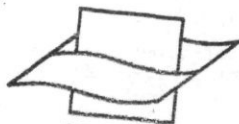


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AIR-WATER PUMPS AS CHEAP AND CONVENIENT
TOOLS FOR HIGH DENSITY CULTURING
OF MICROSCOPIC ALGAE

P. Sorgeloos¹, G. Persoone, F. De Winter,
E. Bossuyt and N. De Pauw
State University of Ghent
Laboratory for Biological Research
in Environmental Pollution
J. Plateaustraat 22
9000 Ghent, Belgium

ABSTRACT

The culturing of microscopic algae in sufficient quantities as a live food source for larval mollusks and crustaceans remains a major problem in many hatcheries, not at least from the technological and financial standpoint. Presently, a variety of more or less sophisticated techniques are utilized, depending on the degree of purity and/or algal volumes required.

After considerable experimentation with a number of different technologies, the authors adopted a modification of the Salser and Mock algal culturing tank as a very convenient and cheap algal culturing system for small as well as large volumes of algae. For indoor culturing, the use of transparent culturing vessels (glass aquaria) illuminated laterally by fluorescent tubes allows a much better and more economical utilization of the expensive artificial light. PVC air-water lifts, inexpensive and easy to handle, assure

¹"Aspirant" at the Belgian National Foundation for Scientific Research (N.F.W.O.)

a constant and most efficient circulation of the algal suspension, providing the maximal possible photosynthetic activity in indoor as well as outdoor conditions.

The controlled culturing of microscopic algae as food for larval stages of interesting aquaculture species is a problem in which quality, quantity and technology can hardly be dissociated. With regard to the latter aspect, it is quite clear that the technological component has received the least attention despite its economic importance; in our opinion many systems presently utilized for culturing algae indoor for aquaculture purposes should be reconsidered.

It is beyond the scope of this short note to give a detailed listing of all the culturing systems preconized nowadays; the reader can find excellent reviews on this matter in recent textbooks such as e.g. that of Kinne (1975). Let us briefly summarize the main types of indoor algal culturing utilized in aquaculture enterprises.

In many laboratories and hatcheries, the classic glass flask and/or jar system (with or without aeration) for culturing algal volumes ranging from a few liters to 40-50 liters is still the only one used, despite the extensive manual labor involved in maintenance and handling. The flasks and jars are usually placed in rows in front of a rack of fluorescent tubes. More recently, the plastic bag-type cultures have gained the favor of scientists as well as commercial aquaculturists : transparent polyethylene bags of 20-30 cm in diameter and 1-2 m length are heat-sealed at the bottom, equipped with a piece of plastic tubing extending to the bottom (for air bubbling) and hung in rows in front of a series of light tubes. Definite advantages of the bag culturing system are the extremely cheap price, the absence of sedimentation and a much better utilization of the artificial (expensive) light necessary for photosynthesis because the bags can be hung close to the light source and are thus exposed over their entire length.

Some aquaculture firms utilize rather expensive fiber-glass troughs (approximately 100-liter contents) with a keel-shaped bottom. Compressed air, which bubbles through small holes in a PVC pipe lying on the keel, counteracts most of the sedimentation. Illumination is provided by fluorescent tubes placed at a certain distance above the tanks.

A few years ago a very appealing system was proposed by Salser and Mock (1973) : a "longitudinal" air-water lift system (made of PVC or perspex) placed along the longest side of a rectangular culturing tank ensures a total water circulation with a dominant laminar flow, by "pumping" the algal cells continuously back from the bottom to the surface; the dimensions of the tank may vary, provided that the width-depth proportions are respected within a certain range.

