Introduction

The intensive fish culture system often needs the introduction of artificial aeration systems (Boyd and Ahmad, 1987). These systems vary from emergency aeration, operated only when the oxygen level drops to dangerous values, through ordinary night-time aeration, to continually operating aeration systems in highly stocked ponds. The obvious role of aeration is to supply oxygen to fish. In addition, aeration of the water may affect a variety of other biological systems in the pond. In the biological treatment of wastewater, aeration is an important process employed to raise the dissolved oxygen (DO) level to allow aerobic bacteria to reduce biochemical oxygen demand of the effluent and thus to improve the water quality. The oxygen supplied must be at a rate sufficient to at least balance the rate of removal of the active biomass. Aerators are the devices used to supply oxygen to meet such demands (Boyd, 1998; Moulick et al., 2002).

Various types of aerators have been developed over the years to maintain desired level of DO concentration in the pond water in an effort to improve the energy efficiency of the oxygen mass transfer process. To meet the aeration requirements, two methods are commonly used: (1) splash aeration by vertical pump, pump-sprayer, cascade and paddle wheel aerators or (2) bubbling aeration by diffused-air systems and propeller-aspirator-pumps. In aquaculture, propeller-aspirator-pump aerators, vertical-pump aerators, diffused-air aeration systems and paddle wheel aerators are widely used. In small ponds (≤1 ha), propeller-aspirator-pump aerators, vertical-pump aerators and diffused-air aeration systems are generally used for aeration. Boyd and Ahmad (1987) evaluated the performance of a large number of electric aerators for oxygen transfer efficiency. The results depict that, in general, paddle wheel aerators were more efficient than other types of aerators. Cascade aerators, a type of gravity aerators, are generally used as pre- or post –aeration system. If site constraints and hydraulic conditions permit gravity flow, the least costly method to raise DO levels is with the use of cascade aeration system (Tchobanoglous et al., 2003).

The cascade aerator basically consists of a series of steps over which the water is allowed to flow as a thin film. During the fall of the water, bubbles rise up as air gets dragged in. Gas exchange occurs between the air in these bubbles and the water. Oxygen diffuses from the air into the water and helps to increase the DO content of the water. In rivers, artificial stepped cascades and weirs are generally introduced to enhance the DO content of polluted or eutrophic streams (Avery and Novak, 1978; Nakasone, 1987). In-stream stepped cascades are also built downstream of large dams to reoxygenate water, e.g., Chatuge weir built by Tennessee Valley Authority (Hauser et al., 1991; Hauser and Morris, 1995). Another example is the series of five aeration cascades built along the Calumet waterway in Chicago (Robinson, 1994). The waterfalls are designed to reoxygenate the polluted canal water and are landscaped as leisure parks, combining flow aeration and aesthetics. With large dams, nitrogen super saturation might also occur and increase the mortality of some fish species. In the Columbia and Snake rivers (USA), 'gas bubble disease' caused by water supersaturated with nitrogen gas was a significant cause of fish mortality for salmonids and steelheads (Boyer, 1971; Smith, 1973). Stepped cascades could be used to reduce the dissolved nitrogen content. In the treatment of drinking water, cascade aeration is used for reoxygenation, denitrification (Hoek, et al., 1992), removal of volatile organic components (VOC) such as methane and chlorine (Toombes and Chanson, 2005), dissolved iron and manganese, carbon dioxide, hydrogen sulphide, as well as the colour and tastes caused by volatile oils.

The research work carried out so far in the area of stepped cascades was particularly focused on stepped spillway design, pre-aeration of raw water or post aeration treatment of wastewater. The stepped spillway is generally used as an energy dissipation unit. The pre-aeration process is generally adopted to remove iron and manganeous salts in the raw water, whereas post aeration introduces high dissolved oxygen (DO) levels (5 to 8 mg/l) in the effluent to meet the effluent standards and permits (Tchobanoglous et al., 2003). The provision of cascade aerator as a main aeration unit in wastewater treatment plant or aquacultural ponds has not been tried. Boyd (1982) reported that cascade aerator produces the lowest aeration efficiency when compared to other ones, viz. diffuser-air, mechanical aerator etc. Hence the idea of using a cascade aeration system may not be a viable one until and unless it is used in conjunction with some other system.

. It is well understood from the literature that rectangular cascade aeration system may not be a good option for re-oxygenating a water body. The main possible reason is the creation of a lesser amount of turbulence associated with high power consumption and thereby lesser aeration efficiency when compared with the other systems. But, if a circular stepped cascade be used in combination with a pump, possibly the symmetrical radial flow pattern will improve the water circulation within a closed water body, leading to better aeration efficiency.

In the present study, an attempt has been made to introduce a circular stepped cascade in combination with a pump as a main aeration unit to be used in aquacultural pond or in wastewater treatment plant. The proposed new aeration system hereafter will be referred to as circular stepped cascade pump (CSCP) aeration system. Being a simple device with only static components, it is strongly believed that introduction of such a system will reduce the cost of maintenance as well as energy consumption when compared to other existing aeration systems. Moreover, it will potentially solve the problems of low dissolved oxygen content, high concentration of volatile organic components, high accumulation of nitrogenous compounds and stratification simultaneously. In the light of the above discussion, the following are the specific objectives of the present study:

(i) Optimization of geometric parameters of CSCP aeration system.

(ii) Development of simulation equations for prediction of aeration characteristics of CSCP aeration system at different dynamic conditions.

(iii) Development and performance evaluation of prototype CSCP aerators.