of eutrophication in the shallow water of the reservoirs is determined by processes in the water and an anthropogenic effect. Natural eutrophication in the water is connected with the character of the area flooded, the absence of flow, the hydrological regime, protection from the action of weather and waves, the amount of water occurring in the year and with an intensive development of vegetable and animal organisms.

The shallow water of hydroelectric power station reservoirs on lowland rivers is similar to that at the shores of lakes. But in contrast to the shores of lakes, the shore regions in reservoirs are characterized by specific features, the most important of which are the multiplicity of morphometric and hydrological properties depending on the origin of the shallow water. As a rule the shallow water of reservoirs is heterogeneous in origin. Taking as an example the Kremenchugskoye reservoir, K.K. SEROV (1) has shown that the area of the shallow water forming in the flooding region makes up 53 percent of the total area. On the other hand the shallow water on the second terrace of the flooding region occupies an area of about 46 percent. In these two main types, which in a number of features are quite dissimilar, a multiplicity of conditions is to be found which is extraordinary for a single stretch of water, since the most different types of water area were flooded (river bed and the system connected with it, lakes, ponds, marshes near to the terrace, tributary mouth regions).

The shore zones have a special role to play in the eutrophication processes since they are located in the region of direct contact between land and water (2, 3); under the conditions of the reservoirs this is of prime importance since the shoreline is very long and there is a direct contact with the catchment area of the adjacent agricultural land through the tributaries flowing into the shallow water.

At present the time of natural eutrophication, i.e. the gradual accumulation of biogenetic elements as a result of processes in the water, is accelerating owing to anthropogenic factors. This brings with it certain difficulties in the delimination of these two types of eutrophication and hence also in the development of measures for limiting eutrophy.

One of the most important preconditions which considerably promote intensive eutrophication as a result of processes in the water under reservoir conditions is the agricultural/geographical position. This phenomenon is quite clearly exemplified by two Dnieper reservoirs, the Kievskoye and Kremenchugskoye reservoirs. In contrast to the mesotrophy in the shallow water of Kievskoye, in the shallow water of Kremenchugskoye reservoir highly eutrophic conditions have developed. Kremenchugskoye reservoir, located in the forest-steppe, belongs to an agricultural region where the soil cover is extremely varied and consists of thick chernozem poor in humus. Soil-forming rock types in the bed of Kievskoye reservoir are low-productive fluvioglacial, loamy sand and sand sediments (4).

At present the most intensive eutrophication processes of all under the conditions of the Dnieper reservoirs take place in the shallow-water areas which formed in the flooded region. It is precisely these shallow waters which become almost entirely overgrown with higher water flora (5) - from 83 to 100 percent. In these areas the ecological group of primary producers, the phytoperiphyton, a group specific to the shore region, reaches maximum values as regards biomass (from 15.4 to 296.8 g/kg raw mass of plants). Only in such areas can the local "blooming" of the blue-green algae of the species Anabaena be distinguished. The massive development of primary producers as a phenomenon of intensive eutrophication takes place against a background of a high content of biogenes in the water, of NH_4 0.808 to 0.937 mg/l, NO_3 0.124 to 0.141 mg/l, and PO_4 0.113 to 0.124 mg/l.

The biogene content in the shallow water of the reservoirs, in particular in that of Kremenchugskoye reservoir, has considerably increased in the last ten years (6) by comparison with the river, which is no doubt connected with the increase of processes of anthropogenic influence.

The influence of runoff as the main source of the biogenetic elements takes effect especially in such shallow-water regions as have developed from the flooded mouth regions of the tributaries. The increase of biogenes (predominantly NH_4, NO_3, PO_4) in these shallow-water regions speeds up considerably during the spring flood (April, May), a phenomenon which has virtually no effect in the regions where there are no tributaries. In the summer months runoff has almost no influence on the shallow water since only very slight flows occur.

In the summer months a very large part is played in the accumulation of the biogenes by the surface runoff direct from the adjacent banks. Particularly noticeable is the increase in the quantity of nitrogen and phosphorus in the shallow-water regions, where the shore is intensively used for cattle grazing and for recreational purposes, and when there are mass accumulations of wild waterfowl. Under these conditions an illustrative factor is the increase of cellulose bacteria in the summertime.

Under relatively stable hydrological conditions in the vegetation period the soils are a very important supplier of biogenes. In the 11th and 12th year of the existence of Kremenchugskoye reservoir disappearance of the organic materials from the flooded soils took place. In sandy soil this loss amounted to 20 to 80 percent compared with the situation before the reservoir was constructed. In this period the meermolm and peat were marked by a high content of mobile and hydrolizing forms of nitrogen and phosphorus and amounted on average to 60 percent, which results in an intensive enrichment of the layers near to the soil and the whole body of water. The mud deposits store up organic substances, the content of which has increased to 200 percent compared with before the reservoir existed. The accumulation of allochthonous organic substances takes place in the shallow-water region where there are no tributaries and which is most isolated from the main part of the reservoir.

The leaching and easily mobile forms of nitrogen and phosphorous contained in soil compounds leads to the enrichment of the water layers close to the soil, and this takes place in the areas with the greatest movement of water, which were flooded in accordance with their origin.

