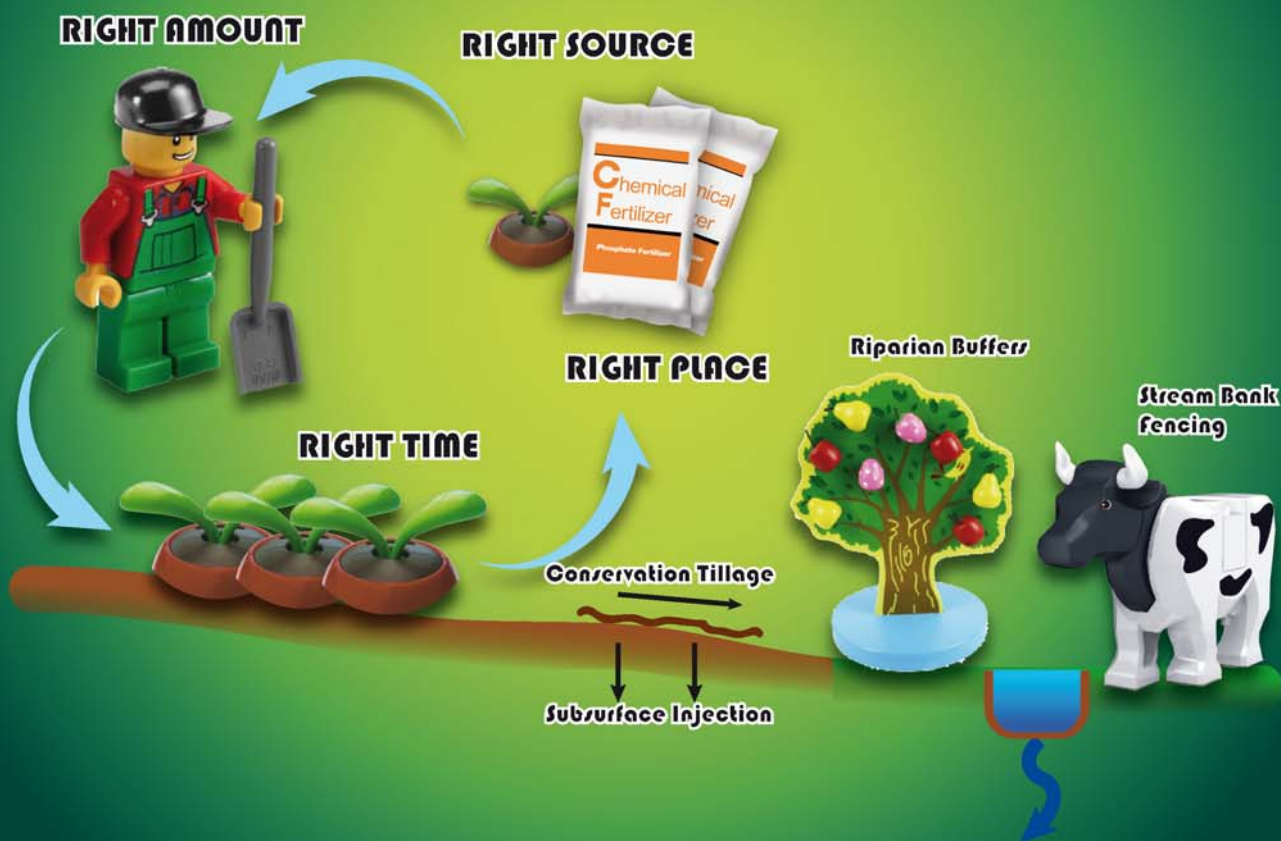


## Management of P in Agricultural Systems



- 1769 Diffuse pollution: A hidden threat to the water environment of the developing world  
Chengqing Yin, and Xiaoyan Wang
- 1770 Managing agricultural phosphorus for water quality: Lessons from the USA and China  
Andrew Sharpley, and Xiaoyan Wang
- 1783 Uncertainty analyses on the calculation of water environmental capacity by an innovative holistic method and its application to the Dongjiang River  
Qiuwen Chen, Qibin Wang, Zhijie Li, and Ruonan Li
- 1791 Settling basin design in a constructed wetland using TSS removal efficiency and hydraulic retention time  
Soyoung Lee, Marla C. Maniquiz-Redillas, and Lee-Hyung Kim
- 1797 Contribution of atmospheric nitrogen deposition to diffuse pollution in a typical hilly red soil catchment in southern China  
Jianlin Shen, Jieyun Liu, Yong Li, Yuyuan Li, Yi Wang, Xuejun Liu, and Jinshui Wu
- 1806 Determination of nitrogen reduction levels necessary to reach groundwater quality targets in Slovenia  
Miso Andelov, Ralf Kunkel, Jože Uhan, and Frank Wendland
- 1818 Integral stormwater management master plan and design in an ecological community  
Wu Che, Yang Zhao, Zheng Yang, Junqi Li, and Man Shi
- 1824 Investigation on the effectiveness of pretreatment in stormwater management technologies  
Marla C. Maniquiz-Redillas, Franz Kevin F. Geronimo, and Lee-Hyung Kim
- 1831 Assessment of nutrient distributions in Lake Champlain using satellite remote sensing  
Elizabeth M. Isenstein, and Mi-Hyun Park
- 1837 Acute toxicity evaluation for quinolone antibiotics and their chlorination disinfection processes  
Min Li, Dongbin Wei, and Yuguo Du
- 1843 Occurrence, polarity and bioavailability of dissolved organic matter in the Huangpu River, China  
Qianqian Dong, Penghui Li, Qinghui Huang, Ahmed A. Abdelhafez, and Ling Chen
- 1851 A comparative study of biopolymers and alum in the separation and recovery of pulp fibres from paper mill effluent by flocculation  
Sumona Mukherjee, Soumyadeep Mukhopadhyay, Agamuthu Pariatamby, Mohd. Ali Hashim, Jaya Narayan Sahu, and Bhaskar Sen Gupta
- 1861 Performance and microbial response during the fast reactivation of Anammox system by hydrodynamic stress control  
Yuan Li, Zhenxing Huang, Wenquan Ruan, Hongyan Ren, and Hengfeng Miao
- 1869 Phytoremediation of levonorgestrel in aquatic environment by hydrophytes  
Guo Li, Jun Zhai, Qiang He, Yue Zhi, Haiwen Xiao, and Jing Rong
- 1874 Experimental study on the impact of temperature on the dissipation process of supersaturated total dissolved gas  
Xia Shen, Shengyun Liu, Ran Li, and Yangming Ou
- 1879 Removal of cobalt(II) ion from aqueous solution by chitosan-montmorillonite  
Hailin Wang, Haoqing Tang, Zhaotie Liu, Xin Zhang, Zhengping Hao, and Zhongwen Liu
- 1885 *p*-Cresol mineralization and bacterial population dynamics in a nitrifying sequential batch reactor  
Carlos David Silva, Lizeth Beristain-Montiel, Flor de María Cuervo-López, and Anne-Claire Texier

## CONTENTS

- 1894 Particle number concentration, size distribution and chemical composition during haze and photochemical smog episodes in Shanghai  
Xuemei Wang, Jianmin Chen, Tiantao Cheng, Renyi Zhang, and Xinming Wang
- 1903 Properties of agricultural aerosol released during wheat harvest threshing, plowing and sowing  
