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An improved aeration method combined with waste-foam removal in a sea-water recycling system.

by

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INTRODUCTION

Recycling in sea-water systems is mainly based on sand, gravel or shell-grit filters (HIRAYAMA, 1966 a, b; SHORT and OLSON, 1970). In semi-closed and open systems sedimentation tanks are very often used in connection with UV-sterilization and/or reaeration (HERALD et al. 1960; WOOD, 1961; SHELBOURNE, 1964; LASKER and VLYMEN, 1969). In a few cases laboratory scale aeration was combined with ozonization in order to destroy metabolic by-products and kill pathogens (BENOIT and MATLIN, 1966; SANDER, 1970; FONDS, 1970; ROSENTHAL,1970). It can be assumed that ultraviolet lamps, commonly used in sea-water sterilization for oyster purification units and supplies of sea-water to public aquaria, produce some ozone directly in the water. As a matter of fact, ultraviolet radiation in air produces ozone, particularly in the very short ultraviolet range.

In fresh water fish culture, gravel filters with backwashing installations are commonly used in hatcheries. Trickling filters (KNÖSCHE, 1971) and activitated-sludge treatment units are used in experimental stations especially for carp and trout culture (MESKE, 1971; SCHERB and BRAUN, 1971).

As SHORT and OLSON (1970) have already shown, metabolic by-products and organic solids can accumulate in foams created by sea-water aeration. The controlled production and removal of waste foam seems to be an important possibility in effective sea-water treatment. On the other hand, optimal utilization of aeration is one of the most important factors in cost-effectiveness-relationship in fish culture work. Theoretical principles of aeration are discussed by HANEY (1954). At present, the equipment for water aeration can be classified into three general types which may be largely modified:

1) waterfall aerators (cascades, spray nozzles)
2) surface aerators (rotating propellers at water surface, etc)
3) injection aerators (compressed air).

A comparison of the efficiency of various aeration devices for oxygenation of water in aquaria was made by SCOTT (1972). KNÖSCHE and ROICKE (1972) discussed the results of experimental aeration by air lifts in intensive fish culture units. In recent years there has been growing interest in the combination of aeration and ozonization. New and more efficient production methods have been developed that reduce operational costs. Furthermore, ozone application offers the possibility of combining partial treatment of water with aeration. As ROSEN (1973) has pointed out, ozone application in waste-water treatment is promising when the problems of proper gas-liquid cantacting are solved. This paper describes an aeration device and its operation, which combines intensive aeration with partial water treatment and waste-foam removal.

DESCRIPTION AND FUNCTION OF THE APPARATUS

The apparatus is shown in Fig. 1. It consists of a reaction tower (20), in which intensive mixing of air, or ozone containing air, with water takes place. The water enters the reaction tower (diameter 35 cm; height 110 cm) tangentially near the top and leaves at the bottom (24). In the lower third of the reaction tower, ozone containing air is dispersed by a high speed rotating disc (2 400 rpm) (Figs 1 and 2, (14)). The continuously produced foam moves upward countercurrently into the separation tube (22) where turbulence is reduced by a sieve plate (21). The relatively dry foam is removed via a collection jar (23). The treated water is reaerated in a container (26) of approximately the same volume as the reaction tower allowing residual ozone to be destroyed as well as to avoid oxygen over-saturation. The valves at the inlet (11) and outlet (24) allow not only regulation of the flow rate through the reaction tower but also adjustment of the height of the water level. Except for the stainless steel axis (13) plastic material was used exclusively. Ozone is produced in an electrical discharge (4). Airflow through the ozonizer is controlled via a flow meter(3) and a valve (6). Air supply for ozone production passes a drying unit (2). Additionally, air can be injected into the waste water prior to entering the reaction tower (7).

Construction details of the dispergator are shown in Fig. 2.