A very important factor for the degree of concentration of the biogenes in the water is the volume of the body of water. The correlation between the volume of the water body and the content of NH_4 in the water was determined taking Kremenchugskoye reservoir as the example. Apparently the increased concentration of other biogenes in the water in years with little water and high summer tempratures is connected with this phenomenon, producing a considerable reduction in the volume of water not only through the drop in level but also through intensive evaporation.

Vegetable and animal organisms play a large part as sources of the biogenetic elements and organic substances. The interdependence between the biogene content in the tissues of the higher water vegetation and in the water (5) can characterize the higher water plants as suppliers of biogenes. Among the higher water plants the narrow-leaved cattail (Typha angustifolia) has a particularly pronounced eutrophicating function which is connected with the withering of the foliage of this plant troughout the growing season as a result of the mining activity of chironomid larvae.

The largest quantity of NH_4 is detectable in the bushes of the half-submerged vegetation and the smallest amount in completely submerged bushes with maximum amounts of NO_2 and NO_3, this indicating intensive nitrification processes promoted by a favourable gas regime. Consequently the different types of bushes create different conditions, which either speed up or slow down the process of accumulation of biogenetic elements. The years of little water favour in the subsequent years an intensive development of most higher water vegetation (according to data from S. J. KOSINA), the mass decay of which leads to the deterioration of the gas regime as a result of the accumulation of biogenetic and organic substances.

The degree of bioproductivity in the shallow water of the Dnieper reservoirs is determined in the present stage of its existence by the hydrometerological conditions in the year in question, which apart from a growing anthropogenic effect contribute to the acceleration of the eutrophication processes, these in turn appearing in different forms in the various zones and finally determining the productivity of the consumers.

The bodies of shallow water in the flooded regions which are eutrophicated to the greatest extent are characterized by relatively low biomass values of the phytophilic invertebrates (6) living on the bottom, the multiplicity of species increasing at the same time. In such areas certain α-mesosaprobic characteristic values undergo a substantial development, which permits those areas which are the most eutrophicated to be assigned to the α-mesosaprobic zone, the zone of high saprotrophy. In the greater part of the shallow water of the Dnieper reservoir region the saproby values are characteristics for trophy, the high extent of which is primarily determined by processes in the water against the background of an increasing anthropogenic import of biogenes. The deterioration of the gas regime in the shallow-water regions with little flow is connected with the massive development of primary producers (higher water plants and phytoperiphyton including thread algae) and is a result of eutrophication, which leads to biological self-pollution. Under such conditions no exyphilic invertebrates develop.

In the 11th to the 14th year of the existence of the reservoirs the productivity of the invertebrates in the shallow water decreases considerably by comparison with the first years. Particularly pronounced is the decrease in productivity of the invertebrates under the conditions of the most eutrophicated regions, where muddy and silty sediments predominate. Here phytophilic biocoenoses form, a large multiplicity of species being present, but no high biomasses which approach the climax conditions under the conditions of the river system. This indicates a more rapid development in the natural successive eutrophication in the reservoirs by comparison with the river waters, conditioned by the increase in the anthropogenic run-off.

With increasing eutrophication, which can assume a volley-like character in shallow water (in years of drought) and can be regarded as an autotrophic succession, there is the possibility that the productivity of the invertebrates increases. If the flow conditions are sufficiently pronounced, phytophilic biocoenoses develop with low multiplicity of species and predominance of the large forms of zooplankton, which occurs in large numbers and with a high biomass.

Increased eutrophication with hyperaccumulation of the organic substances leads in shallow water to deterioration in the quality of the water; this can be regarded as very favourable if one considers that there is no permanent "blooming" in the water through the concentration of the biogenes and the oxygen content. In the most eutrophicated regions there is a retardation in the development of the feeding resources for the fish.

The considerable supplies of biogenetic elements in shallow water can serve as an extremely effective source of biogenes for the phytoplankton in the deep-water regions and accelerate the development of "blooming". This phenomenon occurs only in the autumn months when there is an extreme drop in level.

The negative influence of eutrophication on shallow water can be suppressed to a large extent by a complex of ameliorative measures. These measures have to be taken in the years of drought, when the eutrophication processes are at their most intensive.

The direct removal of the biogenes from the water has to be combined with the conversion of the biogenetic materials from the shore-run-offs, for which shore afforestation is necessary.

It is possible and necessary to remove biogenes from the shallow water by eliminating the surplus of higher water plants. The higher water plants have to be systematically removed since it is only up to a certain limit that they are a very important factor for raising the productivity of the shallow water.

The increase in the biomass of the invertebrates and of the oxygen dissolved in the water in the cattail flags and in the reeds reaches its maximum values at 30 to 50 percent overgrowth, the biomass of the cattails being 4 to 5 kg/m^2 and that of the reeds up to 2 kg/m^2. The increase in the biomass of these species leads to the occurrence of α-mesosaprobic rotifers and saprobic nematodes, which is an indication of decay processes.

In the submerged thicket, even for a biomass of over 4 kg/m^2 and a projective covering of 80 to 90 percent high biomasses of the zooplankton are found, although in a number of other characteristic values an increase in saprobity is to be noted.

Where there is a moderate development of thread algae (up to 6 kg/m^2) the water purification processes predominate; when the biomass is over 6 kg/m^2 the biological pollution becomes predominant. These data can be used as criteria for carrying out amelioration work. Not only the denseness of the thicket is of great importance but also its area. Determination of the optimum areas for maximum bioproductivity of shallow water is a complex task, but one which is very necessary.