Chiara Telloli, Antonella Malaguti, Mihaela Mircea, Renzo Tassinari, Carmela Vaccaro, and Massimo Berico
- 1913 Characteristics of nanoparticles emitted from burning of biomass fuels  
Mitsuhiko Hata, Jiraporn Chomanee, Thunyapat Thongyen, Linfa Bao, Surajit Tekasakul, Perapong Tekasakul, Yoshio Otani, and Masami Furuuchi
- 1921 Seasonal dynamics of water bloom-forming *Microcystis* morphospecies and the associated extracellular microcystin concentrations in large, shallow, eutrophic Dianchi Lake  
Yanlong Wu, Lin Li, Nanqin Gan, Lingling Zheng, Haiyan Ma, Kun Shan, Jin Liu, Bangding Xiao, and Lirong Song
- 1930 Mitochondrial electron transport chain is involved in microcystin-RR induced tobacco BY-2 cells apoptosis  
Wenmin Huang, Dunhai Li, and Yongding Liu
- 1936 Synthesis of novel CeO<sub>2</sub>-BiVO<sub>4</sub>/FAC composites with enhanced visible-light photocatalytic properties  
Jin Zhang, Bing Wang, Chuang Li, Hao Cui, Jianping Zhai, and Qin Li
- 1943 Investigation of UV-TiO<sub>2</sub> photocatalysis and its mechanism in *Bacillus subtilis* spore inactivation  
Yiqing Zhang, Lingling Zhou, and Yongji Zhang
- 1949 Rapid detection of multiple class pharmaceuticals in both municipal wastewater and sludge with ultra high performance liquid chromatography tandem mass spectrometry  
Xiangjuan Yuan, Zhimin Qiang, Weiwei Ben, Bing Zhu, and Junxin Liu

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

ScienceDirect

[www.journals.elsevier.com/journal-of-environmental-sciences](http://www.journals.elsevier.com/journal-of-environmental-sciences)

# Experimental study on the impact of temperature on the dissipation process of supersaturated total dissolved gas

Xia Shen<sup>1</sup>, Shengyun Liu<sup>1,2</sup>, Ran Li<sup>1,\*</sup>, Yangming Ou<sup>1</sup>

1. State Key Laboratory of Hydraulics and Mountain River Engineering, Sichuan University, Chengdu 610065, China.

E-mail: [chenxia19881024@163.com](mailto:chenxia19881024@163.com)

2. Hydrochina Chengdu Engineering Corporation, Chengdu 611830, China

## ARTICLE INFO

### Article history:

Received 27 October 2013

Revised 11 February 2014

Accepted 24 February 2014

Available online 2 July 2014

### Keywords:

Total dissolved gas

Supersaturation

Temperature

Dissipation coefficient

## ABSTRACT

Water temperature not only affects the solubility of gas in water but can also be an important factor in the dissipation process of supersaturated total dissolved gas (TDG). The quantitative relationship between the dissipation process and temperature has not been previously described. This relationship affects the accurate evaluation of the dissipation process and the subsequent biological effects. This article experimentally investigates the impact of temperature on supersaturated TDG dissipation in static and turbulent conditions. The results show that the supersaturated TDG dissipation coefficient increases with the temperature and turbulence intensity. The quantitative relationship was verified by straight flume experiments. This study enhances our understanding of the dissipation of supersaturated TDG. Furthermore, it provides a scientific foundation for the accurate prediction of the dissipation process of supersaturated TDG in the downstream area and the negative impacts of high dam projects on aquatic ecosystems.

