

FEB - FRESENIUS ENVIRONMENTAL BULLETIN

Founded jointly by F. Korte and F. Coulston

Production by PSP - Vimy Str. 1e, 85354 Freising, Germany in
cooperation with PRT-Parlar Research & Technology

Vimy Str 1e, 85354 Freising

Copyright© by PSP and PRT, Vimy Str. 1e, 85354 Freising, Germany

All rights are reserved, especially the right to translate into foreign language or other processes - or convert to a machine language, especially for data processing equipment - without written permission of the publisher. The rights of reproduction by lecture, radio and television transmission, magnetic sound recording or similar means are also reserved.

Printed in Germany-ISSN 1018-4619

FEB-EDITORIAL BOARD**CHIEF EDITOR:****Prof. Dr. H. Parlar**Parlar Research & Technology-PRT
Vimy Str.1e
85354 Freising, Germany**MANAGING EDITOR:****Dr. P. Parlar**Parlar Research & Technology
PRT, Vimy Str.1e
85354 Freising, Germany**CO-EDITORS:****Environmental Spectroscopy****Prof. Dr. A. Piccolo**Universita di Napoli "Frederico II"
Dipto. Di Scienze Chemica Agrarie
Via Universita 100, 80055 Portici, Italy**Environmental Biology****Prof. Dr. G. Schuurmann**UFZ-Umweltzentrum
Sektion Chemische Ökotoxikologie
Leipzig-Halle GmbH,
Permoserstr.15, 04318
04318 Leipzig, Germany**Prof. Dr. I. Holoubek**Recetox-Tocoen
Kamenice126/3, 62500 Brno, Czech Republic**Prof. Dr. M. Hakki Alma**Iğdir Üniversitesi
76000, Iğdir, Turkey**Prof. Dr. A. Reichlmayr-Lais**Technical University of Munich
Arcisstraße 31
80333 Muenchen, Germany**Environmental Management****Dr. K. I. Nikolaou**Env. Protection of Thessaloniki
OMPEPT-54636 Thessaloniki
Greece**Environmental Toxicology****Prof. Dr. H. Greim**Senatkommission – DFG / TUM
85350 Freising, Germany**Environmental Proteomic****Dr. A. Fanous**Halal Control GmbH
Stahlstraße 44
D-65428 Rüsselsheim, Germany**Environmental Analytical Chemistry****Prof. Dr. M. Bahadir**Lehrstuhl für Ökologische Chemie
und Umweltanalytik
TU Braunschweig
Lehrstuhl für Ökologische Chemie
Hagenring 30, 38106 Braunschweig, Germany**Dr. D. Kotzias**Via Germania29
21027 Barza(Va), Italy**Prof. Dr. R. Kallenborn**Norwegian University of Life Sciences
Universitetstunet 3
1430 As, Norway**Environmental Education****Prof. Dr. C. Bayat**Yeni Yüzyıl Üniversitesi
34010 Zeytinburnu, Istanbul, Turkey**Environmental Medicine****Prof. Dr. I. Tumen**Bandirma 17 Eylül Üniversitesi
10200 Bandirma, Turkey**Dr. J. Burhenne**Universitaet Klinikum
Im Neuenheim Feld 410
69120 Heidelberg, Germany***Advisory Board*****K. Bester, K. Fischer, DCG. Muir,
R. Niessner, W. Vetter, D. Steinberg,
J. P. Lay, L. O. Ruzo*****Marketing Manager*****Cansu Ekici, MSc. of B.A.**PRT-Research and Technology
Vimy Str 1e
85354 Freising, Germany**E-Mail: parlar@wzw.tum.de
parlar@prt-parlar.de****Phone: +49/8161887988**



Fresenius Environmental Bulletin is abstracted/indexed in:

Biology & Environmental Sciences, BIOSIS, CAB International, Cambridge Scientific abstracts, Chemical Abstracts, Current Awareness, Current Contents/Agriculture, CSA Civil Engineering Abstracts, CSA Mechanical & Transportation Engineering, IBIDS database, Information Ventures, NISC, Research Alert, Science Citation Index (SCI), Scisearch, Selected Water Resources Abstracts