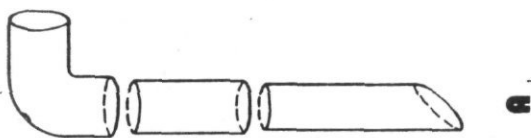
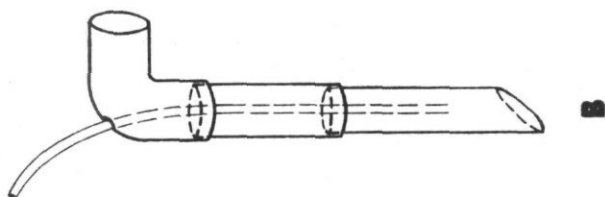
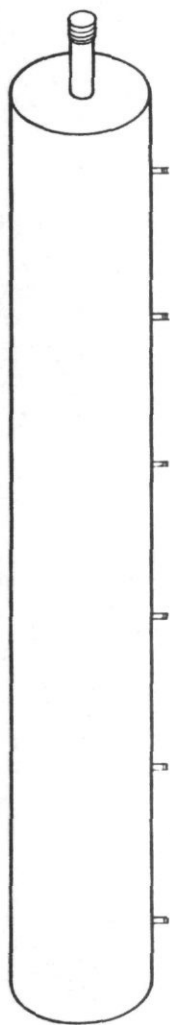


Figure 1 a) air-water lift: separate parts
 b) air-water lift (assembled) with air-tube
 c) expansion vat

The system is illuminated by fluorescent tubes hanging at a certain distance above the tank.

Since in recent years we have been working rather extensively on the problems of high density culturing of microscopic algae at lab scale as well as pilot scale (Persoone and Sorgeloos, 1975 ; Sorgeloos et al., 1976 ; Persoone et al., 1976 : De Pauw et al., 1976), we have had opportunity to work with the different systems mentioned above and to compare the advantages and disadvantages of each. Again it is beyond the scope of this brief note to give a detailed review of our findings which we can, however, briefly summarize as follows:

- 1) If a high degree of purity of the algal cultures is required it is clear that, despite the labor and maintenance involved, "closed" systems which can be reesterilized (flasks or jars) or discarded after use (low-cost plastic bags) should be used.
- 2) If the former prerequisite is not imperative however, the choice of type of "open" system should be dictated by its efficiency to ensure the most rapid algal growth possible, as well as by factors such as construction costs (price of material and simplicity of construction), maintenance costs (simplicity and accessibility of the system for handling and cleaning) and last but not least, energy consumption (light, heating, air-bubbling, CO₂).

With regard to the latter multivariable, we found that the air-water lift sytem, preconized by Salser and Mock (1973) was most efficient for culturing algae in rather large volumes up to several hundreds of liters.

We modified the original version of Salser and Mock as follows: from the point of view of simplicity of construction as well as of decrease of energy consumption, the longitudinal air-water lift (AWL), which is rather complex to construct, is replaced by a row of air-water lifts in PVC-piping; the length of the pipes can be adjusted to the height of the water column by telescoping of the two parts of the tubes (Figure 1 A). The compressed air is led into the PVC - tubes by a small polyethylene tube passing through a hole drilled in the elbow of the air-water lift. The hole should have approximately the same diameter as the outside diameter of the polyethylene tubing in order to ensure that the latter does not move any more after pulling its extremity in the correct position in the PVC-tube (Figure 1 B). It should be emphasized once more, that the diameter of both the air-bubbling and the PVC tube, as well as the location of the extremity of the former into the latter, determine the volume of water displaced and thus the efficiency of the air-water lift. For more details on the operation of air-water lifts we refer the reader to the publication of Castro et al. (1975).

The air-water lifts thus consist of 3 pieces of PVC (2 tubes telescoping, and one elbow) fitting over one other with, as Mock and Ross (1975) emphasize, no necessity of gluing any part; the latter fact greatly facilitates dismantling for cleaning. These are attached at a certain distance from one another to a common support and the