© 2014 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences.

Published by Elsevier B.V.

## Introduction

High dam discharge can lead to total dissolved gas (TDG) supersaturation downstream of the dam and may cause fish to suffer from gas bubble trauma and even death (Weitkamp and Katz, 1980; Weitkamp et al., 2003). Many previous studies have focused on how the TDG dissipation process from supersaturation to saturation is associated with conditions such as water depth, turbulence characteristics, Reynolds number and sediment concentration (Jiang et al., 2008a; Qu, 2011; Feng, 2013; Li et al., 2013). However, there are few studies on the quantitative effects of the water temperature on the supersaturated TDG dissipation process. The construction of a hydropower project can change the water temperature in natural rivers and can consequently affect the generation and dissipation processes of supersaturated TDG. In recent years, many studies have been conducted to understand the water temperature structure in reservoirs and downstream river reaches (Lei et al., 2008; Lindim et al., 2011; Deng et al., 2011; Lee et al., 2013), which may contribute to a more

comprehensive study on the development of the relationship between TDG and temperature.

Harvey (1967) observed a Canadian lake and found that the increased water temperature due to solar radiation could result in TDG supersaturation. Roesner and Norton (1971) considered the effects of temperature on the molecular diffusion coefficient and presented a physical model of TDG generation downstream of a dam. Demont and Miller (1972) reported that the total dissolved gas pressure over the atmospheric pressure was up to 400 mm Hg when warm wastewater was discharged from a factory to the ambient water. Bouck (1984) observed that the TDG pressure in water is different in different seasons. Krise and Smith (1993) and Mesa and Warren (1997) created supersaturated TDG water by mixing hot and cold water artificially. Jiang et al. (2008b) carried out field observations in the Minjiang River downstream of the Zipingpu Dam and showed that the water temperature affects TDG supersaturation. Feng et al. (2010) improved the dissipation model of supersaturated TDG according to observations in many rivers and laboratory experiments. Wang et al. (2010) concluded

\* Corresponding author. E-mail: [liiran@scu.edu.cn](mailto:liiran@scu.edu.cn) (Ran Li).



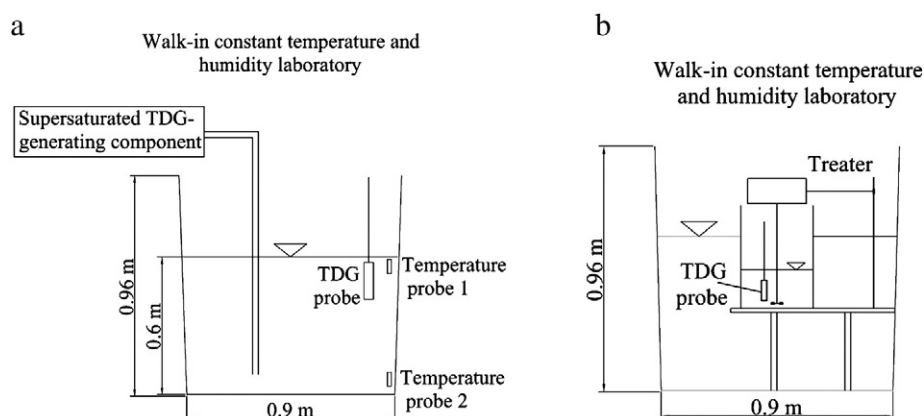


Fig. 1 – Sketch of the experimental apparatus in static water (a) and in stir-induced turbulent water (b). TDG: total dissolved gas.

that the TDG saturation in a river increases with rising temperature and that changes in supersaturated TDG lag behind changes in temperature.

Most of the prior research regarding mass transfer has primarily focused on the reaeration process of dissolved oxygen (DO). Bennett and Rathbun (1972) obtained a relationship between the reaeration coefficient and temperature. Zou et al. (2010) concluded that the oxygen mass transfer coefficient increases with increasing temperature.

Li et al. (2013) indicate that the dissipation process is quantitatively different from the reaeration process, and TDG behavior is quantitatively different from dissolved oxygen (DO). Therefore, it is necessary to carry out research on the quantitative relationship between TDG and temperature.

The present article will provide insight into the effects of temperature on the TDG supersaturation dissipation process based on the experimental results. The experiments were conducted in two types of conditions: static and turbulent. By the use of professional equipment, the TDG dissipation rate at different temperatures in each turbulent case was monitored, and the dissipation coefficients were obtained by data fitting. The results were verified by flume experiment.

