PART - I

Page No.

SECOND ADDITIONAL PAPER 204 - 225

" CONTROL OF AQUATIC VEGETATION IN RAW WATER STORAGE RESERVOIRS "

CONTENTS

ooooooo0Oooooooo
ooooOoooo

CONTROL OF AQUATIC VEGETATION IN RAW WATER STORAGE RESERVOIRS

INTRODUCTION

Storage reservoirs which are used as sources of water supply are of two kinds: (a) those from which a raw water is used for drinking purposes directly without any form of purification; and (b) those from which raw water is taken out through conduits for purification by any one or more of the conventional methods of water treatment before it is used for drinking purposes.

The former are usually very pure upland waters which are located on mountain tops far away from human habitations. Such is lake Thirlmere from which Manchester receives a large portion of its water supply or Lake Tansa from which Bombay receives a portion of its water supply. Practically no purification of such waters is needed save, perhaps, their passage through micro-mesh screens to keep out plankton life and final chlorination to render the waters epidemeologically "safe."

But in the case of (b), the reservoirs are ordinarily located in the plains and the natural conditions of water is not so satisfactory as in the case of (a). They are often subjects to gross pollution, which changes radically the conditions of existence in them. Oxidation of nitrogenous organic matter takes place rapidly in the water and the resultant products serve as food for the growth of both the higher aquatic plants and lower forms of plant life, known as phyto-plankton, which colour the water bluish, greenish or yellowish-green. Often an excessive and annoying growth of water-bloom is developed causing odour and taste troubles besides difficulties in filtration. This is the problem which has specially to be faced in the tropics, where the action of sun-light, while being fatal to pathogenic bacteria, stimulates photosynthesis for the greater part of the day and the year. So, it is this biochemical problem which Water Works Engineers have to deal with in some form or other in the tropics. The methods of algal control have been discussed in another paper (Indira and Ganapati 1964). The Ajwa reservoir which is the source of Water supply to the town of Baroda is almost full of aquatic vegetation which has to be controlled. An attempt has been made in this paper to describe the methods commonly adopted for controlling water weeds and the one eminently suitable for controlling the macrophytic vegetation in the Ajwa Reservoir at Baroda.

II. Types of Aquatic Vegetation:

Aquatic vegetation occurring in storage reservoirs covers a wide range from microscopic to macroscopic forms, and may be broadly classified under six groups: (i) free-floating, rootless, *Lemna* (Duck-weeds), *Azola*, *Pistia*, etc., (ii) floating hydrophytes or plants with their roots attached to soils and the foliage spread upon the water surface such as *Nympheae* (water lilies) *Nelumbium* (Lotus), Trapa and *Potamogeton*; (iii) emergent hydrophytes which are rooted at the bottom, but with the shoots projecting out of the water in the air, such as bulrushes (Scirpus), *Cyperus*, cat's tail (Typha), *Polygonum*, and sedges (Carex); (iv) submerged hydrophytes consisting of rooted plants like certain species of *Potamogeton*, the water-weed (*Hydrilla*), the eelgrass (*Vallisneria*), the naiads (*Naias*), and Stonewarts (*Chara* and *Nitella*). There are also some plants like *Ceratophyllum* which are not rooted at the bottom but grow unattached and submerged in water which are included under this group; (v) plants which are partly rooted and partly free-floating like the water-hyacinth (*Eichornia crassipes*); and (vi) planktonic forms such as minute free-floating algae. The first five types of plants are ordinarily large-sized and are therefore, visible to the naked eye, while the sixth class is seen only under the microscope.

(iii) Role of Aquatic Vegetation in the Economy of a Reservoir:

All aquatic plants play a very important role in the economy of a piece of water. During photosynthesis they liberate oxygen which supplies the respiratory needs of the animal and plant population, and they help to reduce wave action. The large plants retard the growth of obnoxious, microscopic algae, by taking up most of the nutrients and cutting off sunlight.

In the case of fish ponds particularly, the aquatic weeds provide shelter for the fry and fingerlings, and even for adult fish of most species. They harbour various species of insects, snails, etc., which form the food of fish. They extract inorganic nutritive materials of biological significance from the soil (Pearsall 1920, Misra 1938) and water (Welch 1935); on decay they add fertilizing elements to the water and thus increase the food material for the plankton which is the vital link in the fish food chain. They also provide the necessary substrata for the attachment of eggs of several species of fish. The growth of water-hyacinth is advocated from the point of view of malaria control, since a uniform growth of the plant on the water surface inhibits the breeding of the malaria mosquito- Anopheles Philippinensis.

