ISSN 1001-0742
CN 11-2629/X

JES

JOURNAL OF ENVIRONMENTAL SCIENCES

April 1, 2015 Volume 30
www.jesc.ac.cn

MBR in Wastewater Reclamation

ELSEVIER
Science Press

Sponsored by
Research Center for Eco-Environmental Sciences
Chinese Academy of Sciences

Journal of Environmental Sciences Volume 30 2015

www.jesc.ac.cn

Highlight articles

Review articles

Regular articles

CONTENTS

Available online at www.sciencedirect.com

ScienceDirect

www.journals.elsevier.com/journal-of-environmental-sciences

JOURNAL OF ENVIRONMENTAL SCIENCES
www.jesc.ac.cn

Serious BTEX pollution in rural area of the North China Plain during winter season

*Kankan Liu, Chenglong Zhang, Ye Cheng, Chengtang Liu, Hongxing Zhang, Gen Zhang, Xu Sun, Yujing Mu**

Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

ARTICLE INFO

Article history:
Received 25 April 2014
Revised 30 May 2014
Accepted 30 May 2014
Available online 29 January 2015

Keywords:
BTEX
Rural area
Coal combustion

ABSTRACT

Atmospheric BTEX compounds (benzene, toluene, ethylbenzene and xylenes) in a rural site of the North China Plain (NCP) were preliminarily investigated in winter, and the outdoor concentrations (25.8–236.0 μg/m^3) were found to be much higher than those reported in urban regions. The pollution of BTEX inside a farmer's house was even more serious, with combined concentrations of 254.5–1552.9 μg/m^3. Based on the ratio of benzene to toluene (1.17 ± 0.34) measured, the serious BTEX pollution in the rural site was mainly ascribed to domestic coal combustion for heating during the winter season. With the enhancement of farmers' incomes in recent years, coal consumption by farmers in the NCP is rapidly increasing to keep their houses warm, and hence the serious air pollution in rural areas of the NCP during winter, including BTEX, should be paid great attention.

© 2015 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences.
Published by Elsevier B.V.

Introduction

Atmospheric BTEX compounds (benzene, toluene, ethylbenzene and xylenes), mainly emitted from various anthropogenic activities (Buczynska et al., 2009), have already aroused concern due to their adverse health effects (Aksoy, 1989; Dutta et al., 2009) and their roles in atmospheric chemistry (Barletta et al., 2008). The ambient levels of both indoor (Zhong et al., 2005; Guo et al., 2003) and outdoor BTEX in cities (Yuan et al., 2010; Wang et al., 2012; Li et al., 2014: Zhang et al., 2012) have been extensively investigated. However, the levels in rural areas have only rarely been reported (Guo et al., 2006). With the enhancement of farmers' incomes in recent years, the amount of coal combustion is rapidly increasing to keep their houses warm and comfortable during the cold winter season in the North China Plain (NCP). A large quantity of pollutants including BTEX is emitted by domestic coal combustion due to low combustion efficiency, and hence high levels of pollutants were suspected in the rural area of the NCP with high-density dwellings in winter.

In this work, the ambient levels of BTEX in a rural site of the NCP during wintertime were preliminarily investigated and compared with those reported in Chinese cities. In addition, the risk to farmers' health was also roughly estimated.

1. Materials and methods

1.1. Sampling sites

Outdoor air samples were collected at a sampling site in a rural agricultural field (38°40′N, 115°15′E) in Wangdu County, Hebei Province, which is ~200 km southwest of Beijing city, about 120 km northeast of Shijiazhuang city, 35 km southwest of Baoding city, and 10 km east of Wangdu County. The nearest village of Dongbaituo (DBT) is about 200 m away to the west of the sampling site. There are almost no industries in Wangdu County, and pollutant emissions were mainly from coal combustion for cooking and warming during the winter season. Indoor air samples were collected in a farmer's house of the village of DBT.