## 1. Dissipation experiments

### 1.1. Experiments in static water

Experiments were conducted in a walk-in constant temperature and humidity laboratory. The experimental device includes a

component that generates supersaturated TDG (Li et al., 2012) and a cylindrical water tank (900 mm in diameter and 960 mm in height). The experimental device is shown in Fig. 1a.

At the beginning of the experiment, supersaturated water with a specific temperature was generated with the TDG generation component and drained into the tank. The ambient air temperature was controlled at the specified temperatures for each case. The change in the supersaturated TDG saturation versus time was monitored using a PT4 Tracker sensor (Point Four Systems, Inc., Canada). The monitoring results showed that the maximum fluctuation amplitude of the water temperature was 0.7°C/day, and that the humidity was maintained at 45% relative humidity (RH).

The supersaturated TDG dissipation process under different temperatures is shown in Fig. 2. The supersaturated TDG dissipated very slowly in the static condition. The lower the temperature was, the slower the dissipation process was. Using first-order kinetics to fit the dissipation process (US EPA, 2009), the dissipation coefficient of the supersaturated TDG in each temperature case was obtained and is summarized in Table 1. As shown in Table 1 all of the correlation coefficients ( $R^2$ ) were greater than 0.87, indicating the goodness of fit of the process with the first-order kinetic equation. The relationships between the dissipation coefficients and the corresponding temperatures in Table 1 are depicted in Fig. 3.

Table 1 and Fig. 2 show that the TDG dissipation coefficient in static water increased from 0.0065 to 0.0254  $\text{hr}^{-1}$  when the

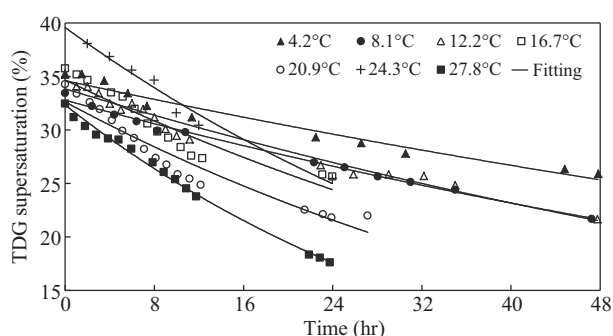


Fig. 2 – TDG dissipation processes and fitting curves at different monitored water temperatures in the static condition.

Table 1 – Dissipation coefficients of supersaturated TDG (total dissolved gas) in static water.

Case number	Temperature* (°C)	Dissipation coefficient (K, $\text{hr}^{-1}$ )	Correlation coefficient ( $R^2$ )
1	4.2	0.0065	0.9638
2	8.1	0.0087	0.9362
3	12.2	0.0095	0.8948
4	16.7	0.0146	0.8775
5	20.9	0.0188	0.9249
6	24.3	0.0192	0.9789
7	27.8	0.0254	0.9962

\* Average water temperature monitored in each case.

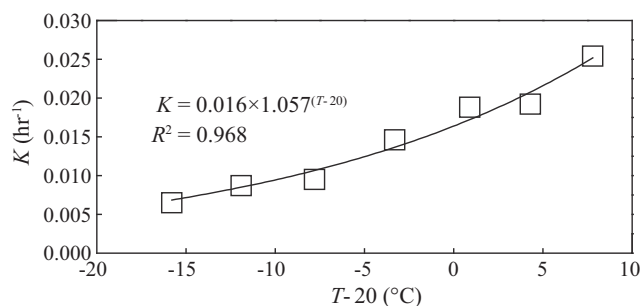


Fig. 3 – TDG dissipation coefficient ( $K$ ) versus temperature in the static condition.

temperature increased from 4.2 to 27.8°C. The mass transfer process of the gas–liquid interface is dominated by the gas molecular diffusion coefficient in static water, and this process is closely associated with the temperature (Ma et al., 1996). As the temperature increases, the kinetic energy of molecules increases, resulting in an increased diffusion rate and a dissipation process of supersaturated TDG.

A prior study showed that the relationship between the reaeration coefficient ( $K_{DO}$ ) and temperature ( $T$ , °C) follows an exponential function (Bennett and Rathbun, 1972):

$$K_{DO} = K_{DO(20)} \times 1.024^{(T-20)}. \quad (1)$$

According to the form of Eq. (1), a similar exponential function is assumed for the dissipation coefficient:

$$K = K_{20}\theta^{(T-20)} \quad (2)$$

where,  $K$  ( $\text{hr}^{-1}$ ) represents the dissipation coefficient at temperature  $T$ ,  $K_{20}$  ( $\text{hr}^{-1}$ ) is the dissipation coefficient at 20°C, and  $\theta$  denotes the temperature coefficient. Based on the experimental results in Table 1, a multiple regression for Eq. (2) was conducted, and  $K_{20}$  (0.016  $\text{hr}^{-1}$ ) and  $\theta$  (1.057) were obtained, as shown in Fig. 3.

Table 2 – Dissipation coefficients of supersaturated TDG in turbulent conditions.