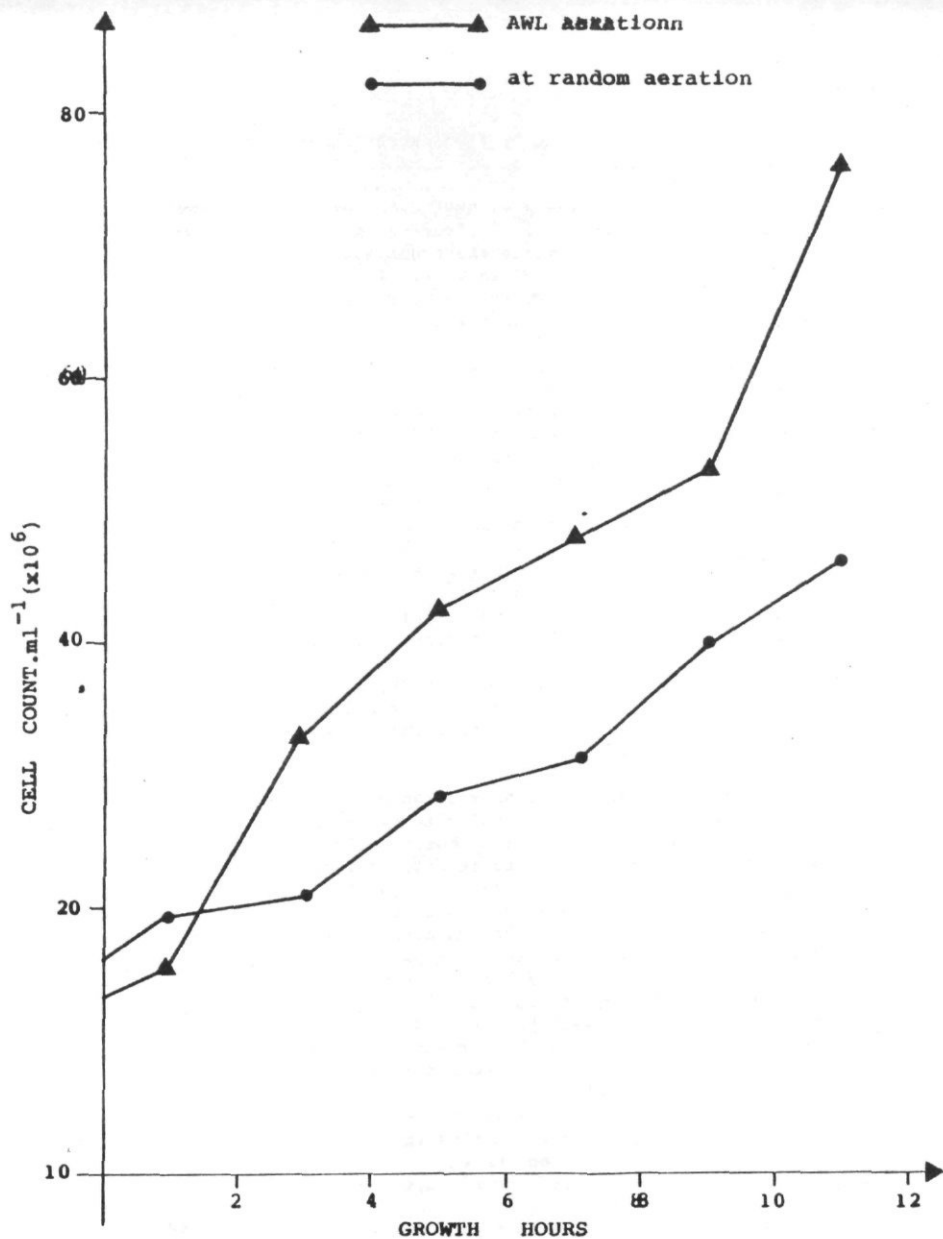


Figure 2 Algal growth curves in 1,000 l fiberglass tanks with AWL aeration or at random aeration

entire set is clamped to the wall of the culturing tank. The free ends of the polyethylene tubings are connected to the source of compressed air, via an expansion vat. The expansion vat (a piece of PVC pipe with a diameter of 10 cm) is closed at one side, connected at the other to the air compressor and provided with a number of PVC nipples to allow connection of the air-water lifts (Figure 1 C).

The beneficial effect of AWL circulation of the culture suspension versus an at random aeration of the tank contents, can be demonstrated by the growth results obtained at the SEAFDEC¹ - Tigbauan Center (Panay, Philippines) with their 1 m³ outdoor cultures of the marine diatom *Chaetoceros* sp.

The 1.0 x 2.0 x 0.6 m fiberglass tanks were provided with 5 AWL pipes (diameter 5 cm) per tank. In the control tank, the culture was aerated by 5 airlines which were kept on the bottom with stones fixed to their ends. 200 g and 20 g of the commercial fertilizers 46-0-0 respectively 16-20-0 were added to the 1,000 l cultures. The water temperature ranged from 29 to 31°C and the illumination at the surface of the culture suspension averaged 35,000 lux. During the experiment the pH increased in both cultures from 8.2 to 8.8. From the growth curves in Figure 2, it is clear that the best results are obtained in the tank with AWL circulation.