1.2. Sampling and analysis

Air samples were collected with a 100-mL syringe and immediately transferred into an absorption tube (15 cm length, 4 mm ID)

* *Corresponding author*. E-mail: yjmu@rcees.ac.cn (Yujing Mu).

http://dx.doi.org/10.1016/j.jes.2014.05.056
1001-0742/© 2015 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

filled with Tenax-TA (80–100 mesh, 100 mg, Alltech Associates, Inc. America). A total of 49 outdoor air samples were collected hourly from 7:00 to 21:00 during 23 to 27 January in 2013, and 31 indoor air samples were collected in the morning, noon, and evening during the same period. The absorption tube was connected to a six-port valve as a loop and BTEX enriched in the absorption tube were injected into a separation column (SE-30, 20 m × 0.53 mm × 1.0 μm), after heating for 40 sec in an oven kept at 300°C, and detected by a gas chromatograph equipped with a Photo Ionization Detector (GC-PID, GC4400, East &West Analytical Instruments, Inc., China) with N_2 as carrier gas. The details on the preparation of the absorption tube as well as sampling and analysis procedures have been described in our previous publications (Liu et al., 2009, 2013; Zhang et al., 2012). The collection efficiencies for benzene, toluene, ethylbenzene, m,p-xylene and o-xylene were 84.2%, 95.6%, 96.4%, 96.1% and 95.5%, respectively. The method detection limits (with a signal-to-noise ratio of 3) were 0.01, 0.02, 0.06, 0.07 and 0.07 μg/m^3, respectively.

2. Results and discussion

2.1. Ambient levels and variation characteristics

Fig. 1 shows the time series of outdoor ambient levels of each BTEX compound and wind speed during the sampling days. The total concentrations of BTEX compounds during the sampling days varied remarkably, from *ca.* 30 to 230 μg/m^3, which was mainly ascribed to the variation in meteorological conditions. Among various meteorological conditions, wind speed is the most efficient factor for accelerating diffusion of pollutants, *e.g.*, a sharp decrease of BTEX concentrations was observed in the afternoon on 24, 26–27 January when wind speed increased. Although the wind speed (the maximum was near 5 m/sec) was the fastest on 25 January, the BTEX concentrations were much higher than those on the day of 26 January when wind speed was less than 2 m/sec, indicating that the concentrations of BTEX near the earth's surface were also controlled by other factors besides wind speed. The boundary height has been found to dominate primary pollutant accumulation (Quan et al., 2013), and the relatively low BTEX concentrations in the afternoon on 26 January were suspected to be due to the fast elevation of the boundary layer. On the other hand, warmer weather is usually coincident with low wind speed, and hence coal consumption for heating by farmers might be less on warmer winter days with low wind speed than on the colder winter days with high wind speed.

2.2. Comparison with previous studies

The average concentrations of BTEX compounds investigated by this study were compared with others reported in China, and listed in Table 1. It is evident that the outdoor concentrations of BTEX compounds (25.8–236.0 μg/m^3) in this study were at least a factor of 3 higher than those reported in Chinese cities or rural areas (Zhong et al., 2005; Guo et al., 2003, 2006; Wang et al., 2008; Wang and Zhao, 2008; Ling et al., 2011; Zhang et al., 2012; Li et al., 2014), indicating that the pollution levels of BTEX in this rural area of the NCP are indeed very serious in winter. The indoor pollution levels of BTEX (254.5–1552.9 μg/m^3) were found to be more serious, a factor of 1.26 higher than the outdoor levels. It should be mentioned that the farmer's house adopted for collecting the indoor air samples was well ventilated by keeping a fan running in the kitchen where the coal stove was used for heating and cooking. Even more serious BTEX pollution was suspected in most farmers' houses without a fan for ventilation.

In addition, outdoor levels of $PM_{2.5}$ and SO_2 in DBT and Beijing were also synchronously measured and the data are illustrated in Fig. 2. It is evident that the levels of $PM_{2.5}$ and SO_2 in DBT during most sampling days were remarkably greater than those in Beijing city, further indicating that the air pollution in the rural area in winter was very serious.