AERATION CAPACITY

Several series of experiments were done in order to evaluate the efficiency of this apparatus in terms of rates of oxygen transfer into the water treated. Fish tank run-off water usually showed the lowest oxygen level in a recycling system. Dissolved oxygen content of the water was determined at the inlet and outlet of the reaction tower using the Winkler-method. In order to verify the initial oxygen content at the inlet of the reaction tower, nitrogen gas was bubbled through the water reservoir at various rates. Table 1 exihibits the oxygen levels determined at the inlet and outlet in three experimental series at various flow rates of water and air.

Using the formula reported by KNÖSCHE (1973), the data can be transferred on the basis of a given initial oxygen content of the water to be treated:

$$\Delta O_{2\,x} = \frac{\Delta O_2 \, (C_S - C_{A\,x})}{C_S - C_A}$$

whare C_S = oxygen content of the medium at saturation

C_A = observed initial oxygen content at the inlet

ΔO_2 = observed rise of oxygen level

O_2x = calculated oxygen enrichment at a given inital oxygen level (C_{Ax}) in mg/l.

Figs 3 and 4 show the calculated results obtained experimental data. From Fig 3 it becomes apparent that a water-flow rate higher than approximately 500 l/h results into lower overall oxygen enrichment when the airflow supplied is limited by 80 l/h.

Table 1

Oxygen content (mg/L) in water at the inlet and outlet of the reaction chamber in relation to different rates of water and air flow. n = number of determinations; $\bar{x}$ = mean; s = standard deviation.

n	oxygen content inlet $\bar{x}$	oxygen content inlet + s	oxygen content outlet $\bar{x}$	oxygen content outlet + s	oxygen enrichment (mg/l)	air flow rate (l/h)	water flow rate (l/h)
5	2.25	0.10	7.56	0.12	5.31	80	270
5	3.25	0.09	7.75	0.05	4.86	80	470
5	2.75	0.23	7.61	0.05	4.50	80	660
5	1.62	0.11	6.62	0.08	5.00	80	1860
5	1.63	0.13	6.21	0.25	4.52	80	1940
5	3.42	0.05	7.97	0.04	4.55	250	400
5	1.93	0.32	7.63	0.06	5.70	250	660
5	1.46	0.26	7.58	0.10	6.12	250	900
5	2.21	0.21	7.30	0.13	5.09	250	1100
5	2.12	0.28	7.45	0.04	5.33	250	1530
[illegible]	1.90	0.12	7.24	0.15	5.34	250	1860
5	0.96	0.14	7.65	0.11	6.69	250 + O_3	850
5	1.00	0.15	7.60	0.18	6.60	250 + O_3	850
5	1.72	0.28	7.34	0.12	9.62	250 + O_3	1510
5	2.36	0.16	7.04	0.17	4.68	250 + O_3	1800
5	1.76	0.09	7.04	0.05	5.28	250 + O_3	1980
5	1.84	0.20	6.98	0.09	5.14	250 + O_3	1980
5	1.83	0.05	6.90	0.17	5.07	250 + O_3	1980

If the air flow rises up to 250 l/h (Fig 4), water-flow rates up to 2 m^3/h do not significantly depress the oxygen level of enrichment regardless of the initial oxygen content of the water at the inlet of the reaction tower. In other words, at an air-flow rate of 250 l/h the aeration capacity of this divice is not fully utilized. On the other hand, minimum air volume supplied per unit time will result in small air-bubble size and therefore guerentee maximum contact surface area between air and water. To reach maximum surface contact is of major importance to ozone application in sea-water treatment because of the high rate of decomposition of ozone in alkaline solution. Furthermore it is well known that ozone has not always to be in solution to initiate reaction.

Oxygen tranfer efficiency was about 4 times as great in the experiments with the lower air volume supply (Fig 5). In many cases oxygen levels reached were close to saturation levels; in several trials oversaturation occurred.

Fig 6 indicates the relationship between the oxygen-transfer rate at different water-flow rates for all aeration levels employed. Regardless of the air flow, oxygen levels increased linearly with water flow rates.

As shown by KROKE (1964) and postulated by BECKER (1920), efficiency of oxygen-transfer rates are strongly dependent on the water-flow rate and the air-bubble size, as pointed out by GILLBRICHT and HARDER (1955). Additionally, countercurrent contacting increases the efficiency of oxygen transfer considerably (DERINGER, 1970).

