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# A Two-Dimensional Model for Simulation of Wind-Induced Flow and Water Quality in Confined Water Bodies with Floating Aquatic Plants

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Closed water bodies, such as lakes and reservoirs, are well-known as major surface water sources for life. Human life depends on them for a multitude of uses including drinking, power generation, agricultural irrigation, etc., but they may also be subject to pollution caused by these and other activities, which may degrade their water quality. Therefore, lakes and reservoirs are still the subject of great environmental concern. One of the key issues, which has drawn attention from researchers in the field of water environment so far, is circulation in lakes and reservoirs because it is closely related to questions of environmental protection, water supply and ecology (Sündermann, 1979). Circulation in closed water bodies is primarily caused by wind shear stress acting on the water surface, affected partly by density gradients, aquatic plants and other factors. Therefore, the circulation is complicated, and we are far from having solved all problems. Therefore, in this research, wind is mentioned as a principal source of mechanical energy for the circulation in closed water bodies.

Because the exchange with external waters is usually small, the wind-induced flow significantly affects the water quality of closed water bodies by mixing the surface waters and transferring heat down through the water column. However, the circulation caused by wind acting on their water surface can be greatly influenced by the excessive growth of floating aquatic plants such as water hyacinths, algae… in summer, which may make their water quality become worse. Floating aquatic plants have been a cause of great concern in terms of environmental and socio-economic impacts because their presence in the closed water bodies has both positive and negative points. Previous researches indicated that some kinds of the aquatic plants could assimilate nutrients and some metals, therefore, to certain extent, contributing to water purification. However, the excessive growth of aquatic plants can cause nuisances such as hindering navigation by clogging water ways, etc. In dynamic aspect, due to the poor exchange with external waters, wind becomes the main factor to help closed water bodies circulate by causing the wind-induced flow (the wind-induced circulation), in addition to thermal convective circulation. In case of aquatic plants' presence, the fetch of free water surface will be narrowed. So, the question raised here is that how the closed water bodies respond to the external sources such as wind and aquatic plants. Answering the question is great of significance in maintaining their water quality in good condition. With that significance, this research has been done to build a two-dimensional, unsteady, laterally averaged model for simulating the circulation and water quality in closed water bodies with floating aquatic plants. The model has been done on the simplifying assumption that the flow in lakes is well-mixed laterally so that a two-dimensional model can be applicable. The equations in the model can not be solved analytically in the differential forms. Therefore, they must be treated by approximation with the finite volume method (FVM). To solve the discretized equations, the SIMPLE algorithm (Patankar, 1980) was applied with the support of the Tri-Diagonal Matrix Algorithm (TDMA).

To verify the model, the Tabiishidani reservoir located in Sasaguri town, Fukuoka prefecture, Japan, was chosen as a case study. Simulations were conducted with assumed cases of 0 %, 20 %, 35 % and 50 % water hyacinth coverage on the water surface. The simulated results have visualized these cases of the flow pattern. It indicated that floating aquatic plants could significantly hinder the wind-induced flow. When the area of floating aquatic plants increases, it creates water regions which are not involved in the circulation under the aquatic plant coverage. To illustrate the methodology for water quality simulation, water temperature of the reservoir was chosen to calibrate the model.

This research shows that the model can be a suitable tool for simulating the wind-induced flow and water temperature in closed water bodies. It can be extended to simulate any variable of water quality.