Computational Studies of Confined Submerge Fan to Circulate and Oxygenate Hypolimnetic Layer in Hydro Power Reservoirs

Muhammad Umar Mushtaq[1], Khairuddin Sanaullah[1], Andrew Ragai Henry Rigit[2], Afrasyab Khan[2] and Harunal Rejan Ramji[1]
[1]*Department of Chemical and Energy Sustainability, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Malaysia.*
[2]*Department of Mechanical and Manufacturing Engineering and Energy Sustainability, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Malaysia.*
muhammadumarmushtaq@gmail.com

***Abstract*—The oxygen level is deficient at the depth of the lakes or reservoirs due to thermal stratification. Due to deficient oxygen level at the bottom of thermal stratified lakes, the reduction reactions occur that form hydrogen sulphide, iron, phosphorous and other compounds which are harmful to the water quality, fish life as well as dam or reservoir structures and other species. Hypolimnetic aeration and oxygenation systems can be used for this purpose to prevent the formation of harmful substances. A prototype design of submerged fan will be used to penetrate at maximum depth of the lakes or reservoirs and find the velocity of the submerged fan through CFD simulations.**

***Index Terms*—Thermal Stratification; Deficient Oxygen; Aeration; Submerged Fan; CFD Simulations.**

I. INTRODUCTION

The preservation of freshwater quality is nowadays becoming a very important issue because of the increasing water demand for last few decades. The threatening problem with the quality of fresh reservoir/dam water for countries in tropical regions is eutrophication. Eutrophication is due to the gathering of the excessive richness of nutrients in a lake or other body of water, which promotes the dense growth of plant life and death of animal life (e.g. bloom, phytoplankton) from lack of oxygen in the bottom layer. During summer, hot temperature causes a stratification process dividing the water volume during a large period of the year. The thermal stratification is a change in the temperature at different depths in the lake and is due to the change in water's density with temperature. It consists of three layers. Epilimnion is the top-most layer in a thermally stratified lake. It is warmer and typically has a higher pH and dissolved oxygen concentration than the hypolimnion. Thermocline is a thin but distinct layer in a large body of fluid (e.g. water, such as an ocean or lake, or air, such as an atmosphere). Hypolimnion is the dense, bottom layer of water in a thermally stratified lake. It is the layer that lies below the thermocline. The hypolimnion may be much warmer in lakes at warmer latitudes. In the hypolimnion of productive (productive lakes means measurements of dissolved oxygen and temperature) lakes the sedimentation of organic matter from the surface water is extensive. Algae and other suspended particles are abundant, light penetration through the water column to the hypolimnion are limited and photosynthesis cannot occur. Under these conditions, the bottom sediments during the decomposition of the organic matter greatly exceed the oxygen produced. This results in depletion and in some cases a complete absence of dissolved oxygen in the hypolimnion layer. Due to the deficient oxygen at the bottom of the lakes or reservoirs causes the reduction processes, which lead to the formation of hydrogen sulphide, iron, manganese and phosphorous and these are harmful to the aquatic life e.g. salmon, roach, carp, trout, turtles, etc. and the water quality which can be harmful if being used for drinking and cooking purposed without treatment.

II. BACKGROUND

According to Singleton [1], there are three primary devices that include airlift aerator, speece cone, and bubble plume diffuser which can be appropriately proposed for restoring hypolimnetic aeration as well as oxygenation systems to dissolve oxygen in the bodies of water in order to preserve stratification. Further, the initial aeration systems were used to have mechanical agitation of water, directly pumped on the surface of a lake from the hypolimnion into a splash basin as reported in the study [2].

Moreover, there are airlift devices which can be used for hypolimnetic aeration; similarly, partial-lift systems can be operated to inject compressed air in the vicinity of the base of the hypolimnion. The mixture of air-water can travel through the vertical tube at the specified depth in the lake. The remaining gas bubbles can be vented to the atmosphere through a pipe to the surface. However, the oxygenated water is revisited towards the hypolimnion; whereas, full lift systems can be considered as the same excluding air-water mixture [3] which can be arisen to the surface prior to releasing the residual gas bubbles [4].

Dr. Richard Speece invented [5]-[7] speece cone device which is comprised on the conical chamber based on large diameter of the reservoir at the bottom or the base and in which water is used from the top of the cone; whereas, the cross-sectional area has been considered as the smallest by means of a submersible pump flows downward.

Many studies including [8]-[9] reported that the most hydrodynamically complex device is used to be called as the bubble-plume diffuser; similarly, air or oxygen bubbles are called into the base of the reservoir from an unconfined bubble diffuser. According to Mobley, the diffuser can be