Removal of the higher water plants is particularly necessary in the most eutrophicated regions since apart from the vegetable mass considerable biogene supplies are also taken out of the water.

In the growing season, common reed contains at 40 t/ha: 600 to 650 kg/ha of nitrogen, 200 to 250 kg of phosphorus and 400 kg of potash. Rough calculations based on the determination of the supplies of thread algae in Kremenchugskoye reservoir showe that for the reservoir as a whole the quantity of nitrogen in the algae can amount to 20 to 30 t and the quantity of combined phosphorus 3 t. The removal of higher water plants and thread algae can be an extremely important regulator of the content of biogenetic elements.

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RESIDUES OF FERTILIZER AND AGROCHEMICALS IN RELATION TO EUTROPHICATION IN SRI LANKA +)

C. S. WEERARATNA
Faculty of Agriculture, University of Sri Lanka, Paradeniya
Sri Lanka

The term "eutrophication" has been defined in a number of ways. D. J. HALLIDAY /1/ has defined eutrophication as "enrichment of waters by nutrients which can directly fertilize the growth of aquatic plant and algae". KOLENBRANDER /2/ has indicated eutrophication as nutrient enrichment of waters. Enrichment of waters by nutrients derived from fertilizers and other agrochemicals such as insecticides, herbicides etc. could be considered under this process. In Sri Lanka a large amount of fertilizers and agrochemicals are used in agriculture (table 1).

Eutrophication due to fertilizers

Of the fertilizers used a considerable portion is applied for paddy which is cultivated under lowland conditions while the balance is applied for plantations, crops such as tea, rubber, coconut etc.

Sri Lanka receives a relatively high annual rainfall varying from about 50" inches per annum in the dry zone to 150" per annum in the low-country wet zone. Most of this rain comes down in two distinct periods and as a result rainfall of very high intensities are obtained in some parts of the country. The areas which receive high rainfall have hilly to rolling topography. Most of the soils are ultisols and alfisols and pH varies from 5 to 7.5 in most of the soils. The rate of infiltration in most soils is fairly high, around 2" per hour initially.

Due to the above factors enrichment of waters by fertilizers specially nitrogenous and potassic tend to be very high. High rainfall and hilly topography causes removal of surface soils which nutrients are removed too. The pH values in the soils are favourable for nitrification by added ammonium-nitrogen fertilizers, and investigations carried out in the Department of Agricultural Chemistry of the University of Sri Lanka, indicate

+) Paper received after completing the General Report to complex C that there is rapid nitrification by added ammonium ions, in the soils (table 2). Hence it is possible that these nitrates get leached down and enter water bodies such as lakes, rivers and tanks (found in dry zone). Further the CEC of most of the soils of Sri Lanka is relatively low; the average being 10 m. Eq/100 g.

Therefore, it is possible that even potassium applied to soil gets leached down and enter water bodies. Relatively little work has been done on the nutrient content of waters in lakes, rivers etc. in Sri Lanka. Investigations carried out by AMARASIRI /3/ indicate that water sampled from irrigation tanks in Sri Lanka contains considerable amounts of potassium (2.85 to 15.80 ppm) and other nutrients such as Na, Ca, and Mg.

In Sri Lanka in most of the paddy fields there is slow movement of water and the drainage waters of these paddy fields are also likely sources of high nutrients in water bodies.

With regard to phosphorus as has been indicated by a number workers /4/ leaching-out of phosphate ions is likely to be very little, mainly due to high P fixation capacity in Sri Lanka soils /5/.

Eutrophication due to agrochemicals

Enrichment of water by agrochemicals could also be considered under eutrophication. A considerable amount of agrochemicals of different types are used and these are biologically active compounds in that they influence metabolic processes in organisms /6/. It has been shown that most of the agrochemicals commonly used such as 2, 4 -D, MCPA are decomposed. By these substances in water could be influenced the growth of organisms. Initial studies carried out on the decomposition of some common herbicides used in Sri Lanka indicate that 3.4-dichlorophenyl-dimethyl urea and pentachlorophenol tend to decompose only very slowly while 2, 4 -D, MCPA, dalapon and sodium trichloroacetate decompose to very low levels in 12 weeks (table 3). Under flooded conditions all the herbicides studied have decomposed in small amounts (table 4). Hence the possibilities for these toxic compounds entering water bodies without getting detoxified is high.

No studies have been carried out on the concentration of agro-chemicals in water bodies such as lakes, streams etc. in Sri Lanka but it is likely that the relcalcitrant compounds tend to accumulate gradually influencing the growth of organisms in water.

Those compounds which serve as energy sources to organisms are likely to promote the growth of such organisms while some compounds could retard the growth of organisms by virtue of the fact that they are toxic.

Results given in table 5 indicate that TCA has formed a toxic compound during its decomposition under flooded condition. Similar results have been reported by AUDUS /8/ with sodium 2 (2, 4-dichlorophenoxy) ethyl sulphate.