Mixing speed (r/min)	$K_{20}$ ( $\text{hr}^{-1}$ )	$\theta$	$R^2$
750	2.088	1.066	0.984
900	2.803	1.057	0.979
1000	3.423	1.066	0.994
1200	4.342	1.057	0.980
1250	4.944	1.061	0.994
1500	9.525	1.061	0.993

## 1.2. Experiments in stir-induced turbulent water

Experiments were conducted in the walk-in constant temperature and humidity laboratory. The experimental device includes the supersaturated TDG-generating component (Li et al., 2012), an experimental water tank with a 0.28 m inside diameter, and an electrical stirrer (the rotational speed can be adjusted from 0 to 1500 r/min). The experimental water container was immersed in a larger water tank for a constant temperature bath. The experimental device is shown in Fig. 1b.

First, supersaturated water with a specific temperature was generated with the supersaturated TDG-generating component and drained into the tank. The stirrer was then started at a fixed speed. The change in the supersaturated TDG saturation versus time was monitored using a PT4 Tracker sensor. For each temperature case, the following six different revolution speeds were tested: 750, 900, 1000, 1200, 1250, and 1500 r/min.

Supersaturated TDG was released more quickly in turbulent water than that in static water. The measured time evolution of supersaturated TDG is shown in Fig. 4. The first-order kinetic fitting method was employed for each process. The experimental results show that the dissipation process of supersaturated TDG accelerates as the temperature and turbulence intensity increase.

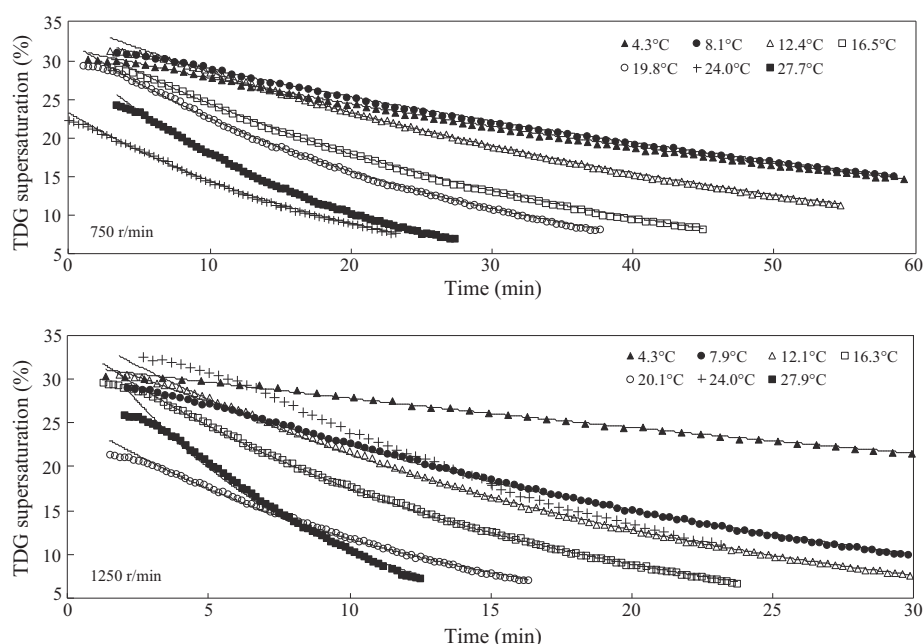


Fig. 4 – TDG dissipation processes and fitting curves at different monitored water temperatures in turbulent conditions.

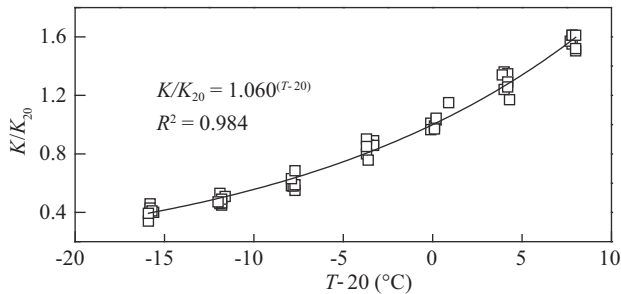


Fig. 5 – Relationship between  $K/K_{20}$  and temperature.

On the basis of Eq. (2), the same analysis procedure as in the static experiment was adopted for each turbulent condition and the results are shown in Table 2.  $K_{20}$  ( $\text{hr}^{-1}$ ), increases obviously with the increasing turbulence intensity, whereas the temperature coefficients  $\theta$ , which indicate the temperature effects for different conditions, are very close and vary from 1.057 to 1.066. This result implies that one constant value for the temperature coefficient may be found.

## 2. Relationship analysis between the dissipation coefficient and temperature

The universal relationship between the dissipation coefficient and temperature can be determined through a comprehensive analysis of the experimental results both in static and turbulent water.

By dimensional analysis, Eq. (2) can be rewritten as follows:

$$K/K_{20} = \theta^{(T-20)}. \quad (3)$$

According to the results of the dissipation coefficients both in static and turbulent conditions, the regression between  $K/K_{20}$  and water temperature is illustrated in Fig. 5. The value of parameter  $\theta$  is 1.060. Thus, the expression for the dissipation coefficient as a function of temperature can be written as follows:

$$K = K_{20} \times 1.060^{(T-20)}. \quad (4)$$

In 90% of experimental cases, the curve fitting error from the experimental data was less than 10%, whereas that of the other cases was within 15%. This result affirmed that the relationship between the supersaturated TDG dissipation coefficient and water temperature is reasonable.