2.3. Sources identification

The ratio of benzene to toluene (B/T) is usually used as an indicator to identify their sources' origination because different B/T ratios are characteristic of different sources. A B/T ratio of around 0.6 has been reported to be characteristic of vehicular emissions (Perry and Gee, 1995; Brocco et al., 1997; Barletta et al.,

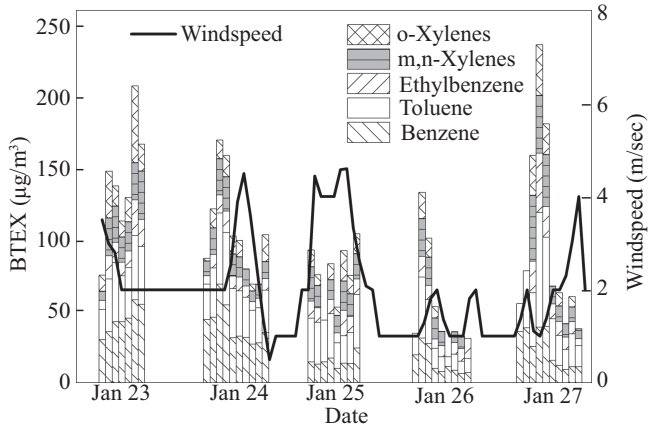

Fig. 1 – Concentrations of outdoor BTEX (benzene, toluene, ethylbenzene and xylenes) compounds and wind speed from 23 to 27 January, 2013.

Table 1 – Comparison of BTEX (benzene, toluene, ethylbenzene and xylenes) levels measured in the rural area with those reported in Chinese cities (unit: μg/m³).

Location	(sampling time)	Number of samples	Benzen	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	References
Indoor	Dongbaituo, Hebei (1/2013)	31	34.4 ± 20.4 (10.8–88.7)	58.9 ± 43.1 (12.9–184.1)	28.0 ± 18.7 (5.4–105.8)	58.1 ± 42.9 (6.9–177.3)	30.2 ± 8.5 (14.9–54.6)	This work
	Hongkong, Home (2001)	24	5.0 ± 2.6 (1.4–10.3)	59.1 ± 19.8 (29.9–83.1)	2.7 ± 2.2 (0–6.9)	5.3 ± 2.6 (1.4–10.8)	3.9 ± 2.6 (1.0–11.0)	Guo et al., 2003
	Hongkong, Restaurant (2001)	16	10.3 ± 5.5 (3.7–18.3)	85.8 ± 49.5 (17.6–152.2)	8.6 ± 5.7 (3.0–17.4)	10.9 ± 8.8 (2.1–24.6)	5.9 ± 7.1 (0–18.5)	Guo et al., 2003
	Hangzhou (5/2002,10,11/2003)	31	4.899	21.37	15.10	19.96	9.76	Zhong et al., 2005
Outdoor	Dongbaituo, Hebei (1/2013)	49	27.2 ± 16.0 (6.6–68.9)	29.3 ± 14.6 (6.4–80.1)	12.0 ± 6.8 (4.8–41.3)	18.0 ± 9.6 [6.1–45.8]	15.7 ± 10.4 (1.9–53.3)	This work
	Beijing (Winter, 2008)	190	6.9 ± 6.7 (0.9–24.1)	10.4 ± 10.6 (0.8–41.0)	2.5 ± 2.5 (0.2–11.9)	4.9 ± 4.4 (0.4–21.9)	2.2 ± 2.0 (0.2–9.9)	Zhang et al., 2012
	Beijing (Winter, 2009)	140	9.2 ± 7.6 (0.8–31.2)	14.5 ± 13.2 (1.2–58.7)	4.4 ± 4.5 (0.3–18.2)	7.5 ± 7.1 (0.6–34.1)	3.5 ± 3.2 (0.3–14.8)	Zhang et al., 2012
	Beijing (8–9/2012)	43	1.7 (0.2–5.1)	5.4 (0.4–22.3)	1.2 (0.1–5.8)	2.1 [0.1–10.5]	0.5 (0.1–2.6)	Li et al., 2014
	Pearl River Delta, (10–12/2007)	102	2.5 (0.7–9.3)	18.0 (0.4–116.1)	6.2 (0.2–119.5)	9.5 (0.3–365.5)	3.5 (0.1–115.9)	Ling et al., 2011
	Guangzhou (7,11/2002)	169	8.9 ± 11.5	40.3 ± 56.8	7.3 ± 12.5	6.2 ± 12.3	4.6 ± 11.6	Wang et al., 2008
	Nanjing (4/2006–1/2007)	430	6.4 ± 3.8	19.8 ± 10.3	2.9 ± 2.1	3.4 ± 2.8	2.1 ± 2.2	Wang and Zhao, 2008
	TaiO, Hongkong (10–12/2001,2012)	32	3.0 ± 3.2 (0.1–35.9)	23.3 ± 29.3 (0.1–201.2)	4.0 ± 5.8 (–38.4)	4.6 ± 8.8 (–69.7)	1.8 ± 2.7 (–20.5)	Guo et al., 2006