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Table 1a: Amounts of fertilizers used in Sri Lanka (tons)

Fertilizer	1971	1972	1973	1974
Ammonium sulphate	82,000	105,944	122,300	139,674
Urea	67,442	56,875	68,190	91,500
Triple Super	13,500	12,300	23,000	17,000
Rock phosphate	45,800	43,000	42,400	50,500
Muriate of Potash	45,113	49,427	49,255	62,231

Table 1b: Amounts of agrochemicals used in Sri Lanka in 1967 and 1968 in quintals

Agrochemical	1967	1968
DDT and related compounds	46	605
BHC and Lindane	-	5080
Aldrin	34	37
Endrin	273	377
Organo phosphorus insecticides	148	122
Lime sulphur	-	24
Copper Compounds	20	1042
Mercury Compounds	10	10
Dithiocarbamate	-	15020
Fungicids	109	254
Herbicides	2528	2385

Table 2: Ammonium and nitrate content in a soil incubated with 100 ppm NH_4^+-N

	Weeks												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Ammonium - N	100	95.5	86.7	80.2	74.5	70.6	65.3	60.2	55.4	51.3	45.6	40.4	36.4
Nitrate - N	1.6	6.0	14.6	21.2	26.9	30.9	36.3	41.4	46.2	50.3	56.0	61.2	65.2

Table 3: Residual concentration of the herbicides in soils incubated under unflooded condition at fortnightly intervals in ppm

	Weeks							
	0	1	3	5	7	9	11	13
<u>2,4-D</u>								
RBE	1.5	1.0	1.0	1.0	0.8	0.6	0.4	0.2
RBL	1.5	1.0	1.0	1.0	0.9	0.8	0.7	0.6
IBL	1.5	1.0	1.0	1.0	0.9	0.8	0.6	0.4
LHG	1.5	0.8	0.7	0.6	0.5	0.3	0.1	0.05
<u>MCPA</u>								
RBE	2.0	1.0	1.0	1.0	0.8	0.6	0.4	0.2
RBL	2.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6
IBL	2.0	1.0	1.0	0.8	0.7	0.6	0.4	0.4
LHG	2.0	0.8	0.8	0.6	0.5	0.4	0.2	0.1
<u>Dalapon</u>								
RBE	15	10	9	8	8	6	4	4
RBL	15	10	10	10	10	8	6	4
IBL	15	10	10	10	8	6	6	4
LHG	15	10	8	6	4	2	2	2
<u>Karmex</u>								
RBE	2	1.5	1.5	1.5	1.5	1.0	1.0	0.8
RBL	2	1.5	1.5	1.5	1.4	1.3	1.3	1.2
IBL	2	1.5	1.5	1.3	1.1	1.0	0.8	0.6
LHG	2	1.5	1.0	1.0	1.0	0.8	0.6	0.5
<u>P_{20}</u>		+	+	+				
RBE	20	10	10	10	10	10	10	5
RBL	20	10	10	10	10	10	10	5
IBL	20	10	10	10	10	10	10	10
LHG	20	10	10	10	10	10	5	5
<u>TCA</u>								
RBE	10	8	8	8	6	4	4	4
RBL	10	8	8	8	6	6	6	4
IBL	10	8	8	6	6	6	6	4
LHG	10	8	8	6	6	4	4	2

+ Indicates values greater than the value given.

Table 4: Residual concentration of the herbicides in soils incubated under flooded condition at fortnightly intervals in ppm

	Weeks							
	0	1	3	5	7	9	11	13
2,4-D								
RBE	1.5	1.0	1.0	1.0	1.0	1.0	0.8	0.8
RBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	1.5	1.0	1.0	1.0	1.0	1.0	0.8	0.6
LHG	1.5	1.5	1.0	1.0	1.0	0.8	0.8	0.6
MCPA								
RBE	2.0	1.5	1.5	1.5	1.0	1.0	1.0	1.0
RBL	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
IBL	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
LHG	2.0	1.5	1.0	1.0	1.0	0.8	0.8	0.8
Dalapon								
RBE	15	10	10	10	10	10	8	8
RBL	15	10	10	10	10	10	8	8
IBL	15	10	10	10	10	10	8	8
LHG	15	10	10	10	10	8	6	6
Karmex								
RBE	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
RBL	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
IBL	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LHG	2	1.5	1.5	1.5	1.5	1.5	1.0	1.0
P_{20}		+	+	+	+	+	+	+
RBE	20	10	10	10	10	10	10	10
RBL	20	10	10	10	10	10	10	10
IBL	20	10	10	10	10	10	10	10
LHG	20	10	10	10	10	10	10	10
TCA								
RBE	10	10	8	6	0	0	0	0
RBL	10	10	8	4	0	0	0	0
IBL	10	10	8	6	4	2	0	0
LHG	10	10	8	4	4	>10	>10	>10

+ Indicates values greater than the value given.

COMMENT TO THE GENERAL REPORT TO COMPLEX C

D. BARTHELMES
Institut für Binnenfischerei, Berlin
German Democratic Republic

It is a pleasure to note the excellent way the contributions were analysed and reviewed by the rapporteur. The material is thoroughly condensed in the conclusions and recommendations and we only wish to underline the major points where experiences collected in the GDR might be of value in other countries too. This seems to be the care especially in the field of chemical control measures and with respect to equilibrate weed growth by herbivorous and other fish species. Certainly there are differences in ecological conditions between different countries which have to be met with by adequate research programmes. For instance the grass carp, Ctenophyryngodon idella, proved to be of great value for contracting excessive weed growth in GDR water bodies above some minimal dimensions. But in hot climates its application might be restricted because of locally very high salinities due to strong evaporation. Such and similar problems will emerge in transferring experiences from one country to another. In spite of that we may be sure that pooling results as aimed by the symposium will reduce costs and efforts to overcome the problems connected with weed luxurations. Perhaps the discussion to Complex C will be of further value to the final recommendations of this symposium. We agree fully with those already drawn by the rapporteur.