The experimentally obtained oxygen transfer of 5.5 g O_2/m^3 at a temperature of 22°C and a salinity of approximately 32°/oo results in an efficiency of operational costs of 0.45 kg O_2/KWh when the water flow rate was adjusted to 2 m^3/h. Comparable values for oxygen transfer rates in sea-water are not available. At lower temperatures (15 - 17°C) in fresh water KNÖSCHE (1973) reports a somewhat higher efficiency of about 0.53 kg O_2/Kwh.

FOAM SKIMMING

The energy input is not only utilized for oxygen transfer but also for partial water purification by effective foam skimming. The amount of foam produced varies with the total organic load of the water. The water level in the reaction tower has to be adjusted when the amount of foam produced is relatively low resulting in a very dry and consistent foam, which sometimes blocks the outlet at the scum beaker (23). Using a water-flow rate of about 660 l/h (air flow 250 l/h) continuous foam skimming is most efficient when 8 to 10 l liquid waste can be collected daily, which is equivalent to about 0.7% of the total volume of our laboratory system.

The foam contains a high amount of particulate and dissolved organic matter ($KMnO_4$ consumption 10 times as much as in untreated water; i.e. ~ 800 - 900 mg/l). In other words, during an 8 h operation period about 10% of the organic load was removed from the total system, which contains about 1 600 l with an average load of 80 - 120 mg/l ($KMnO_4$ values). Nitrite in the water treated with ozone containing air was negligible (< 0.01 mg/l), indicating that ozone quantitatively oxidized nitrite to nitrate within the reaction time.

CHANGES IN pH VALUES DURING OZONATION

Slight pH reduction could be observed during intensive aeration or ozonization depending on the residence time (i.e. water-flow rate) of the water in the reaction chamber and the total organic load. During the experiments reported here, in a few cases pH decreased during treatment of the water as much as 0.1 to 0.3 units (Fig 7). The initial lowering of the pH value is not very surprising. The mechanism of ozonolysis of organic material in aqueous solution is not yet fully investigated. There is evidence that the initial peroxidic ozonolysis products are decomposed to aldehydes and/or carboxylic acids.

DISCUSSION

The apparatus developed combines aeration with partial chemical treatment of water. The oxygen transfer efficiency of this small-scale operating unit in sea-water is well in the order of magnitude of that obtained using other techniques in fresh water. The system has some advantages with respect to ozone application when compared with other contacting devices (e.g. injection). The amount of air introduced into the reaction chamber can be minimized to allow (a) optimum air-flow rate through the electrical discharge for maximum ozone production, (b) maximum contacting between air and water in the reaction chamber. According to the theory of aeration a large interface of water and air is necessary, but too rapid renewal of this interface is detrimental to oxygen-transfer efficiency (PASVEER, 1966). Countercurrent contacting proved to be a real possibility to extend the time of contact of air bubbles and water.

At a given speed of revolution of the rotating disc and a given pressure due to the height of the water column, the initial size of air bubbles depends on the amount of gas dispersed by the rotating disc. From photographic measurements it can be assumed that the initial bubbles size obtained is of at least one order of magnitude smaller than those obtained by using the injection method or compressed air. This is advantageous as it increases the air-water interface. Intensive contacting reduces operational costs of ozone application considerably. Intensive initial contacting is necessary because of the rapid decomposition of ozone in alkaline solutions. On the other hand, the speed of decomposition of ozone in sea water reduces the possibility of residual ozone in the fish tanks.