CONTENTS

REVIEW

- A REVIEW OF RESEARCH PROGRESS ON HYDROCARBON SOURCE CORRELATION TECHNOLOGY 837
Hu Li

ORIGINAL PAPERS

- PATHOGENIC DIVERSITY IN *Ascochyta rabiei* IN CHICKPEA (*Cicer arietinum* L.) IN THE WESTERN OF ALGERIA 848
Bettouati Abdelkader, Meziane Malika, Setti Benali, Hamdi Samia
- A SYMBIOTIC ASSOCIATION BETWEEN HUMAN CAPITAL AND AGRICULTURAL GROWTH IN PAKISTAN; ASSESSMENT THROUGH AUTO REGRESSIVE DISTRIBUTED LAG MODEL 857
Sehresh Hena, Sufyan Ullah Khan, Abdul Rehman, Shazia Khalid, Farooq Shah, Luan Jingdong
- DECADAL CHANGES OF OASES IN THE KASHGAR REGION FROM 1975-2015 867
Aynur Mamat, Jianping Wang, Yuanxu Ma, Liming Wang
- IMPROVING BIODEGRADABILITY OF ARECA-COOKING WASTEWATER BY AERATION ALUMINUM-CARBON MICRO-ELECTROLYSIS 876
Peng Shu, Zhiyong Yan, Zugen Liu, Bing Liao, Peng Xiong, Huimin Li, Huili Liu, Dingbo Yuan, Dingding Chen, Junfeng Chen
- STUDY ON COUPLING AND COORDINATION OF SOCIETY, ECONOMY AND ENVIRONMENT IN GANZI PREFECTURE, SICHUAN PROVINCE 888
Jing Zhou, Li Luo
- CHARACTERIZATION OF A BACTERIAL STRAIN CAPABLE OF DEGRADING DIESEL UNDER AEROBIC CONDITIONS AND ITS APPLICATION IN BIOREMEDIATION OF CONTAMINATED SOIL 895
Hui Wang, Yingying Zhao, Luoge Rong, Lina Sun, Yinggang Wang, Qing Luo, Xiaoxu Wang, Hao Wu
- SPATIAL DISTRIBUTION, ORIGIN IDENTIFICATION AND POTENTIAL RISKS OF HEAVY METALS IN SUBURBAN FARMLAND SOILS OF TIANJIN, CHINA 902
Jing Zhang, Wanqing Zeng, Dongli Ji, Xinbo Zhang
- CHARACTERISTICS OF CARBONIFEROUS MARINE CARBONATE RESERVOIRS IN EASTERN MARGIN OF PRECASPIAN BASIN 911
Jue Hou, Bobiao Liu, Shuqin Wang, Jianxin Li, Wenqi Zhao, Yaping Lin
- INVESTIGATION OF REHABILITATION OPPORTUNITIES IN PIT MINING: THE CASE OF NIGDE MADENKOY BASIN 922
Nuriye Ebru Yildiz, Gulden Sandal Erzurumlu
- STUDY ON THE INFLUENCE MECHANISM OF HYDRAULIC FRACTURE CAUSED BY LIQUID EXPLOSIVE FRACTURING IN HORIZONTAL WELL 932
Diguang Gong, Junbin Chen, Xiaowei Dong, Hang Gao, Yi Cao, Xiangrong Nie, Kehan Tian
- SPATIAL AND TEMPORAL VARIABILITY OF TYPICAL AIR POLLUTANT CONCENTRATIONS IN THE URBAN AREA OF QINGDAO, CHINA 940
Xun Zhang, Bin Zhang, Yuchai Wan, Yanling Xu, Xiansheng Liu
- REMOVAL BEHAVIOR OF ENDOCRINE DISRUPTING CHEMICALS (EDCS) BY OZONATION IN SECONDARY EFFLUENT 954
Xiurong Si, Xinru Tian, Jianhua Zhou, Ding Ding, Feng Chen, Zunfang Hu
- MINERAL COMPOSITION OF EMMER WHEAT (*Triticum turgidum* L. VAR. *dicoccum*) LANDRACES 963
Sancar Bulut
- CYTOTOXIC, ANTIMICROBIAL AND BRAIN PROTECTIVE EFFECT OF BIOACTIVE PHENOLIC COMPOUNDS PRODUCED FROM *Portulaca oleracea* L. 971
Gamal Gabr, Hazem Hassan, Rabab El Kashef, Nasra Abd-Elhak, Amira Soliman
- DEACTIVATION AND REGENERATION OF COMMERCIAL HONEYCOMB V₂O₅-WO₃/TiO₂ SCR CATALYST 979
Minghua Duan, Ming Kong, Honghui Liu