(iv) Need for Control :

The advantages of aquatic vegetation are really great so long as their growth is moderate. But once it begins to grow dense and thick covering almost the entire volume of water as in the Ajwa Reservoir at Baroda it becomes a pest and causes no small amount of inconvenience. For example Ricket (1922, 1924) found in lakes Mendota and Green lake, Wisconsin, a wet weight of 14,000 lbs. per acre and dry weight of 1800 lbs. per acre of aquatic weeds. In the case of irrigation wells, the plants reduced the area of open water surface, choke the foot valve of pumps and cause intensely foul odour on their death and decay. More troubles are caused in the case of fish ponds. They interfere with fishing, especially with the casting and dragging of nets and cause unpleasant tastes and odours to the flesh of fish. A wild growth of submerged and emergent plant life leads to over-population of stunted fish and reduction in fish crop. Also, large scale fish mortality often results through the exhaustion of the oxygen dissolved in the water, due to the rapid de-composition of the dead plants. They form the food of snails and other organisms which are the intermediate hosts in the life cycle of many fish parasites.

(v) Methods of Control:

So it is necessary to keep under control all forms of abundantly growing aquatic vegetation for the healthy development of fish life, for preventing tastes and odours in water supplies and for recreation purposes. The method of control employed at the present day can be classified under three heads: physical, chemical and biological.

(a) Physical methods:

Draining, dredging, dragging, cutting and raking offers a direct method of control. Emergent weeds like tules, cattails, sedges, pickerel weeds and some grasses, are treated by cutting below the surface of water. Oiling, burning, dragging, chaining, booming and dredging or protection from sunlight have their applications when the level of water is low or when the area to be covered is small. The exposed weeds can be spread with a heavy fuel or diesel-oil and allowed to dry for two weeks. Then a light oil can be sprayed on it and burnt. Such methods are time-consuming and may or may not be costly, depending upon the cost of labour. Though they have the advantage of removing substantial amounts of organic matter from circulation, they are, in any case, only temporary expedients. Such methods have been applied in the case of water-hyacinth throughout the world. In our parts, water-plants like the lotus, the water-lily, Potamogeton, Hydrilla, Ceratophyllum, Naias, etc., which cover nearly threefourths of village tanks and large reservoirs, are removed by under-water saws and hooked cables which pull up weeds by the roots. In India, where labour is far cheaper than in European or American countries, the removal of these superflous weeds can be largely effected by manual labour. But it is necessary that they should be removed before they mature and set seeds. The growth of new plants could thus be prevented. In this way some of the large ponds in Cuttack have been kept entirely free from water-hyacinth for more than five years. A careful watch is, however, necessary after their removal.

(b) Chemical methods:

The use of chemicals may seem to be far more satisfactory than physical methods, but is neither so simple nor safe as any careleness might result in killing inadvertently men, cattle and fish and in the causation of objectionable tastes and odours in drinking water supplies. Complete eradication is considered impossible by this process also. A wide range of chemicals such as nigrosine, orthodichloro-benzene, copper sulphate, sodium arsenite, sodium chlorate and ammonium sulfamate have been used. But they have not become popular because while they appear to be effective for the control of plant life, they are toxic to fish life, higher animals and man. The typical herbicides extensively used at the present day are: copper sulphate, sodium arsenite, chlorine, benoclor and methoxone. Of these copper sulphate and sodium arsenite are the two chemicals which are extensively used on account of their cheapness.

(1) Copper sulphate: Copper sulphate in general, is ineffective for killing larger aquatic plants.

It has been proved ineffective against Gladophora.
However, a concentration of 0.018 per cent or more kills plants like the water-hyacinth and Potamogeton, Chara and Hydrodiction. In the case of water-hyacinth it has been stated that it liberates calcium oxalate on its death, and that the oxalate neutralizes the poisonous effect of copper sulphate. Thus, a few of the plants occasionally escape the effect of the poison. So, spraying is unsuccessful. But the addition of 1 per cent of sodium chloride (calculated on the volume water) is stated to be very effective in killing the plant in about a week (Ganapati 1947).