The flexibility of the entire setup, its simplicity of construction, dismantling and adaptation to larger or smaller tanks make such air-water lifts a very cheap and most attractive system for culturing algae. As noted previously the labor involved in maintenance and handling of any system and the operational energy costs are key factors in any commercial aquaculture venture.

In regard to illumination it is evident that the closer the light source is brought to the culture, the greater the number of lux the algae will receive, and the denser the culture can become. The self-shading effect which reduces light penetration in the culture with resultant limitation of the photosynthesis, will decrease as a function of the increase in light intensity. Lamps or light tubes placed only a few centimeters above the algal culturing tanks are impractical for several reasons (observation, harvesting, cleaning, etc.). On the other hand, every increase in distance of light source from the algae means a decrease in growth rate as well as in final output.

In order to check the importance of the light factor, we have compared another modification of the Salser-Mock tank, this time with lateral illumination, to the original system where the lights are placed above the cultures. This modification, however, implies the utilization of culturing tanks with at least one transparent longitudinal side. All types of conventional glass aquaria are of course suited. The fluorescent tubes are placed in a horizontal row along the longitudinal side of the culturing tank; the other side

¹ South East Asian Fisheries Development Center - Aquaculture Department

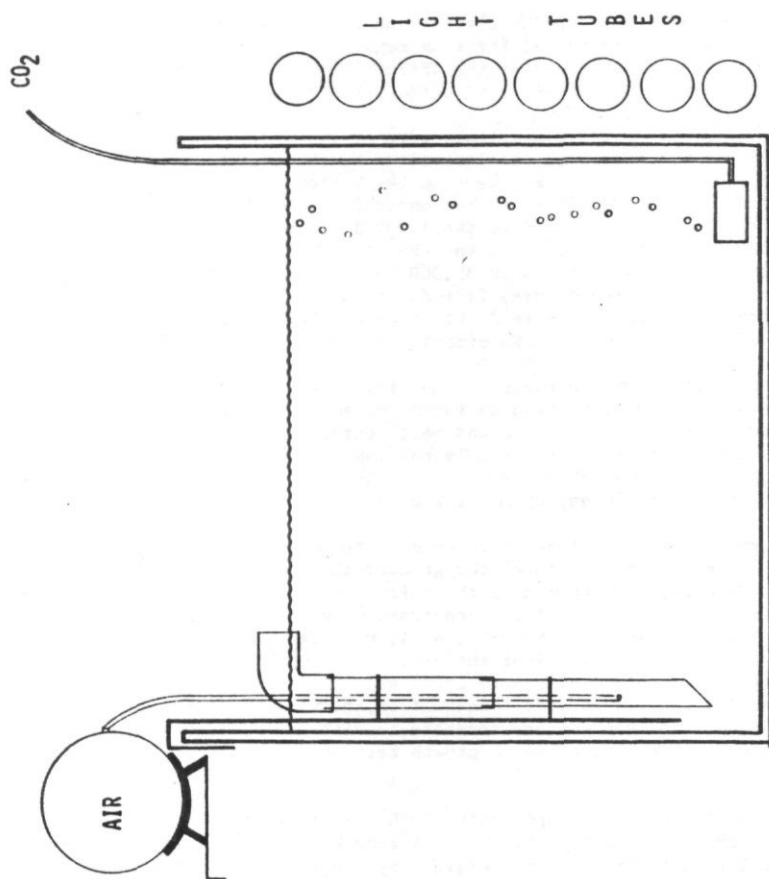


Figure 3 Algal culturing tank in glass, with lateral illum

is provided with a row of air-water lifts (Figure 3). The self-starters and the ballasts of the light tubes are placed at a certain distance from the tanks. By the action of the air-water pumps, the algae are continuously blown towards the illuminated wall and are thus brought very close to the light source. Since the surface of the culturing tank is left free, it is very accessible for any handling.