BREEDING, REARING, TRANSPORTING PHYTOPHAGOUS FISH AND CONTROLLING ECOSYSTEMS - EXPERIENCES AND CONCEPTS IN GDR

H. JÄHNICHEN and D. BARTHELMES
Institut für Binnenfischerei, Berlin
German Democratic Republic

Under the climatic conditions in GDR Hypophthalmichthys molitrix and Ctenopharyngodon idella reach maturity after 7-8 years, while Aristichthys nobilis does so after approximately 10 years. Spawning in nature does not occur. Artificially breeding is confined to two plants, which use thermal effluents.

In March-April the overwintering ponds are fished. The parent-fish are brought into little ponds of 600-5,000 m^2 area. Stock dencity is 100-1,000 fish/ha. Separation of seces is not necessary, but of species would be recommendable. These ponds serve as prematuring ponds, full maturity being reached with ascending water temperature in June, normal weather conditions provided. Inflow of heated water is of value, since breeding may take place earlier in the year, beginning already in the middle of May. Stage of maturity is tested by palpation (mass of gonads, protuding of the posterior part of the body cavity, consistence of the area of the gonoporus). Fish that have arrived at full maturity are transported to the breeding plants and here are put into containers with water temperatures between 23 and 26 °C. Ovulation is provoked by 2 injections of hypophyses, which are taken from three-year-old carp (Cyprinus carpio) during winter. The total dosis employed for females is 3 mg of dry hypophyses per kg of fishmass and in case of males it is 1-1.5 mg/kg. The first injection should contain 10 % of total dosis. The second injection is given 24 h later. Males are also injected two times. At water temperatures of 23-26 °C it is possible to take the eggs for fertilization from females 8-9 h after the second injection. For fertilization it is necessary to have 10 ml sperm on 1 kg eggs. It is advisable to take this sperm from 2-3 males. After fertilization water is given to the eggs, this being changed several times. 15 minutes later eggs may be put into the incubators. Volumina of 7-200 l are in use. In GDR there have been proved best glasses of 20 l, which are stocked with up to 400,000 eggs. Eggs not fertilized show a diameter of approximately 1 mm. In water they gain 4.5-5 mm. Duration of incubation is temperature-dependent. At 21-25 °C larvae hatch after 33-23 h. Up to the end of yolk-sac resorption larvae are stored in gauze-cages. Then, with the beginning of active feeding, they are sold to pond-farms for further rearing. For easier handling of the parent-fish a solution of trichlorbutylalcohole (chloretone) is used.

In 1975 in GDR there were bred 15 mill. of Ctenopharyngodon and 6 mill. of Hypophthalmichthys. Breeding of Hypphthalmichthys has just begun in our country and experience is still scarce.

Rearing of the larvae is most successful in extra nursery ponds. Separated to species the fish remain for 3-4 weeks in these ponds with rich plankton. In further rearing they are mixed with common carp. As a rule, stock density of H. molitrix equals that of carp (100 %), while A. nobilis and C. idella are stocked only at 25 % of the carp density. The three fish species in GDR reach the following weight during this polyculture (in g):

species	rearing year		
	1	2	3
C. idella	20	200 - 300	800 - 1,000
H. molitrix	15	180 - 200	400 - 500
A. nobilis	30	300	1,000 - 1,500

As a rule, mortality rate is 80 % in the first year, 50 % in the second and 10-30 % in the third. If the share of the special species in polyculture is as pointed out above, competition between phytophygous fish and carp is absent or only slow. The growth of carp is not affected in any case. Of great importance for successful rearing the phytophagous fish seems to be an adequate device in the in- and outflow of the ponds against migratory activities of the fish.

All handling of the phytophagous fish has to be done with caution. Once the skin is damaged, the fish suffer severely from infections. This causes severe losses, too. Storing the fished fish in small ponds, in nets or containers should be avoided. Transport also has to proceed cautiously. The fish should as little as possible come into touch with net catchers, sorting desks and weighing containers.

These special requirements excluded, one and two years old phytophygous fish are being transported in the same manner and with the same devices as common carp of corresponding age. Larvae are best transported in bags made of polyethylene. The volume of 60 l is filled to 1/3 with water, the rest must be filled with oxygen. Stocking density of the bags may reach 150,000 specimen at water temperatures of 22-24 °C and 2 h duration of transport. Up to 8 h duration of transport allow 50,000 specimen/bag. Though fingerlings of phytophagous fish can be transported in the same bags as larvae, they mostly are transported in metal containers like carp fingerlings. In the case bags are used stock density varies in accordance with duration of transport, water temperature and dimensions of the single fish between 5,000-25,000 specimen/bag.

Production of phytophagous fish for the market in GDR attained 34 t in 1973, 191 t in 1974, and 500 t in 1975.

