THE POTENTIAL IMPACTS OF TEMPERATURE CHANGE ON WATER QUALITY PARAMETERS IN YOSHINO RIVER, JAPAN

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ABSTRACT**:** Water quality is an important component of sustainable water resources and environmental management. The prime objective of present paper is to examine water quality trends and to elucidate the impact of temperature change on selected water quality parameters in Yoshio River, Shikoku, Japan. A rise in annual mean global temperature will create a shift towards an increase in precipitation and extreme events. Air temperature is in close equilibrium with water temperature and rise in air temperature may result in an increase in thermocline depth and mean water temperature. The statistical analyses of historical water quality data, ranging from the years 1996 to 2010, collected at Sameura Dam reservoir were performed. Water temperature and dissolved oxygen are found to be well correlated. The results of the research showed that the change in water temperature may provide a reliable basis in predicting ecological state of water bodies.
KEYWORDS: Water Quality parameters, Temperature, Impact

1. INTRODUCTION

Of all the water on Earth, only 2.5% is freshwater and has an uneven distribution in both space and time. Freshwater that is found in rivers, streams and lakes forms a complex system. Climate changes become a major environmental concern and may introduce increased inter- and intra- annual variation in water quantity and quality. A rise in surface water temperatures (0.2 - 2 °C) was observed since the 1960's in Europe, North America and Asia, mainly due to atmospheric warming in relation to solar radiation increase [1]. Climate change is expected to have far-reaching consequences for river regimes, flow velocity, hydraulic characteristics, water levels, inundation patterns, residence times, changes in wetted areas and habitat availability, and connectivity across habitats [2]. More intense rainfall and flooding could result in increased loads of suspended solids [3], sediment yields [4], *E. coli* and contaminant metal fluxes [5] associated with soil erosion and fine sediment transport from the land [6]. Water temperatures have an impact on internal lake processes like diffusion, mineralization and vertical mixing [7]. Also, it is predicted that especially shallow lakes will experience an increase of temperature in epilimnion and hypolimnion during summer [8]. The meteorological parameters influencing water temperature are air temperature, net solar radiation, cloud cover, relative humidity and wind speed. Other parameters affecting stream temperature include: flow rate, groundwater inflow rate and temperature, thermal conductivity of the sediments, wind sheltering and shading, and cooling/ waste water inputs [9]. Water quality represents the physical, chemical and biological characteristics of water and measure the ability of water bodies to support beneficial use to society [10]. If water temperatures increase, specially at critical times of the year, water quality would be adversely affected. The prime objective of present research is to examine the correlation between different water quality parameters and to elucidate the relationship between ambient temperature, water temperature, and dissolved oxygen.

2. MATERIAL AND METHODOLOGY

Sameura dam reservoir (33°45'42" N and 133°30'17.8" E) is located in the upstream of the Yoshino River. The catchment area of the dam is 472 km^2 and most of the catchment area is covered with dense forest. The reservoir water depth range from 50 to 75 m. A detailed water quality and biological features survey has been carried out monthly by Sameura dam water quality monitoring team, Japan water Agency. The water temperature and dissolved oxygen (DO) measured along the vertical profile at the dam lake, ranging from 1996 to 2010, were comprehensively analyzed. The water samples were taken at three depths in the vertical profile: i) 0.5 meter below the surface, ii) in the middle, and iii) 1m above the bottom of the lake. Moreover, the trends in other water quality parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), total nitrogen (TN), total phosphorus (TP) and chlorophyll-a (Chl-a) were also examined.

2.1 Description of Water Quality Parameters

Water temperature: Water temperature is one of the most important physical characteristics of aquatic systems and affects a number of water quality parameters. Temperature significantly influence the kinetic rates of nutrient transformation; the rate of chemical reactions increase with the temperature. Temperature significantly influences the temporal and spatial distribution of microbial process rates and fishes. Algal growth usually thrives within a certain temperature range. It increases with temperature until an optimum temperature is reached and further increase in temperature will inhibit algal growth. Temperature affects water column density, an important factor in hydrodynamics circulation.