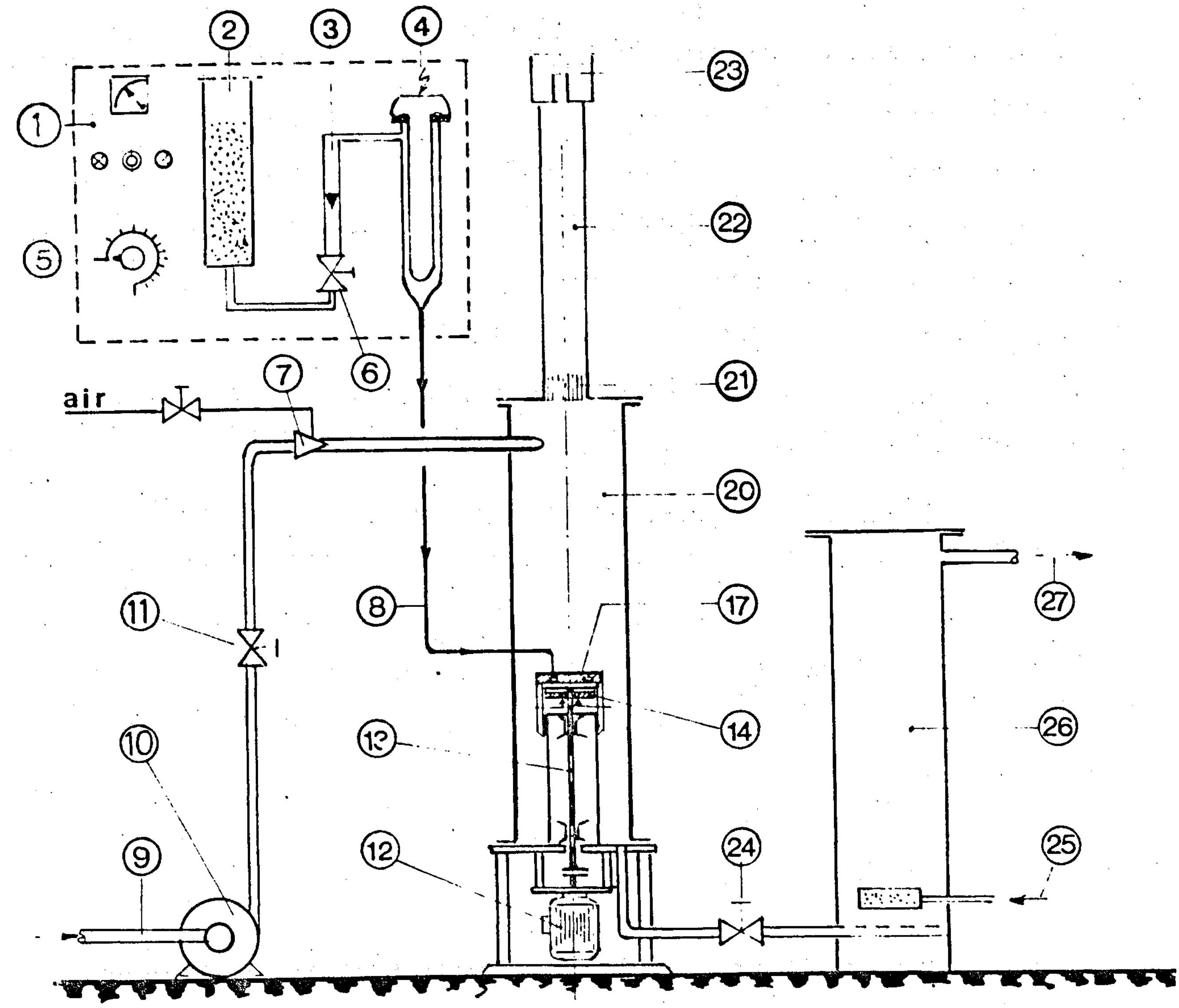

Fig. 1: Aeration device combined with ozonization and foam skimming.
1 = Voltmeter; 2 = air drying unit; 3 = flow meter;
4 = electrical discharge; 5 = power switch; 6 = valve;
7 = injector; 8 = tube connection (ozone containing air);
9 = raw wastewater; 10 = water pump; 11 = valve,
12 = motor (2 400 rpm); 13 = stainless steel axis;
14 = rotating disc; 17 = sieve plate for ozone and air supply;
20 = reaction chamber; 21 = sieve plate to reduce turbidity;
22 = foam separation tube; 23 = scum beaker; 24 = valve;
25 = reaeration with compressed air; 26 = reaeration chamber;
27 = outlet to fish tank.