Guiding water ecosystems with the aid of phytophagous fish makes special knowledge indispensible of how these fish influence their environment. This influence depends to a high degree on fish density and temperature. The actions on macrophytes, phytoplankton, and zooplankton are of central importance. Since these components of the ecosystem are more or less strongly linked together, stocking of phytophagous fish may result in different relations of all three components to one another. This applies already to Ctenopharyngodon idella, which feeds only on macrophytes, but to a still greater extend to the plankton feeders Hypophthalmichthys molitrix and Aristichthys nobilis. Exploration of these relations might be possible under given climatic conditions by pond experiments with different stock densities. In applying these results in waters with native fish stocks their influence has to be approximated and to be included. Also have to be taken into account the extra-conditions emerging from stocking lakes with thermal stratification.

Control of the applied fish stock is relatively easy under climatic conditions as in GDR. All the fish species acclimatisized to our country (C. idella, H. molitrix, and A. nobilis) do not spawn under natural conditions as mentioned above. Therefore the stock cannot multiply naturally. On the other side, all the fish do suffer only very little from diseases according to our observations up to now. On account of this stock, density will remain nearly constant if predators are sufficiently controlled. Stock reductions - if necessary - is possible by seine fishery during winter months.

Summing up there are relatively good possibilities to control stock density. This seems to allow principally fish density regulation in certain waters of high economic value according to operative investigations of phyto- and zooplankton.

POSSIBLE APPLICATION OF FISH FOR BIORECULTIVATION

Z. KAJAK

Polish Academy of Sciences, Institute of Ecology, Warsaw

Poland

I should like to draw your attention to the problem of biorecultivation, that is the improvement of the purity of water, by applying biological means.

The most common and easiest way of biorecultivation is the introduction of fish or increasing the stock of fish.

In one of the works done in my Institute in cooperation with the Institute of Inland Fisheries in Poland, the significant improvement of water purity in an eutrophic lake, and essential change in the structure of biocenosis and functioning of ecosystem was obtained by introduction of common carp, and thus doubling the benthophagous fish stock. Our papers on this problem are already published. Similar results were obtained by several other authors.

Recently many works are being done on silver carp, with the hope for the improvement of water purity. This filtratory fish, consuming bigger forms of seston, should directly purify the water. We obtained such result in the eutrophic lake - the biomass of phytoplankton under heavy silver carp (stock was permanently kept 5 times lower than in the control, without silver carp).

But in the fish ponds with the higher phytoplankton biomass and lower percentage of this biomass being removed by silver carp, the phytoplankton biomass increased instead of decreasing (works and papers done in the Institute for Inland Fisheries in Poland).

To diminish the water blooms by silver carp, probably very high densities of this fish must be applied - so that the fish remove about 30 % or even higher percentage of the biomass of algae, especially if this biomass is very high.

If we assume that 30 % of algae should be removed in the eutrophic lake, where the biomass of algae is 40 mg/l, and the epilimnion is 5 m deep, and if the daily food ration of silver is 20 % of its biomass, the density of silver carp should be

60 g/m^3 or 3,000 kg/ha. This is the fish stock never encountered in natural temperate lakes, but probably not impossible to apply, taking into account that silver carp is very plastic in feeding, and that it can feed on detritus.

It is quite possible that silver carp could efficiently purify the water indirectly - by the removal of zooplankton. Sometimes the percentage of the zooplankton removed is very high. Taking into account that the food rations of the filtratory zooplankton are several times higher than those of silver carp, it is clear that the removal of some amount of zooplankton results in saving several times higher amounts of small phytoplankton, which otherwise would be eliminated by filtratory zooplankton.

So one can suppose that silver carp promotes the development of nannoplankton by the removal of its competitor - macrophytoplankton, and its consumer - filtratory zooplankton.

Unfortunately the food selectivity of the silver carp differs very much in various situations - both the selectivity between phytoplankton and zooplankton, and the selctivity of particular species within zooplankton.

In light of the discussed above complex interrelationships of silver carp (and other filtrators) with the other components of an ecosystem, it is clear that the results of its activity can be different in various situations - from the strong decrease of the phytoplankton biomass to its increase and change in dominance relationships.

To understand it better, and to be able to predict possible, especially indirect effects of silver carp on plankton, further work is necessary, especially on:

- food selectivity and food rations,
- amount of feaces products of metabolism, their influence on decomposition processes and their role for the circulation of matter,
- development of plankton and benthos at various stock of silver carp,
- influence of various stock of silver carp on the functioning of different ecosystems.

All this should of course be examined in a broad range of conditions - temperature, trophy, movement of water, abundance and composition of phyto- and zooplankton, abundance and composition of accompanying ichthyofauna and others.

MEASURES TAKEN IN AGRICULTURE TO CONTROL THE EUTROPHICATION OF WATERS

H. KORIATH and D. KRAMER
Akademie der Landwirtschaftswissenschaften der DDR, Institut für Düngungsforschung, Leipzig und Potsdam, and
Institut für Wasserwirtschaft, Berlin
German Democratic Republic

The optimal supply of the crops with nutrients is decisive for intensifying the production of foodstuffs. In the German Democratic Republic the yield increases in plant production are to 50 per cent attributable to fertilizing and manuring. In view of the extensive use of mineral fertilizers and organic manure great attention is being attached, both in research and practice, to the problems of the eutrophication of waters, all the more since the attainment of great achievements in production and the development of a sound agricultural landscape represent tasks of equal importance to socialist agriculture in the GDR. This overlapping of parallel interests of agriculture, water management and environmental protection finds its special expression in the demands for great soil fertility and the best possible soil culture. These include biological, biophysical and biochemical conditions and processes within the soil, which are responsible for the storage and transformation of nutrients as well as for the formation of the soil structure, and which influence heat regulation, air content, water content, the balance between the organisms of the soil population and, finally, the phytosanitary resistance of the soil as well as its overall capacity to decompose noxious substances. These properties, qualities and actions of the soil determine its eminent importance as the site, working medium and subject of labour of plant production and thus as the principal means of production in agriculture. At the same time they are of decisive importance to the great purifying capacity of the soil-plant system, a function which - seen in connection with the growing intensification of production and the growing industrialization - becomes more and more significant for developing and preserving the biosphere.