## 3. Verification of the relationship in a straight flume

Liu (2013) conducted an experimental study on supersaturated TDG dissipation in a straight flume at different temperatures (Table 3). Liu found that the dissipation coefficient in a straight flume at 20°C ( $K_{20}$ ) in the experimental flume was 3.7  $\text{hr}^{-1}$ . By introducing the dissipation coefficient  $K_{20}$  of the flume 3.7  $\text{hr}^{-1}$ , into Eq. (4), the theoretical dissipation coefficient at various experimental temperatures can be computed, as listed in Table 3. The relative errors between the calculated and measured results ranged from –5.9% to 9.5%. The result shows that the relationship between the dissipation coefficient and the water temperature has good applicability.

## 4. Conclusions

This article carried out an experimental study on the impact of temperature on supersaturated TDG dissipation in static and turbulent conditions. The experimental results show that the supersaturated TDG dissipation coefficient increases with the temperature and turbulence intensity. According to the experimental results, the quantitative relationship between the dissipation coefficient of supersaturated TDG and water temperature was developed and verified with straight flume experiments. The description of this relationship can provide an important scientific basis for the prediction of the dissipation process of supersaturated TDG at different water temperatures.

## Acknowledgments

This work was supported by the National Natural Science Foundation of China (No. 51279115).

## REFERENCES

- Bennett, J.P., Rathbun, R.E., 1972. *Reaeration of Open Channel Flow*. US Government Printing Office.
- Bouck, G.R., 1984. Annual variation of gas supersaturation in four spring-fed Oregon streams. *Prog. Fish Cult.* 46 (2), 139–140.
- Demont, J.D., Miller, R.W., 1972. First reported incidence of gas bubble disease in the heated effluent of a steam electric generating station. *Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners*, 25, pp. 392–399.

Table 3 – Comparison between the calculated and measured dissipation coefficients in the flume.

Case number *	Temperature (°C) *	Discharge flow (L/sec) *	$K_{\text{measured}}$ ( $\text{hr}^{-1}$ ) *	$K_{\text{calculated}}$ ( $\text{hr}^{-1}$ ) *	Relative error (%)
1	15.4	0.452	2.67	2.83	–5.9
2	15.8	0.440	2.92	2.89	1.2
3	20.4	0.419	3.54	3.78	–6.8
4	20.3	0.437	3.67	3.76	–2.5
5	23.1	0.466	4.93	4.46	9.5
6	24.1	0.442	5.00	4.72	5.5
7	26.8	0.439	5.34	5.53	–3.5
8	27.9	0.462	5.69	5.94	–4.3

\* Data were cited from the literature of Liu (2013).