(2) Sodium Arsenite: Commercial meta-arsenite ($NaAsO_2$) containing 4 lbs. of As_2O_3 per gallon is being used widely and effectively in fish-ponds, irrigation wells and storage reservoirs. It is no doubt poisonous to man and animals and its use must be so carefully controlled as not to increase the residual concentration above 0.25 parts per million. It would appear that the hazards of its use in storage reservoirs are slight if careful control is maintained. Arsenicals are usually sprayed on the surface of water so as to give a dose

1.0 to 2.0 parts per million of arsenic. The treatment is repeated twice or thrice at intervals of a fortnight. For marginal weeds growing to a depth of eight feet a dose of 7.5 ppm is used; and for those growing at greater depths, control is unsatisfactory. Plants like Cera-tophyllum and Potamogeton have controlled successfully with this chemical. Also weeds like arrow head, water plantain, bladderwort, coontail, wild celery, water crowfoot, water milfoil are effectively killed. Chara, and water lilies are unaffected.

(3) Chlorinated Hydrocarbons: Three names: Benoclor No. 3 regular, miscible Benoclor No.3 special, and Benoclor No. 3 C are given to trichlorinated benzenes put on the market. These substances have a pungent odour, are non-inflammable, non-toxic, heavy (specific gravity 1.45), and non-corrosive. They form a milky white cloud when sprayed under water. They are readily absorbed and turn the green plants white in 4-5 days. Animal life is also destroyed. So, it is better to treat one-half of a piece of water so that the fish and other animals present in it may migrate to the untreated half, which may be treated later, after a week or two. Chlorinated hydrocarbons are used at rates varying

from 15-50 gallons per acre of water surface, on surface-borne weeds like water chestnut, water-hyacinth and water lettuce. Cattle refrain from drinking the water so treated on account of the medicinal taste imparted to it. The response of Benoclor treatment varies with the different flora. *Chara* and *Elodea* are easily killed, while *Potamogeton* is intermediate in response. The destruction of the weeds often increases plankton growth which in turn, increases fish productivity although the toxicity of the chemical to fish life is so high that its use has been prohibited by some Fish and Game Commissions in the States. The objectionable taste, which can only be removed with difficulty is a great deterrant in its use in potable waters.

(4) Plant Hormones: Several simple synthetic organic chemicals have appeared in the market with growth regulating properties. In 1940, the differential effect of alpha-naphthylácetic acid on different plant species of dicotyledons was noted and later resulted in the development of 2, methyl-4 chloro-phenoxy acetic acid or methoxone and the corresponding dichloro-compounds as selective weed killers.

Formulated dusts and liquids containing the three active materials are being used in spraying or dusting crops of the Gramineae family against weeds of Brassica or other families of the dicotyledon type. Later observations by scientists go to show that methoxone has been successfully employed in Burma during the second world war for combating excessive growths of water-hyacinth (a monocotyledon) in canals and swamps. Experiments carried out at the Fresh Water Biological Research Station of the Madras Government Fisheries and the Agricultural College, Coimbatore, have confirmed these observations. A dose of 2 gallons per acre of 1 percent solution is effective in killing the water-hyacinth in about 2 weeks. Lemna, Pestia and Salvinia are killed by spraying with a dose of 0.1%. But concentrations higher than 0.5 per cent (by volume) have resulted in death of minnows like Rasbora.

Sodium salts, amine salts and esters of "2-4D" are now available and a product commercially known as "Dicoton", a May & Baker product containing the ethyl ester of "2,4-D" are extensively being used for control of aquatic weeds. The treatment consists of applying the chemical to the leaves which absorb and translocate to the roots through the stem. Vaas (1951) has stated that this chemical can kill all floating types of vegetation but not submerged plants like Hydrilla verticellata. But Srinivasan and Chacko (1952) have shown that even submerged plants like Hydrilla verticellata and Naias gramineae are killed by Dicoton application at the rate of 1 oz. per 100 sq. ft. The edges of leaves develop brown streaks a week after treatment and the weeds finally are killed in 20 days. Also rooted aquatics like Valisneria spiralis and Nymphea rubra are affected. They also state that a dosage of 2 oz. per 100 sq. ft. administered in three equal instalments at intervals of 7 days kills the above plants in about 16 days. Also, they state that the above dosage is not harmful either directly or indirectly to carps like, Catla catla, Labeo fimbriatus, Cirrhina reba and Barbus sarana. Invariably there is a phenomenal increase in the density of fresh water biota; and the cost of treatment works out to Rs. 70.25 per acre of water surface.