Dissolved Oxygen (DO): DO is the amount of oxygen that is dissolved in water and is used to measure the amount of oxygen available for biochemical activity in water. DO saturation is a function of water temperature. DO is one of the most important water quality parameter and is a basic requirement for a healthy aquatic ecosystem. Low DO is a sign of possible pollution in a waterbody. As DO levels in water drop < 5.0 mg/l, aquatic life is put under stress. Oxygen concentrations < 2mg/l are considered hypoxic. The prolonged periods of depressed oxygen can alter the vital ecosystem.

Algae: Algae are a group of aquatic plants that contain chlorophyll and grow by photosynthesis. Algae uptake nutrients and release oxygen to water. Chl-a is commonly measured in water quality monitoring campaigns and is an indicator of the abundance of phytoplankton in the water. An overabundance of algae is known as eutrophication.

Nutrients: Nutrient loads are expected to increase under climate change [11]. Nutrients are chemical elements or compounds necessary for the growth of living organisms. Nitrogen, phosphorus, carbon dioxide, and silica are essential nutrients required for algal growth and survival. Nitrogen to phosphorus (N/P) ratio in the algae is 7.2 and carbon to phosphorus ratio (C/P) is 41.

Statistical analysis of physicochemical data such as temperature, DO, turbidity, nutrients, contaminants, and depth provides information about water quality condition. The statistics for selected water quality parameters are tabulated in the table 1.

Table1: Statistics of selected water quality parameters

	Minimum	*Maximum*	*Median*	*Average*	*SD*	*CV,%*
Temp (^{o}C)	5.70	28.80	17.50	16.80	6.40	38.10
Turbidity (Degree)	0.20	44.50	1.20	1.75	2.64	150.39
DO (mg/l)	5.50	12.40	9.20	9.33	1.01	10.78
COD (mg/l)	0.00	2.60	0.60	0.63	0.44	69.80
BOD (mg/l)	0.30	6.50	1.60	1.66	0.60	36.13
SS (mg/l)	0.00	26.30	1.10	1.44	1.88	130.85
(T-N) (mg/l)	0.00	0.57	0.00	0.01	0.05	366.10
(T-P) (mg/l)	0.00	0.07	0.00	0.00	0.01	152.56
Chl-a (μg/l)	0.20	15.20	1.30	1.80	1.70	94.17
River Inflow (m^3/s)	1.60	1221.50	12.15	24.97	77.05	308.62

3. RESULTS & DISCUSSUION

Spatial and temporal variations in water quality parameters were observed. The dam lake is classified as Case-II water because of weak correlation between Chl-a and SS (Figure 1).

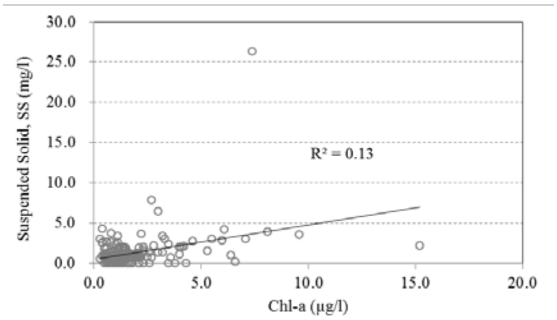

Figure 1: Correlation between Chl-a and SS

It was noted that water temperatures ranged between 5.7°C to 26.80 °C at a depth of 0.5 m. The temperature decrease with the depth and vertical temperature profile of the lake vary with season. A clear thermocline was observed from April to December, and the water was found to be vertically homogenous during January to February. Lake stratification begins in spring and reaches its peak in late summer. The vertical structure generally varies from year to year due to difference in solar energy, wind and inflow. It is evident from the graph (Figure 2) that the lake may become physically stratified into three identifiable layers: i) epilimnion, ii) thermocline (metalimnion), and iii) hypolimnion. The epilimnion is the upper layer where the temperature is relatively uniform over depth. The middle zone, thermocline, represents the transition from warm surface water to cooler bottom water. The hypolimnion zone extends to the bottom of the lake where the temperature steadily decreases. Compared with the epilimnion, water in the hypolimnion is much colder.