- Deng, Y., Tuo, Y.C., Li, J., Li, K.F., Li, R., 2011. Spatial-temporal effects of temperature control device of stoplog intake for Jinping I hydropower station. *Sci. China Technol. Sci.* 54 (1), 83–88.
- Feng, J.J., 2013. The Dissipation Mechanism for Total Dissolved Gas Downstream of High Dams and its Application PhD thesis Sichuan University, Chengdu, Sichuan, China.
- Feng, J.J., Li, R., Li, K.F., Li, J., Qu, L., 2010. Study on release process of supersaturated total dissolved gas downstream of high dam. *J. Hydraul. Eng.* 29 (1), 7–12.
- Harvey, H.H., 1967. Supersaturation of lake water with a precaution to hatchery usage. *Trans. Am. Fish. Soc.* 96 (2), 194–201.
- Jiang, L., Li, J., Li, R., Li, K.F., 2008a. A study of dissolved gas supersaturation downstream of Zipingpu dam. *Adv. Water Sci.* 19 (3), 367–371.
- Jiang, L., Li, J., Li, R., Li, K.F., 2008b. The supersaturation of dissolved gas in downstream of high dam. *J. Sichuan Univ.* 40 (5), 69–73.
- Krise, W., Smith, R., 1993. Eye abnormalities of lake trout exposed to gas supersaturation. *Prog. Fish Cult.* 55 (3), 177–179.
- Lee, H., Chung, S., Ryu, I., Choi, J., 2013. Three-dimensional modeling of thermal stratification of a deep and dendritic reservoir using ELCOM model. *J. Hydro Environ. Res.* 7 (2), 124–133.
- Lei, B.L., Huang, S.B., Qiao, M., Li, T.Y., Wang, Z.J., 2008. Prediction of the environmental fate and aquatic ecological impact of nitrobenzene in the Songhua River using the modified AQUATOX model. *J. Environ. Sci.* 20 (7), 769–777.
- Li, R., Qu, L., Li, J., Li, K.F., Deng, Y., Yi, W.M., et al., 2012. The Generation Experiment Device of Total Dissolved Gas Supersaturation by the Formation of Water Jet with High Speed Air Flow: China, 201010124171.7 Authorized announcement 2012-10-31.
- Li, R., Hodges, B.R., Feng, J.J., Yong, X.D., 2013. Comparison of supersaturated total dissolved gas dissipation with dissolved oxygen dissipation and reaeration. *J. Environ. Eng.* 139 (3), 385–390.
- Lindim, C., Pinho, J.L., Vieira, J.M.P., 2011. Analysis of spatial and temporal patterns in a large reservoir using water quality and hydrodynamic modeling. *Ecol. Model.* 222 (14 SI), 2485–2494.
- Liu, S.Y., 2013. Temperature Impact on Supersaturated Total Dissolved Gas Generation and Dissipation Master thesis Sichuan University, Chengdu, Sichuan, China.
- Ma, Y.G., Ba, P., Yu, G.Z., 1996. Progress of theoretical studies on gas liquid mass transfer. *Chem. Eng.* 24 (6), 7–10.
- Mesa, M.G., Warren, J.J., 1997. Predator avoidance ability of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) subjected to sublethal exposures of gas-supersaturated water. *Can. J. Fish. Aquat. Sci.* 54 (4), 757–764.
- Qu, L., 2011. Relation of total dissolved gas supersaturation and suspended sediment concentration of high-dams. *Adv. Water Sci.* 22 (6), 839–843.
- Roesner, L.A., Norton, W.R., 1971. A nitrogen gas (N<sub>2</sub>) model for the lower Columbia river, Final Report. Prepared for the Portland District. North Pacific Division, U. S. Army Corps of Engineers, Portland, Oregon Report, 2, pp. 1–350.
- US EPA (United States Environmental Protection Agency), 2009. National Recommended Water Quality Criteria.
- Wang, H.R., Zhou, Z.L., Xing, Y.N., 2010. Discussion on total dissolved gas supersaturation problems of hydraulic engineering. *Prog. Sci. Technol. Water Resour.* 30 (5), 12–15.
- Weitkamp, D.E., Katz, M., 1980. A review of dissolved gas supersaturation literature. *Trans. Am. Fish. Soc.* 109 (6), 659–702.
- Weitkamp, D.E., Sullivan, R.D., Swant, T., DosSantos, J., 2003. Gas bubble disease in resident fish of the lower Clark Fork River. *Trans. Am. Fish. Soc.* 132 (5), 865–876.
- Zou, L.P., Zhao, H.T., Liu, Z.R., Zhan, J.M., Yang, K.L., Ding, G.J., 2010. Study on the effect of water quality on oxygen transfer. *J. North Cent. Univ. (Nat. Sci. Ed.)* 31 (1), 45–49.





## Editorial Board of Journal of Environmental Sciences

### Editor-in-Chief

**Hongxiao Tang** Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China

### Associate Editors-in-Chief

**Jiuhui Qu** Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China  
**Shu Tao** Peking University, China  
**Nigel Bell** Imperial College London, United Kingdom  
**Po-Keung Wong** The Chinese University of Hong Kong, Hong Kong, China

### Editorial Board

#### Aquatic environment

**Baoyu Gao**  
Shandong University, China  
**Maohong Fan**  
University of Wyoming, USA  
**Chihpin Huang**  
National Chiao Tung University  
Taiwan, China  
**Ng Wun Jern**  
Nanyang Environment &  
Water Research Institute, Singapore  
**Clark C. K. Liu**  
University of Hawaii at Manoa, USA  
**Hokyoung Shon**  
University of Technology, Sydney, Australia  
**Zijian Wang**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Zhiwu Wang**  
The Ohio State University, USA  
**Yuxiang Wang**  
Queen's University, Canada  
**Min Yang**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Zhifeng Yang**  
Beijing Normal University, China  
**Han-Qing Yu**  
University of Science & Technology of China

#### Terrestrial environment

**Christopher Anderson**  
Massey University, New Zealand  
**Zucong Cai**  
Nanjing Normal University, China  
**Xinbin Feng**  
Institute of Geochemistry,  
Chinese Academy of Sciences, China  
**Hongqing Hu**  
Huazhong Agricultural University, China  
**Kin-Che Lam**  
The Chinese University of Hong Kong  
Hong Kong, China  
**Erwin Klumpp**  
Research Centre Juelich, Agrosphere Institute  
Germany  
**Peijun Li**  
Institute of Applied Ecology,  
Chinese Academy of Sciences, China

#### Michael Schloter

German Research Center for Environmental Health  
Germany  
**Xuejun Wang**  
Peking University, China  
**Lizhong Zhu**  
Zhejiang University, China

#### Atmospheric environment

**Jianmin Chen**  
Fudan University, China  
**Abdelwahid Mellouki**  
Centre National de la Recherche Scientifique  
France  
**Yujing Mu**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Min Shao**  
Peking University, China  
**James Jay Schauer**  
University of Wisconsin-Madison, USA  
**Yuesi Wang**  
Institute of Atmospheric Physics,  
Chinese Academy of Sciences, China  
**Xin Yang**  
University of Cambridge, UK