In the studies on the likely eutrophication of ground and surface waters by fertilizers made in the GDR, nitrogen and phosphorus as plant nutrients have been in the foreground.

Under the climatic conditions prevailing in the GDR the N-output due to washing-out from soils whose ground-water levels are rather low and on which cultivated plants are raised, is fairly small, particularly during the growing period and, if assessed from the point of view of water quality, by no means critical.

Rather, the influence of mineral nitrogenous fertilizers on eutrophication processes is attributable to the fact that the growing amount of roots and harvest remains left in the soil effect an increase in the content of organically linked nitrogen in it, part of which - mobilized as nitrate - is subject to being washed out during the non-growing agricultural period. This process is generally activated under the conditions of field irrigation which, as an essential measure of intensifying agricultural production in the GDR, is rapidly being expanded, and of the programme for the chemicalization of the plant production, which guarantees that useful plants are supplied with mineral nutrients to a growing extent. As regards measures aimed at influencing the processes by which nitrogen is being washed out, it should be taken into account that the by far biggest share of the nitrogen that is being washed out comes from the nitrogen content of the soil.

From the scientific findings that have so far been obtained on the causes of the washing out of nitrogen, conclusions have been drawn for fertilizing as applied in the GDR which find their expression in fertilization recommendations calculated annually by means of electronic data processing. Thus, the big amounts of nitrogen to be applied to the fields are divided up and spread on several occasions in accordance with the stage of development of the plants. Operative soil investigations are made so as to establish the exact amount of nitrogen to be applied in the spring season, and, particularly, to find out how much nitrogen from the previous year is still contained in the soil. No nitrogenous fertilizer is spread in the autumn on those fields where winter grain will be sown. An exception is made only where there is straw-manuring in the autumn. If winter rape-seed is cultivated, nitrogen fertilization in early spring should not be carried out if the soil is frozen, or if the fields are still covered by a layer of snow, since on sloping ground this may result in losses due to washing-off and in an eutrophication of waters.

Catch crop-growing is very important to prevent or limit the washing-out of nitrogen, for it reduces the non-growing periods and enhances the agricultural use of mobilized nitrogen. This effect of catch crop-growing is illustrated by the fact that the biggest washing-out of nitrogen occurs where there are no plants and that the by far smallest washing-out of nitrogen can be observed on grassland where there is permanent vegetation.

As far as phosphatic fertilizing is concerned the available research results confirm that only extremely small amounts of phosphorus from arable land enter the waters. Where it does happen it is mainly due to erosion or surface flow-off of precipitations during the non-growing periods, which is counteracted by meliorative and agricultural measures, such as the spreading of phosphatic fertilizers prior to ploughing.

In the field of organic manures quite a change has been taking place in the GDR during the last few years. With the transition to industrial-type processes in animal production the amount of semi-liquid manure has increased considerably, while that of farmyard manure has decreased. As compared with the farmyard-manuring system the environmental protection requirements concerning the storage, transportation and spreading of semi-liquid manure are much higher. Legal regulations have been passed to ensure that absolutely no local eutrophication of ground and surface waters takes place. These regulations are based on the constitution of the GDR which provides that all branches of the economy, all enterpises and all citizens are obliged to keep the waters clean and to protect the landscape. Semi-liquid manure may be stored in water-proof tanks only. Its transport to the fields has to be by vehicles or pipe-lines that will exclude any uncontrolled leakage. For the spreading of semi-liquid manure on agricultural areas, binding instructions have been laid down by the state authorities in agriculture and water management which provide for the optimum amounts and the limits of its use, while taking account of the type of semi-liquid manure, of the soil and the cultivated crops. Special regulations are applicable for drinking-water protection areas, areas with seasonal flooding and health resorts.

The optimality criteria worked out for the use of semi-liquid manure and other types of organic manure have been included into calculating acreage-related manuring recommendations by means of electronic data processing.

There are general restrictions applicable to certain areas independent of the crops cultivated there. Some of them have been given in summarizing report. No semi-liquid manure is to be used on fields where the ground-water level is less than 0.4 m. In lowland areas with ground-water levels ranging from 0.4 to 1.0 m manuring and fertilizing must not exceed 250 kg of nitrogen per hectare and year. On shallow soil covering jointed or karst rock in mountainous country, the total amount of manure and fertilizers is limited to 300 kg of nitrogen per hectare and year. If semi-liquid manure is spread on sloping fields bordering on surface waters the untreated stretch of land between the water and the manured area must be 10 to 100 m depending on the slope of ground and the soil characteristics.