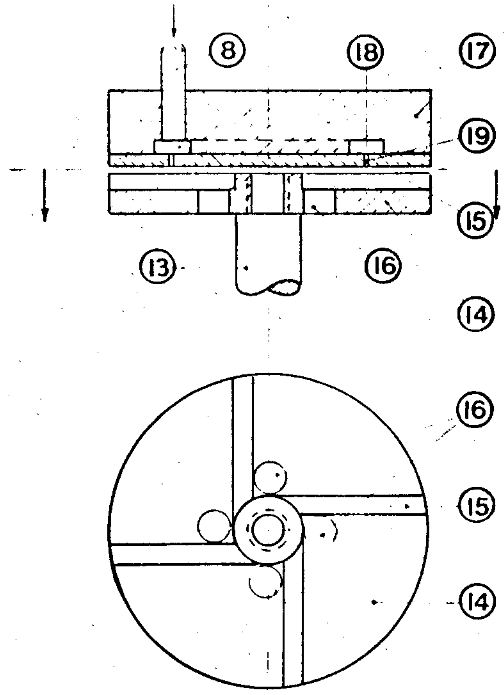

Fig. 2: Construction details of the high-speed rotating disc.

14 = disc;
15 = radial bars;
16 = holes for water supply;

8 = supply of ozone containing air;
13 = stainless steel axis;
17 = plate carrying a ringcanal (18 with supply holes (19)).

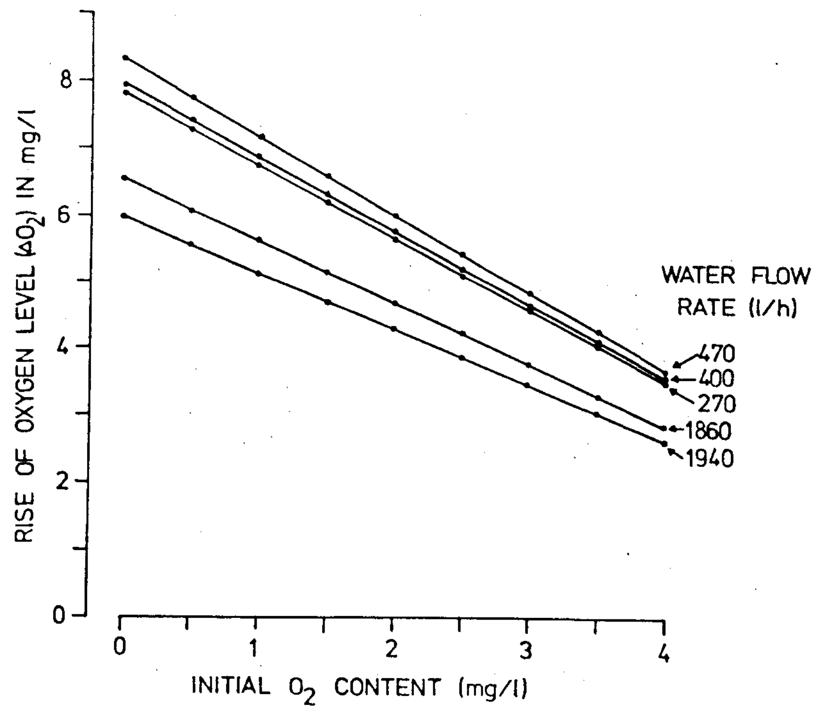

Fig. 3: Oxygen enrichment in relation to water flow rate and initial oxygen content at a constant air supply rate of 80 l/h.