Again, Srinivasan and Chacko (1952 b) carried out further experiments with "Fernoxone" a product of Plant Protection Ltd., England and marketted by the Imperial Chemical Industries(India)Ltd., containing about 80% of the active material in the form of the sodium salt of 2,4-D. They found that submerged plants like Hydrilla verticellata, *Naias naias*, and *Potomogeton indicus* were killed by the chemical within 20 days at 2 ppm; and that the dose was harmless to fish life and biota. The quantity of Fernoxone required for treatment at 2.0 ppm worked out to 5.44 lbs for one acre foot and cost Rs.22/- as compared with Rs.70.25 per acre required for Dicoton. But Dicoton being an oily compound which acts on plants leaves on water surface is independent of depth, while Fernoxone easily dissolves in water and so the quantity increases with the volume of the pond water to be treated.

Ammonia, ammonium sulphate, super-phosphate and taficide were effective in killing weeds in fish ponds. The cost of cleaning with ammonia was Rs.300-500 per hectacre. Barium chloride gave equally good results in the case of *Hydrilla*. (Indian Fisheries Bulletin, 1963, p.19).

(5) Biological Methods: There are certain types of fish which live upon some of these plants. If these fishes are stocked in waters, it is possible to control the excessive growth of weeds. The carp, *Cyprinus carpio*, is stated to control submerged vegetation both by rooting it out and by increasing the turbidity of water. Gourami, which is purely a vegetable feeder lives upon plants like *Hydrilla*

Naias, Ceratophyllum, Water lily, lotus etc. (Ganapati 1947). Another species of fish called Barbus hexagonolepis is very fond of grass and other marginal vegetation. Chinese carps, known also as grass carps ctenopharyngodon idellus - are able to clear completely all kinds of weeds in a month if 30-40 fish are stocked per acre (Indian Fisheries Bulletin 1963 p. 19). Another method according to Swingle and Smith (1938, 1942) and Surber (1946-1948) consists in developing an algal bloom or dense growth of filamentous algae by applying fertilisers in order to fade out the larger submerged aquatics. While this may increase the productivity of water, Ganapati et al (1950) have shown that in such cases the resulting oxygen depletion may cause large scale fish mortality.

****

VI. DISCUSSION

The cost of mechanical cleaning has been worked out by Senior-White in India as ranging from Rs.5.75 per acre, per round, before the war. This rate is at the commencement of the control operations; but as eradication continues every year the cost will be considerably reduced. In the States, the cost of mechanical control is costlier than chemical control. The average cost of the former is stated to be $ 150-600 per mile, while chemical treatment is only 30 $ per mile, per treatment. Using Benoclor, the cost of treatment in America is stated to be $ 140 per acre.

The methods of control will vary with different plants. For successful control, it is essential first to identify and to know the life-history of the plant which has to be controlled. It is also necessary that the stage of its growth, when the treatment is done, should be known. Then the method of control which is effective, economical and best suited to local conditions should be decided. Next, the dose of the chemical (if chemical treatment is preferred) and the period of contact or the type of fish (if biological treatment is preferred) should be decided. Again, in the case of chemical treatment, the chemical should not cause any hazard to man, animal or fish, and should not vitiate the taste or produce bad odour in supplies of drinking water. The residual chemical after treatment should also be determined.

Of the three methods of control discussed above, the biological method of cortrol is the cheapest and the best. The fish to be introduced is the chinese grass carp which will eat away any aquatic vegetation in a standing reservoir. Also the fish is a good edible fish. So, it is suggested that the chinese grass carp should be introduced in all our raw water storage reservoirs to keep down the aquatic vegetation. The fry of this fish can be had from the Gujarat Fisheries Department or the Central Inland Fisheries Department at Cuttak in Orissa.

Two questions will immediately arise regarding fish life in raw water storage reservoirs, which serve as a source of raw water supply. They are : (a) weather fish are detrimental or advantageous to the Water Engineer; and (b) whether artificial stocking is practicable or desirable. The answers are given below:

(a) The excreta of fish do not contain pathogeneic bacteria and are harmless to human beings.