Data are presented as mean value ± standard deviation and the ranges in bracket.

2005; Liu et al., 2009), and values ≥1 have been reported for biofuel, charcoal burning and coal burning (Moreira dos Santos et al., 2004). The B/T ratios of 1.17 ± 0.34 in this work strongly suggested that coal burning was the main source in the rural area.

2.4. Health risk assessment

In order to evaluate the threat to the local inhabitants' health caused by BTEX, the non-cancer hazard (Hazard Quotient, HQ) and life cycle cancer risk (CR) due to the exposure to BTEX were roughly estimated (listed in Table 2) based on the data investigated in this work and the health risk assessment method proposed by US EPA (see: rais.ornl.gov). Here, the exposure concentration (EC, μg/m³) was calculated from Eq. (1):

$$EC = CA \times ET \times EF \times ED/AT \quad (1)$$

where, CA (mg/m³) is the concentration of the pollutant, which was derived by averaging the concentrations of BTEX in winter (four months) and other seasons (eight months). The average concentrations obtained by this study were adopted as the concentrations in winter, the concentrations in other seasons

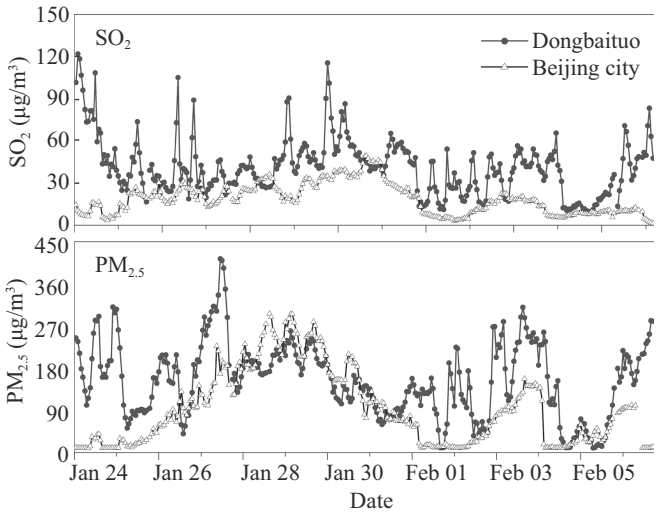

Fig. 2 – Outdoor concentration levels of $PM_{2.5}$ and SO_2 in DBT (Dongbaituo) and Beijing city from 24 January to 6 February, 2013.

Table 2 – Hazard quotient and cancer risk of BTEX (benzene, toluene, ethylbenzene and xylenes) in the rural area.

BTEX	EC ($\mu g/m^3$)		RfC	IUR	HQ		Risk	
	Indoor	Outdoor	(mg/m^3)	($m^3/\mu g$)	Indoor	Outdoor	Indoor	Outdoor
Benzene	11.5	9.7	0.03	7.8E−06	3.82E−01	3.24E−01	8.94E−05	7.59E−05
Toluene	19.6	9.8	5		3.93E−03	1.95E−03		
Ethylbenzene	9.3	4.0	1.0		9.33E−03	4.00E−03		
m,p-Xylene	19.4	6.0	0.1		1.94E−01	6.00E−02		
o-Xylene	10.1	5.2	0.1		1.01E−01	5.23E−02		

were assumed to be 0 $\mu g/m^3$; ET (24 hr/day) is the exposure time; EF (365 days/year) is the exposure frequency; ED (70 years) is the exposure duration, and AT ($70 \times 365 \times 24$ hr) is the averaging time.