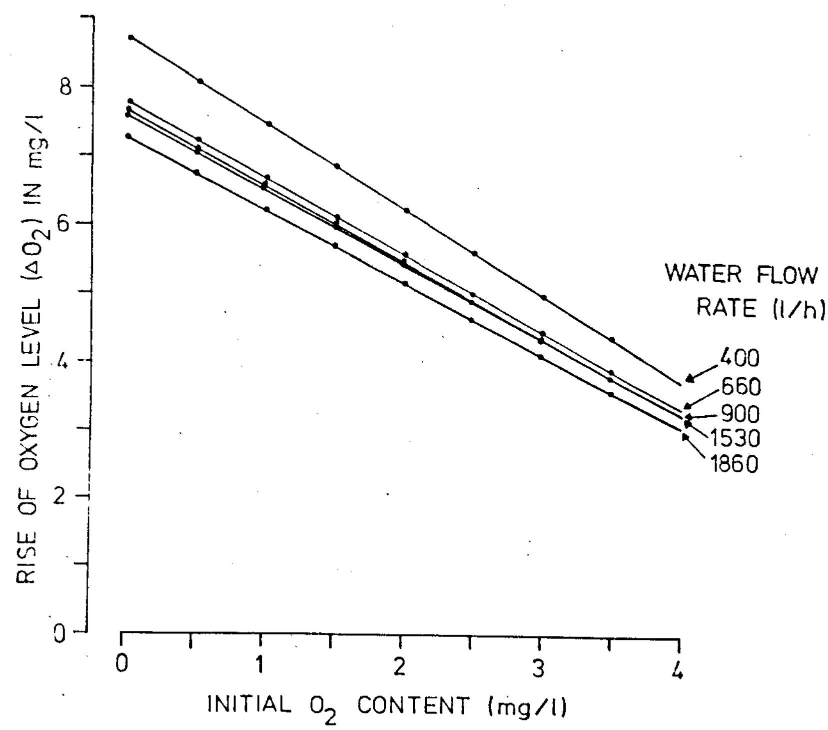

Fig. 4: Oxygen enrichment in relation to water flow rate and initial oxygen content at a constant air supply of 250 l/h.