The research carried out in this field has produced many positive results thanks to the cooperation of experts from the socialist countries within the framework of the Council of Mutual Economic Assistance. The extensive exchange of experiences and the coordinated joint research concepts make it possible to compare the results obtained on large areas and to gain insights which will speed up the process of acquiring new knowledge.

In view of the increase in soil fertility and the intensification of plant production the washing out of nitrogen from the soil cannot be completely excluded. It can, however, be greatly reduced by certain manuring and fertilizing as well as management measures. To apply these measures purposefully in accordance with the given local situation is a task facing agriculture, water management and environmental protection alike.

CHEMICAL CONTROL OF HIGHER AQUATIC PLANTS AND PHYTOPLANKTON BY HERBICIDES

D. KRAMER and G. SCHMALAND
Institut für Wasserwirtschaft, Berlin
German Democratic Republic

The removal of macrophytes and algae is necessary to keep many waters in function or serves aesthetic aims.

Due to the nature of the ground in and on waters, plant cutting and removal cannot be mechanized or only mechanized inefficiently. Before the introduction of new methods of plant control (70-80 % of the waters where the plants had to be controlled) required manual work for which labour became unavailable due to the general increase of mechanization. Only a small part of these waters can be treated by biological control methds. Thus, this problem was and is being increasingly solved in the GDR by the application of chemical methods of plant control.

We consider the application of herbicides in and on our waters a measure which serves the conscious management of human environment. It should not contradict the efforts made by environmental protection. Thus our efforts are aiming at the development of methods which from the point of view of national economy are optimal.

Accordingly, the development of methods and their supervision is not only the responsibility of agriculture which is in charge of the practical implementation of chemical plant control but also that of water management. Thus the methods are also based on considerations of how to prevent water pollution. In this sense special attention should be paid to the selection of preparations.

The preparations registered in the GDR refer to a chemical method of bottom control, that is control of mainly emerged macrophytes, which is primarily based on Dalapon. This is largely unobjectionable from the toxicological point of view. Other preparations are as to warm-blooded animals it has an acute oral LC_{50} value of approx. 9000 mg/kg. As to fish, the LC_{50} values are between 7000 ->10,000 ppm. For the control of dicotyl species, it is combined with 2,4-DP, MCPA or CMPP. As to their acute oral toxicity in respect of warm-blooded animals, these preparations have also very favourable LD_{50} values between 800 and 1000 mg/kg. As to fish, they also show a low toxicity with LC_{50} values between 300 and 500 ppm compared with the small quantity to be applied of approx. 0.5 g/m^2. This proportion between quantity to be applied and toxicity is used as the most important criterion for the selection of preparations. For this purpose, the respective concentration forming in waters of 30 cm depth where herbicides are applied is calculated. The safety factor is the quotient of LC_{50} divided by this concentration.

For all substances mentioned so far there is in this way a more than 250-fold safety in respect of harmful effects on the waters. Amitrol, in its mode of action especially suited for chemical plant control but disputed in respect of its human-toxicological effects, is being applied at present only in combinations, so that only very small quantities of active substances act upon the waters. It is ensured by a number of regulations governing the application of these combinations - minimum water depths, applications on partial surfaces or local stipulations in conformity with water management and hygiene are laid down - that there will be no harmful side effects of herbicides.

Gramoxones and reglones are very quickly removed from the waters by sorption and are for this reason evaluated very highly from the point of view of water toxicology. In bodies of running waters it is also ensured in controlling submerged macrophytes by short-acting injections that only for a short time which is 30 minutes at the most the ecosystem will be exposed to detrimental effects.

Emerged macrophytes occurring in GDR waters can be definitely controlled by herbicides or their combinations (1-6).

Gramoxones and reglones make the elimination of submerged plants possible. Simazine-containing preparations and gramoxones have primarily algicidal effects.

The agents, the quantities to be applied and the directives for their application are laid down in the GDR as binding in Standard TGL 24 351/01-02. It is by help of special forms of organizations that the results are applied in practice in conformity with environmental protection and controlled correspondingly.

Table 1: Herbicides and quantities to be applied for chemical bottom treatment

Serial No.	Herbicide or tank mixture	Active substance	Field of application	Quantity to be applied g/m2
1	Sys 67 Omnidel + Sys 67 Prop[1]	Dalapon + 2,4-DP	R, L, P, I	4.0 + 0.5
2	Sys 67 Omnidel-N + Sys 67 Prop[1]	Dalapon + 2,4-DP	R, L, P, I	3.5 + 0.5
3	Sys 67 Omnidel + Azaplant + Sys 67 Prop[1]	Dalapon + Amitrol + 2,4-DP	R, L, P	1.7 + 0.7 + 0.3
4	Sys 67 Omnidel + Azaplant-Combi + Sys 67 Prop[1]	Dalapon + Simazine + Amitrol + 2,4-DP	R, I	1.7 + 1.5 + 0.3
5	Azaplant-Combi	Amitrol + Simazine	R, I	3.0
6	CKB 1018	Amitrol + Simazine + 2,4-D	R, L, P	3.5
7	Gramoxones	Paraquat	R, L, P	2.5
8	Reglones	Diquat	R, L, P	2.0
9	W 6658	Simazine	I, P	3.5

Explanations concerning the table:
[1] also MCPA or CMPP
R = Receiving water P = Pond
L = Lake I = Inlet rill