#### Environmental biology

**Yong Cai**  
Florida International University, USA  
**Henner Hollert**  
RWTH Aachen University, Germany  
**Jae-Seong Lee**  
Sungkyunkwan University, South Korea  
**Christopher Rensing**  
University of Copenhagen, Denmark  
**Bojan Sedmak**  
National Institute of Biology, Slovenia  
**Lirong Song**  
Institute of Hydrobiology,  
Chinese Academy of Sciences, China  
**Chunxia Wang**  
National Natural Science Foundation of China  
**Gehong Wei**  
Northwest A & F University, China  
**Daqiang Yin**  
Tongji University, China  
**Zhongtang Yu**  
The Ohio State University, USA

#### Environmental toxicology and health

**Jingwen Chen**  
Dalian University of Technology, China  
**Jianying Hu**  
Peking University, China  
**Guibin Jiang**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Sijin Liu**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Tsuyoshi Nakanishi**  
Gifu Pharmaceutical University, Japan  
**Willie Peijnenburg**  
University of Leiden, The Netherlands  
**Bingsheng Zhou**  
Institute of Hydrobiology,  
Chinese Academy of Sciences, China

#### Environmental catalysis and materials

**Hong He**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China  
**Junhua Li**  
Tsinghua University, China  
**Wenfeng Shangguan**  
Shanghai Jiao Tong University, China  
**Yasutake Teraoka**  
Kyushu University, Japan  
**Ralph T. Yang**  
University of Michigan, USA

#### Environmental analysis and method

**Zongwei Cai**  
Hong Kong Baptist University,  
Hong Kong, China  
**Jiping Chen**  
Dalian Institute of Chemical Physics,  
Chinese Academy of Sciences, China  
**Minghui Zheng**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China

#### Municipal solid waste and green chemistry

**Pinjing He**  
Tongji University, China  
**Environmental ecology**  
**Rusong Wang**  
Research Center for Eco-Environmental Sciences,  
Chinese Academy of Sciences, China

### Editorial office staff

**Managing editor** Qingcai Feng  
**Editors** Zixuan Wang Suqin Liu Zhengang Mao  
**English editor** Catherine Rice (USA)

# JOURNAL OF ENVIRONMENTAL SCIENCES

环境科学学报(英文版)  
(<http://www.jesc.ac.cn>)

## Aims and scope

*Journal of Environmental Sciences* is an international academic journal supervised by Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. The journal publishes original, peer-reviewed innovative research and valuable findings in environmental sciences. The types of articles published are research article, critical review, rapid communications, and special issues.

The scope of the journal embraces the treatment processes for natural groundwater, municipal, agricultural and industrial water and wastewaters; physical and chemical methods for limitation of pollutants emission into the atmospheric environment; chemical and biological and phytoremediation of contaminated soil; fate and transport of pollutants in environments; toxicological effects of terrorist chemical release on the natural environment and human health; development of environmental catalysts and materials.

## For subscription to electronic edition

Elsevier is responsible for subscription of the journal. Please subscribe to the journal via <http://www.elsevier.com/locate/jes>.

## For subscription to print edition

China: Please contact the customer service, Science Press, 16 Donghuangchenggen North Street, Beijing 100717, China. Tel: +86-10-64017032; E-mail: [journal@mail.sciencep.com](mailto:journal@mail.sciencep.com), or the local post office throughout China (domestic postcode: 2-580).

Outside China: Please order the journal from the Elsevier Customer Service Department at the Regional Sales Office nearest you.

## Submission declaration

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere. The submission should be approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out. If the manuscript accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

## Submission declaration

Submission of the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere. The publication should be approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out. If the manuscript accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

## Editorial

Authors should submit manuscript online at <http://www.jesc.ac.cn>. In case of queries, please contact editorial office, Tel: +86-10-62920553, E-mail: [jesc@263.net](mailto:jesc@263.net), [jesc@rcees.ac.cn](mailto:jesc@rcees.ac.cn). Instruction to authors is available at <http://www.jesc.ac.cn>.

## Journal of Environmental Sciences (Established in 1989)

Vol. 26 No. 9 2014

<b>Supervised by</b>	Chinese Academy of Sciences	<b>Published by</b>	Science Press, Beijing, China
<b>Sponsored by</b>	Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences		Elsevier Limited, The Netherlands
<b>Edited by</b>	Editorial Office of Journal of Environmental Sciences P. O. Box 2871, Beijing 100085, China Tel: 86-10-62920553; <a href="http://www.jesc.ac.cn">http://www.jesc.ac.cn</a> E-mail: <a href="mailto:jesc@263.net">jesc@263.net</a> , <a href="mailto:jesc@rcees.ac.cn">jesc@rcees.ac.cn</a>	<b>Distributed by</b>	
		Domestic	Science Press, 16 Donghuangchenggen North Street, Beijing 100717, China Local Post Offices through China
		Foreign	Elsevier Limited <a href="http://www.elsevier.com/locate/jes">http://www.elsevier.com/locate/jes</a>
<b>Editor-in-chief</b>	Hongxiao Tang	<b>Printed by</b>	Beijing Beilin Printing House, 100083, China
CN 11-2629/X	Domestic postcode: 2-580		Domestic price per issue RMB ¥ 110.00

ISSN 1001-0742