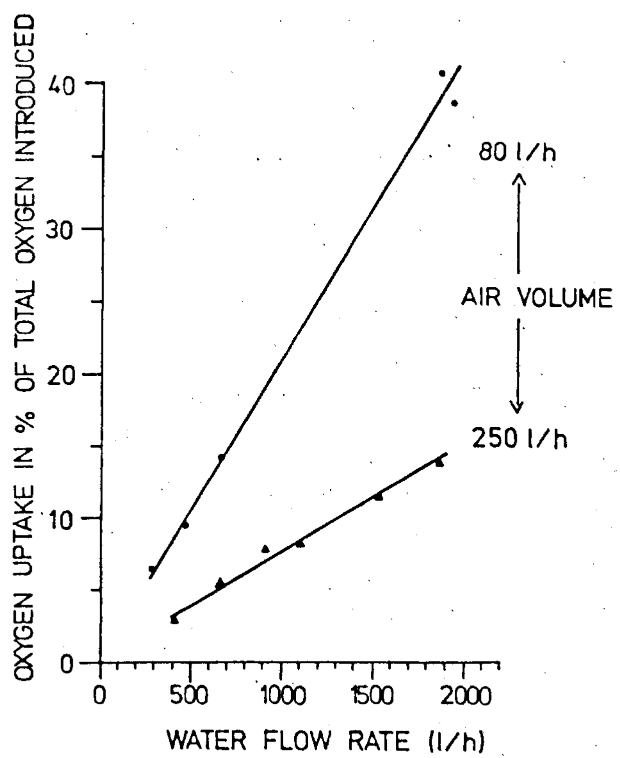

Fig. 5: Oxygen transfer rates in relation to water flow rate and air supply

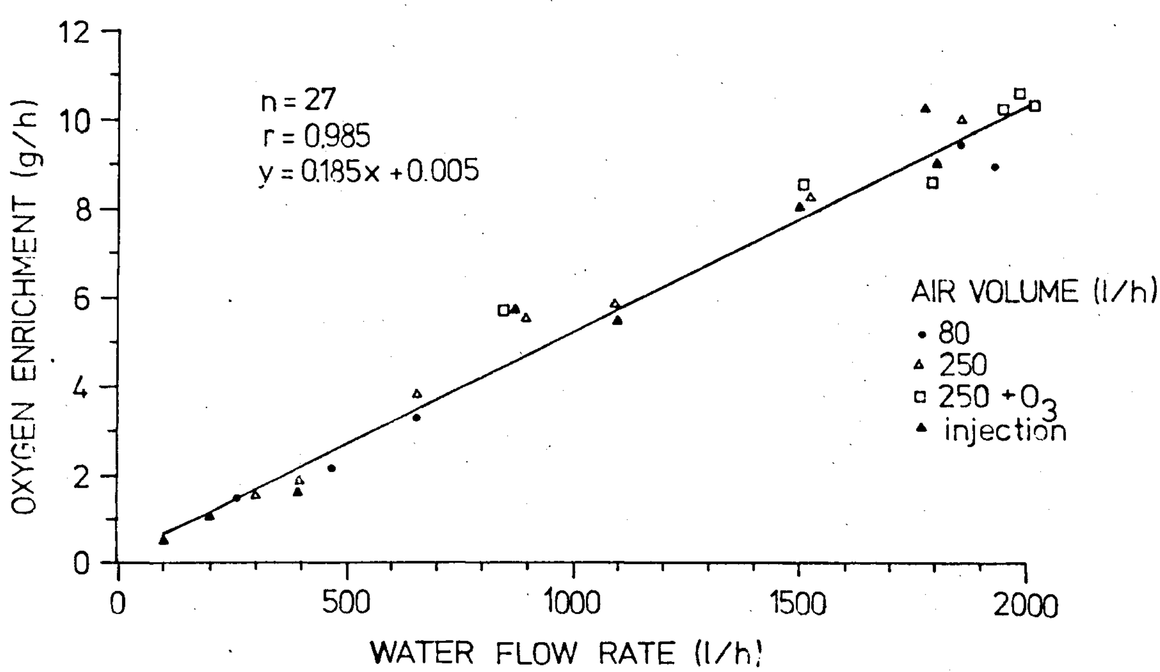

Fig. 6: Oxygen enrichment at different water flow rates and varying air volume introduced.

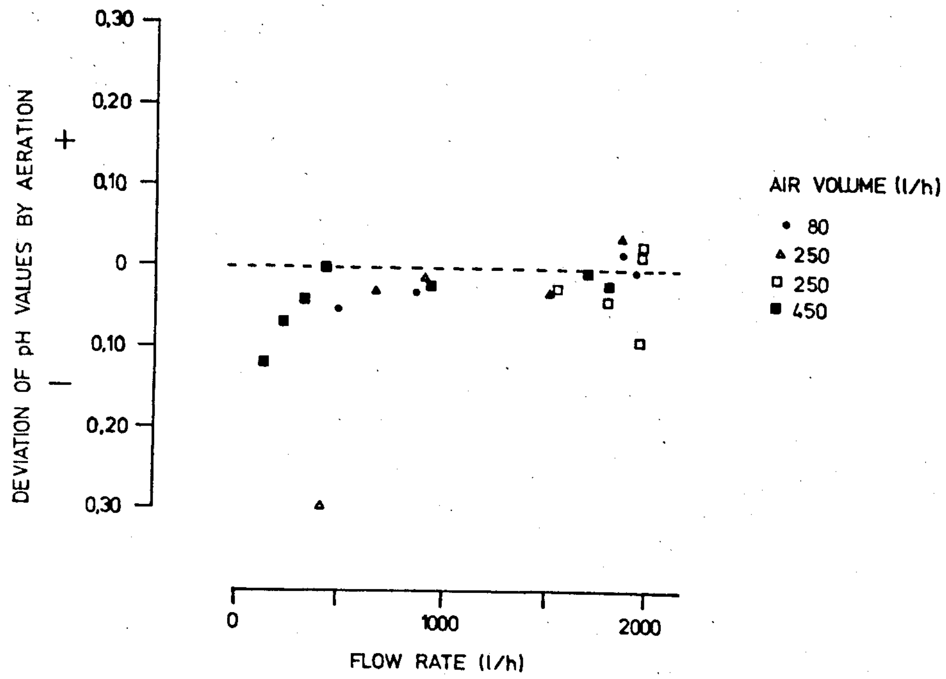

Fig. 7: Changes in pH values in relation to air and water flow rates.

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