We have carried out a comparative experiment with two identical glass aquaria of 150 liter contents; one tank was illuminated laterally by 6 light tubes, the other received light from the top, from a row of 6 identical fluorescent tubes fixed in a frame suspended 40 cm above the water surface. The algal species utilized was the marine flagellate *Dunaliella viridis* Teodoresco, inoculated at a starting concentration of 0.1×10^6 cells/ml. The temperature of the cultures during the entire experiment fluctuated only between 18.5 and 20°C in the first tank and between 19.5 and 20.5°C in the second one. The pH was regulated by addition of CO_2 and kept within a range of 7.5-8.0.

As expected, the results of this experiment, shown in Figure 4, reveal that growth rate as well as final yield are higher in the aquarium with lateral illumination. The plateau phase in both cultures was reached in 4 days, with concentrations of 2.1 and 1.4×10^6 cells/ml respectively.

As mentioned above, the better results obtained with lateral illumination could be expected: the light intensity measured at the surface of the illuminated wall of the aquarium averaged 14,000 lux, whereas in the second tank, measured at the water surface, the illumination ranged from 5,600 lux at the edges to 7,200 lux in the center. We cannot say that one system is better than the other; the only practical conclusion is that an illumination, be it lateral or from the top but very close to the surface of the algal suspension, can increase the yields by more than 50% (0.9 versus 1.45×10^6 cells/ml within 3 days of culturing in the experiment mentioned above).

In order to maximally utilize the light energy we went a step further and tested a battery of 3 aquaria placed next to one other, with a row of light tubes sandwiched between 2 adjacent culturing tanks (Figure 5). In such a disposition, the middle aquarium receives, of course, twice as much light as each of the lateral ones, and this again leads to an increase in the obtainable algal densities. In an experiment with glass aquaria (of the same size as those already mentioned) we obtained in the central aquarium densities of more than 3×10^6 cells/ml in 4 days, starting from 0.2×10^6 cells/ml.

An advantage or disadvantage of such a triple system, depending on the temperature of the culturing room, is the warming up of the algal culture from heat radiated by the light tubes. As this heat cannot escape in the sandwiched position of the lights between two aquaria, it is transferred to the algal culture through the glass wall. In our system the temperature in the cultures rose 5-8°C above the ambient temperature.