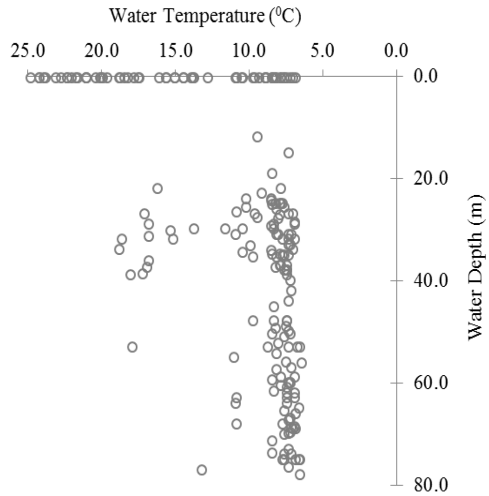

Figure 2: Monthly water temperature profile along water depth for the years 2005 - 2010

Dissolved oxygen (DO) is higher in surface water than in deeper water due to reduced photosynthesis and reduced DO downward mixing from the surface

[10]. The dissolved oxygen concentrations in the epilimnion (0 to 5 m) varied from 5.5 to 12.40 mg/l. Dissolved oxygen indicates the capability of the water body to support a balanced ecosystem. DO is well correlated with the water temperature; however, the relationship is inversely correlated. The correlation between different water quality parameters are tables as below.

Table 2: Correlation b/w different water quality parameters

	Temp (^0C)	*DO* (*mg/l*)	*BOD* (*mg/l*)	*T-N* (*mg/l*)	*T-P* (*mg/l*)	*Chl-a* (*µg/l*)
Temp		-0.80	0.80	0.62	0.53	0.40
DO	-0.80		-0.50	-0.35	-0.34	0.04
BOD	0.80	-0.50		0.84	0.68	0.79
T-N	0.62	-0.35	0.84		0.85	0.74
TP	0.53	-0.34	0.68	0.85		0.55
Chl-a	0.40	0.04	0.79	0.74	0.55	

It was found that the water quality parameters are well correlated; however, the inter-relationship is complex and depends on many factors. The review of the literature reveals that the rise in air temperature due to global warming may result in an increase in thermocline depth and mean water temperature. It influences directly the physical, biological and chemical characteristics of the rivers and dam lakes. Stream temperature is affected by weather, hydro-geologic and anthropogenic factors. The impact of water temperature on eutrophication is not straightforward as number of factors such as nutrients, light conditions, water temperature, residence time and flow conditions interplay in the process of eutrophication. A variety of approaches have been suggested by researchers to predict stream water temperatures. Linear regression models of stream temperature versus air temperature are attractive for climate change effect studies because only one input variable, air temperature, is used and General Circulation Models (GCMs) simulate this variable better than other climate variables [14]. Linear regression models of stream temperature and air temperature have also been used to project stream temperatures under a 2 x CO_2 (doubled atmospheric carbon dioxide) climate change scenario [15]. Assuming no change in the geology, hydrology and ecology, under double CO_2 climate conditions, one can project future stream temperatures. It was found that air temperature is a good index of stream temperature at timescales of greater than one week. Mean weekly air temperature versus water temperature is plotted as depicted in figure 3. It is noteworthy that the air-water temperature relationship is well correlated with high correlation coefficient (R^2) but the slope and intercept are a function of the time scale. Liner regression models are more accurate when the air temperature is above 0^oC. At the highest temperature and lowest temperatures below 0^oC, the water/air relationship showed nonlinear behavior.