The fish fry usually find their way into drawoff tower, and reach the pretreatment units of a water treatment Plant. If slow sand filtration is adopted, then the fish fry reach the sand filters where they reach adult size. They are removed only when the sand filters are allowed to dry for cleaning purposes. But this difficulty can be got over by installing fish traps just ahead of the filters.

Many fish obtain their food from the Zoo-or phyto-plankton or both and also from higher aquatic vegetation. The presence of fish is generally considered as an indication of the purity of a water; and it would appear better to have nutrient elements locked up on fish rather than dissolved in the water and thus be available for the much more troublesome algal growths. Indeed it has been suggested that the periodical netting of large numbers of fish would be a valuable way of reducing the over-all content of nitrogen and phosphorous when the water is too productive.

" Also, on general grounds, a reservoir which provides good angling is an amenity which, provided it is strictly controlled can be a valuable asset to the water undertaking in its public relations". (Manual of British Water Supply Practice 1954).

" So, artificial stocking of a reservoir with particular species of fish is desirable and it is being done by the Fisheries Department in several States in India.

VII Control of Aquatic Vegetation in the Ajwa Reservoir at Baroda.

It has been shown in the very first paper that there is a super-abundance of macro-vegetation which is not only a source of nuisance but is also interfering in the day to day operation in the Ajwa reservoir. There is a dire need for control of the aquatic weeds, which restrict the space for storage of water. So it is necessary to stock it with those types of fishes which will eat away the vegetation. The carps which are well known to live upon the hydrophytes are the famous chinese carps or grass carps known as Ctenopharyn-idellus. Thirty to forty fish per acre of water surface will clear away all the weeds in a month according to the Central Indian Fisheries authorities. The Ajwa reservoir has an area of about six square miles or 3840 acres. The reservoir may have to be stocked with 30 x 3840 or 115,200 fingerlings of the chinese grass carp. When they attain tablesize they should be harvested and sold for food.

There are also local and other exotic fishes like Barbus hexagonolopis and Osphronemus Gorami which are weed eaters and also good edible fishes. So, the Baroda Borough Municipality has been advised to undertake a Five Year Programme of stocking and harvesting under the guidance of the Director of Fisheries, Gujarat State;

and if they carry out these suggestions they will not ~~only~~ only be able to clear away the aquatic vegetation but also will be getting annual revenue of not less than two lakhs of rupees. This is the cheapest, safest and the most economical method of weed control recommended for the Ajwa reservoir.

VIII SUMMARY

Several problems are concerned with the maintenance of water quality in raw water storage reservoirs used as sources of water supply. Chief among them is the control of aquatic vegetation of water weeds.

Three methods of control are discussed and of these the biological method of control is advocated on account of its simplicity, harmlessness and utility.

So, the biological method of control is suggested for controlling the macrophytic vegetation in the Ajwa reservoir at Baroda.

****

R E F E R E N C E S

1. Ganapati, S.V.,
   Industries & Commerce Jl., 3, 37(1947)

2. Ganapati, S.V., Chacko, P.I. and R. Srinivasan:
   Jl. Zool. Soc. India 2, 97(1950).

3. Indian Fisheries Bulletin:
   9, 19 (1963).

4. Indira, S.T. & S.V.Ganapati,
   Environmental Health, 6,166 (1964).

5. Manual of British Water Supply Practice:
   Complied by the Institution of Water Engineers,
   England, 2nd Ed., 756(1954).

6. Misra, R.D.,
   Jl. Ecol., 26,411 (1938).

7. Pearsall, W.H.,
   Jl. Ecol., 8, 163 (1920).

8. Rickelt, H.W.
   Trans. Wis. Acad. Sci. Arts. Lett.20,501(1922).

9. ------------.
   Ibid., 21, 381(1924).

10. Srinivasan, R. and P.I.Chacko:
    Jr. Bom. Nat. Hist. Sco. 51, 164 (1952).

11. Surber, E.W.
    Trans. Am. Fish Soc. 73, 377 (1946).

12. -----------
    Progressive Fish Culturist, 10, 53(1948).

13. Swingle, H.S., and E.V.Smith:
    Trans. Am. Fish Soc. 68, 126 (1938).

14. ------------
    Ibid., 71, 94 (1942).

15. Vaas, K.
    Gen. Agri. Stat. Bogor. Report Indonesia.,
    120, 259 (1951).

16. Welch, P.
    Limnology, McGraw Hill Book Co., Inc.,
    471 pages, 1935.

****