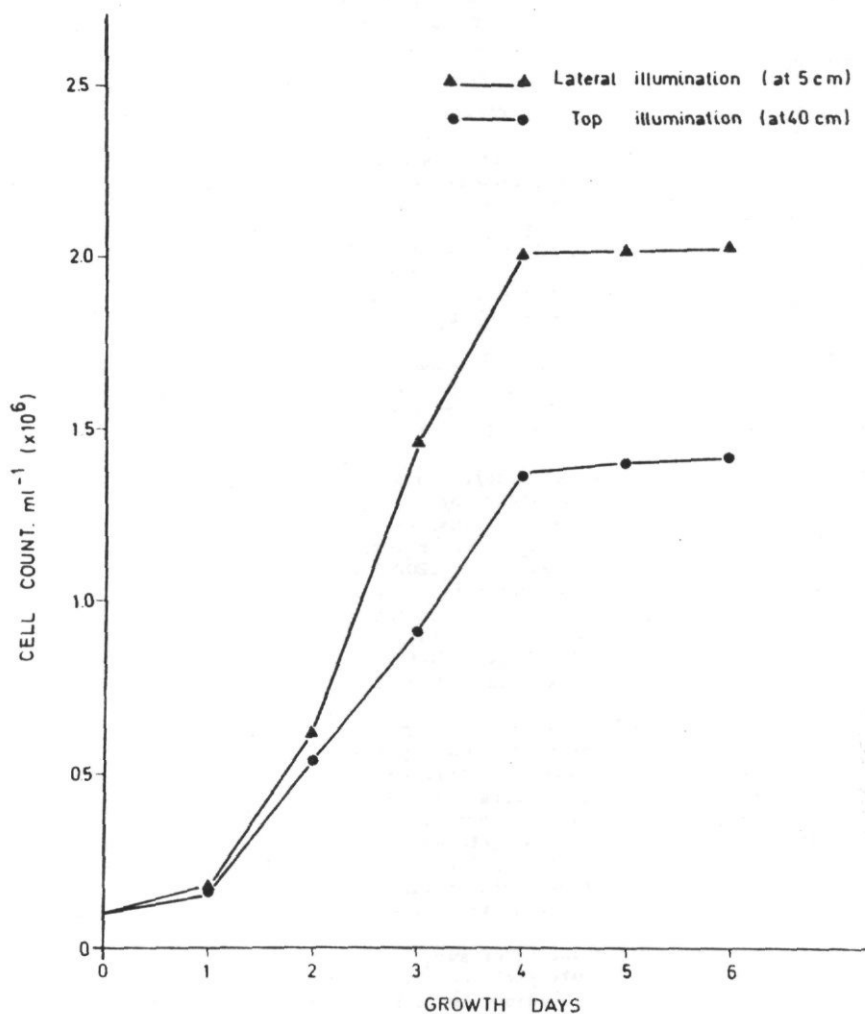


Figure 4 Algal growth curves in 150 liter glass aquaria with lateral illumination (at 5 cm) versus top illumination (at 40 cm)

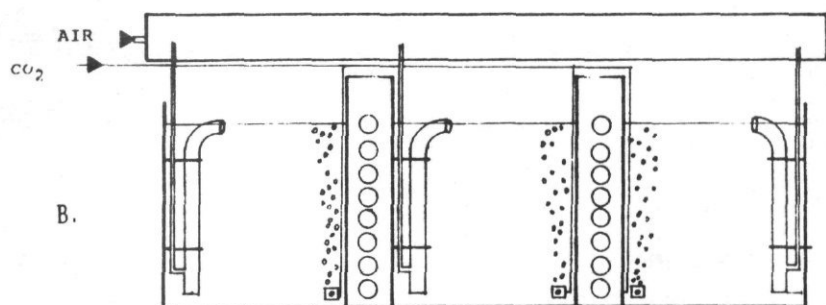
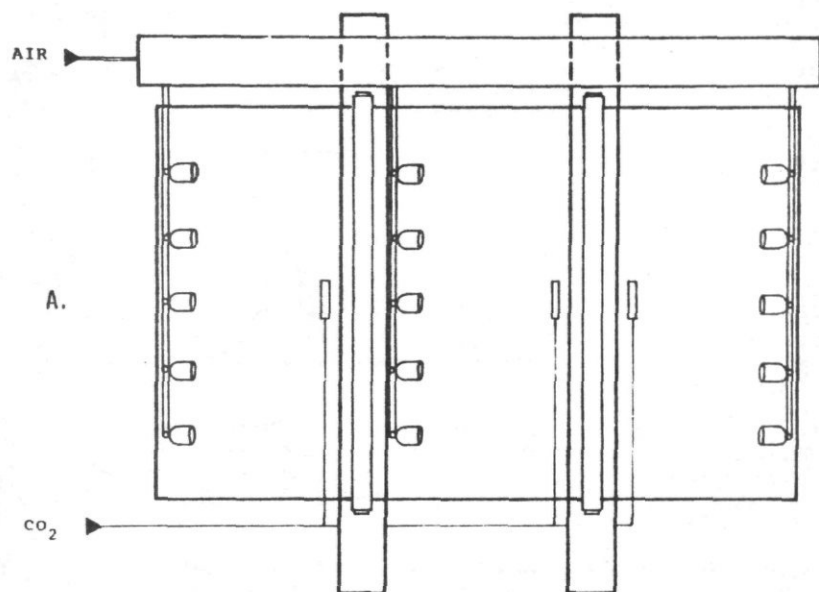


Figure 5 Triple algal culturing system
 a) top view
 b) section view

To conclude we feel that algal culturing systems based on simple air-lift pumps, by their simplicity of construction and their intrinsic property of bringing the algae continuously back towards the light source, should receive much more attention in aquaculture. The higher densities and reduction in culturing time obtained when placing the light source very close to the algae can have a marked repercussion on the cost-benefit in commercial enterprises. Last but not least we would like to mention that preliminary experiments carried out in large outdoor culturing tanks of several m³ contents, which are equipped with rows of air-water lifts, have already given the most promising results.

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