The HQ and CR were calculated from Eqs. (2) and (3):

$$HQ = EC/(RfC \times 1000) \quad (2)$$

$$CR = EC \times IUR \quad (3)$$

where, RfC (mg/m^3) is the reference concentration and IUR ($m^3/\mu g$) is the inhalation unit risk.

According to USEPA document "EPA-540-R-070-002", if the HQ of a specific pollutant is lower than 1, the pollutant has no obvious non-cancer risk to human health, and the acceptable value of cancer risk for an ordinary adult is 1E−06 (Li et al., 2014). The HQ values of 0.38 and 0.32 in this work for indoor and outdoor benzene respectively suggest that benzene poses no obvious non-cancer risk to the farmers in the rural area. However, the cancer risks for both indoor and outdoor benzene greatly exceeded the threshold value of 1E−06, and hence the chronic health effect due to the high concentration of benzene in rural areas of the NCP in winter must be given attention.

3. Conclusions

In this study, the atmospheric levels of outdoor and indoor BTEX in a rural area of the NCP were investigated. The extremely high levels of BTEX in the rural area compared with those reported in cities were mainly ascribed to domestic coal combustion for heating during the winter season. The extremely high values of Hazard Quotient and cancer Risks for both the indoor and outdoor benzene indicated that the high pollution levels of benzene in the rural area of the NCP were threatening the farmers' health, and hence effective control measures are urgently needed to improve the air quality in rural areas of the NCP during the winter season.

Acknowledgments

This work was supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (No. XDB05010100), the National Basic Research and the Development Program 973 (No. 2010CB732304), the National Natural Science Foundation of China (No. 21177140, 41203070), and the China Postdoctoral Science Foundation (No. 2012M520404).

REFERENCES

Aksoy, M., 1989. Hematotoxicity and carcinogenicity of benzene. Environ. Health Perspect. 82, 193–197.

Barletta, B., Meinardi, S., Rowland, S.F., Chan, C.Y., Wang, X.M., Zou, S.C., et al., 2005. Volatile organic compounds in 43 Chinese cities. Atmos. Environ. 39 (32), 5979–5990.

Barletta, B., Meinardi, S., Simpson, I.J., Zou, S., Rowland, S.F., Blake, D.R., 2008. Ambient mixing ratios of nonmethane hydrocarbons (NMHCs) in two major urban centers of the Pearl River Delta (PRD) region: Guangzhou and Dongguan. Atmos. Environ. 42 (18), 4393–4408.

Brocco, D., Fratarcangeli, R., Lepore, L., Petricca, M., Ventrone, I., 1997. Determination of aromatic hydrocarbons in urban air of Rome. Atmos. Environ. 31 (4), 557–566.

Buczynska, A.J., Krata, A., Stranger, M., Godoi, A.F., Kontozova-Deutsch, V., Bencs, L., et al., 2009. Atmospheric BTEX-concentrations in an area with intensive street traffic. Atmos. Environ. 43 (2), 31–318.

Dutta, C., Som, D., Chatterjee, A., Mukherjee, A.K., Jana, T.K., Sen, S., 2009. Mixing ratios of carbonyls and BTEX in ambient air of Kolkata, India and their associated health risk. Environ. Monit. Assess. 148 (1–4), 97–107.

Guo, H., Lee, S.C., Li, W.M., Cao, J.J., 2003. Source characterization of BTEX in indoor microenvironments in Hong Kong. Atmos. Environ. 37 (1), 73–82.

Guo, H., Wang, T., Blake, D.R., Simpson, I.J., Kwok, Y.H., Li, Y.S., 2006. Regional and local contributions to ambient non-methane volatile organic compounds at a polluted rural/coastal site in Pearl River Delta. China Atmos. Environ. 40 (13), 2345–2359.

Li, L., Li, H., Zhang, X.M., Wang, L., Xu, L.H., Wang, X.Z., et al., 2014. Pollution characteristics and health risk assessment of benzene homologues in ambient air in the northeastern urban area of Beijing, China. J. Environ. Sci. 26 (1), 214–223.

Ling, Z.H., Guo, H., Cheng, H.R., Yu, Y.F., 2011. Sources of ambient volatile organic compounds and their contributions to photochemical ozone formation at a site in the Pearl River Delta, southern China. Environ. Pollut. 159 (10), 2310–2319.