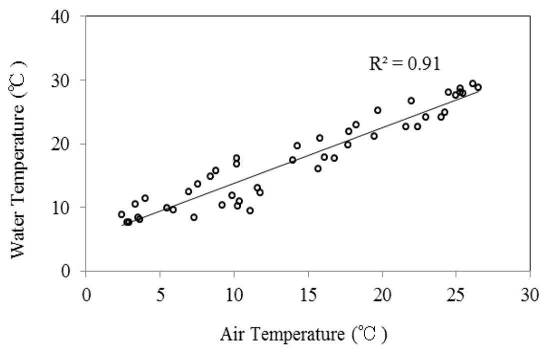

Figure 3: Correlation b/w mean weekly air temperature and water temperature (2010)

The relationship is flat at low temperatures, has a slope near unity at moderate temperatures and a moderate slope with tendency towards leveling off at high temperatures, which overall resembles S-shaped function. The weekly air/temperature relationship can be well described by a S-shaped function. Mohseni, et al., 1998 [16] studied 573 streams at different location in the United States and observed a non-linear behavior between air and water temperature at weekly interval. The developed logistic S-shaped function to predict average weekly stream temperature is as follow;

$$T_s = \mu + \frac{\alpha - \mu}{1 + e^{\gamma(\beta - T_a)}}$$

where T_s is the estimated stream temperature, T_a is the air temperature, the coefficient α is the upper bound stream temperature, μ is the lower bound stream temperature, γ is a measure of the steepest slope of the function, and β represents the air temperature at the inflection point. The schematic representation of the logistic function parameters is illustrated in figure 4.

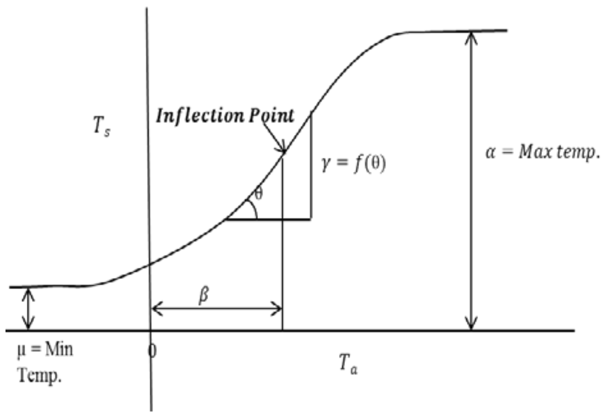

Figure 4: Schematic representation of the logistic air-water temperature function parameters

The nonlinear function provides information about the change in water temperature due to change in air temperature caused by global warming. The water temperature is a major factor to control the processes in water bodies. With the rise in water temperature, DO decrease and the depletion of DO affects the physical and chemical process in the water bodies. All the process in the water bodies are inter-related and change in one parameter may cause positive or negative impact on other parameters. It is vital to observe the air-water temperature and DO patterns to manage the water resources effectively.

4. CONCLUSSION

The paper describes the air/water temperature relationship and effect of water temperature on DO and other water quality parameters. The crux of the present research work is that climate change has negative impact on water quality. Thermal behavior of rivers, lakes and reservoirs is strongly correlated with water quality, physical and chemical processes and engineering applications related to management of the water resources. It was found that linear and nonlinear regression models are accurate and simple to describe the air-water relationship. The linear relationship works well when temperatures are averaged at weekly or more timescale. However, for rivers/streams with wide maximum and minimum temperature variations, the nonlinear regression models are more accurate. A good understanding of air-water temperature relationship helps to protect the endangered ecosystems. It is imperative to develop and provide water quality modeling tools to water resources manager and policy makers for sustainable management. Coupling geology, hydrological, ecological and water quality models may offer a new scientific insight into the freshwater management under the changing climatic conditions.

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