Liu, J.F., Mu, Y.J., Zhang, Y.J., Zhang, Z.M., Wang, X.K., Liu, Y., et al., 2009. Atmospheric levels of BTEX compounds during the 2008 Olympic Games in the urban area of Beijing. Sci. Total Environ. 408 (1), 109–116.

Liu, K.K., Quan, J.N., Mu, Y.J., Zhang, Q., Liu, J.F., Gao, Y., et al., 2013. Aircraft measurements of BTEX compounds around Beijing city. Atmos. Environ. 73, 11–15.

Moreira dos Santos, C.Y., de Almeida Azevedo, D., de Aquino Neto, F.R., 2004. Atmospheric distribution of organic compounds from urban areas near a coal-fired power station. Atmos. Environ. 38 (9), 1247–1257.

Perry, R., Gee, I.L., 1995. Vehicle emissions in relation to fuel composition. Sci. Total Environ. 169 (1–3), 149–156.

Quan, J.N., Gao, Y., Zhang, Q., Tie, X.X., Cao, J.J., Han, S.Q., et al., 2013. Evolution of planetary boundary layer under different

weather conditions, and its impact on aerosol concentrations. Particuology 11 (1), 34–40.
Wang, P., Zhao, W., 2008. Assessment of ambient volatile organic compounds (VOCs) near major roads in urban Nanjing. China Atmos. Res. 89 (3), 289–297.
Wang, B.G., Zhang, Y.H., Shao, M., Zhou, Y., Feng, Z.C., 2008. Sources apportionment of anthropogenic C2–C9 non-methane hydrocarbons in the atmosphere of Guangzhou, China. Acta Sci. Circumst. 28 (7), 1430–1440.
Wang, Y.S., Ren, X.Y., Ji, D.S., Zhang, J.Q., Sun, J., Wu, F., 2012. Characterization of volatile organic compounds in the urban area of Beijing from 2000 to 2007. J. Environ. Sci. 24 (1), 95–101.
Yuan, B., Shao, M., Lu, S.H., Wang, B., 2010. Source profiles of volatile organic compounds associated with solvent use in Beijing. China Atmos. Environ. 44 (15), 1919–1926.
Zhang, Y.J., Mu, Y.J., Liu, J.F., Mellouki, A., 2012. Levels, sources and health risks of carbonyls and BTEX in the ambient air of Beijing, China. J. Environ. Sci. 24 (1), 124–130.
Zhong, T.X., Liu, S.F., Tian, J., 2005. Source apportionment and pollution survey of aromatic compounds in indoor air of Hangzhou. Environ. Monit. China 21 (6), 66–70.

Editorial Board of Journal of Environmental Sciences

Editor-in-Chief

X. Chris Le University of Alberta, Canada

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, UK
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
Hokyong 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,
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
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

Editorial office staff

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

Copyright© Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V. and Science Press. All rights reserved.

JOURNAL OF ENVIRONMENTAL SCIENCES

环境科学学报(英文版)

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, 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 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@rcees.ac.cn. Instruction to authors is available at http://www.jesc.ac.cn.

Journal of Environmental Sciences (Established in 1989)
Volume 30 2015

Supervised by	Chinese Academy of Sciences	**Published by**	Science Press, Beijing, China
Sponsored by	Research Center for Eco-Environmental		Elsevier Limited, The Netherlands
	Sciences, Chinese Academy of Sciences	**Distributed by**	
Edited by	Editorial Office of Journal of	Domestic	Science Press, 16 Donghuangchenggen
	Environmental Sciences		North Street, Beijing 100717, China
	P. O. Box 2871, Beijing 100085, China		Local Post Offices through China
	Tel: 86-10-62920553; http://www.jesc.ac.cn	Foreign	Elsevier Limited
	E-mail: jesc@rcees.ac.cn		http://www.elsevier.com/locate/jes
Editor-in-chief	X. Chris Le	**Printed by**	Beijing Beilin Printing House, 100083, China

CN 11-2629/X **Domestic postcode: 2-580** **Domestic price per issue RMB ¥ 110.00**

ISSN 1001-0742