CARBON AND OXYGEN ISOTOPE COMPOSITION OF CARBONATE MINERALS IN CARBONACEOUS SHALE AND ITS GEOLOGICAL SIGNIFICANCE-A CASE STUDY FROM THE CARBONIFEROUS DAWUBA FORMATION SHALE, SOUTHERN GUIZHOU AREA CHINA Xiaofu Li, Kun Yuan, Xinxin Fang, Ting Wang	990
IMPROVED METHYLENE BLUE BIOSORPTION ONTO GREEN ALGAE: <i>Ulva Lactuca</i> Sinan Mehmet Turp, Guldane Ash Turp, Necla Ekinci, Saim Ozdemir, Kaan Yetilmezsoy	998
REGIONAL POLLUTANT TRANSPORT CONTRIBUTIONS TO PM _{2.5} IN JINAN DURING A SEVERE POLLUTION EPISODE Yajie Feng, Ruiping Li, Lishu Lian, Zhaoyu Zhang, Baofu Li	1010
STUDY ON ECOLOGICAL HEALTH EVALUATION OF WETLAND TOURISM IN NATURE RESERVE BASED ON THE 3S TECHNOLOGY Haizhi Yu	1020
STUDY ON THE PROPERTY OF GREEN AND ENVIRONMENT FRIENDLY ASSEMBLY OF MONOLITHIC CONCRETE SHEAR WALLS ON ECOLOGICAL PERSPECTIVE Liqun Wang, Liangsong Li, Haiwen Yin, Peng Xiao	1029
EXPERIMENTAL STUDY OF STRUCTURE FORMATION OF EUTECTIC BY ELECTRON MICROSCOPY IN NEW AS CAST Al-Cu15-Mg-Ti ALLOYS Biljana Zlaticanin	1034
THE EFFECT OF INDOOR AMBIENT AIR ENVIRONMENTAL QUALITY ON HUMAN BLOOD INDICES AFTER DIFFERENT INTENSITY EXERCISE Lei Chen, Huaxia Zhang	1045
ACCUMULATION OF PAHS IN BIVALVES (<i>Crassostrea gigas</i> AND <i>Mytilus coruscus</i>) FROM ZHEJIANG COASTAL CHINA AND ASSOCIATED HUMAN HEALTH RISK ASSESSMENT Lei Li, Xianyin Ping, Ziniu Li, Guodong Xv, Cuihua Wang, Mei Jiang	1055
HYDROLOGICAL MODELS SIMULATION IN AGRICULTURAL WATERSHED OF WADI KHAROUBA IN NORTH-WESTERN COAST REGION - EGYPT Mohamed Ahmed Ibrahim Abdalla, Mohamed Abd El-Wahab, Mohamed Tawfik, Islam Khater	1063
RESEARCH ON PROCESSING TECHNOLOGY OF NEW GREEN AND ENVIRONMENTALLY FRIENDLY REORGANIZED BAMBOO AND WOOD STRUCTURE BASED ON ECOLOGICAL PERSPECTIVE Xiao Yang, Mingming He, Ting Yu, Yu Gong	1079
RESEARCH ON EMERGENCY MECHANISM OF SUDDEN ENVIRONMENTAL POLLUTION EVENTS IN THE CONTEXT OF BIG DATA Rong Wu, Hongxia Li, Shuicheng Tian	1085
CONGO RED ADSORPTION FROM AQUEOUS SOLUTION BY FORMALDEHYDE MODIFIED WALNUT SHELL Yinghua Song, Lin Zhuo, Hui Xu, Mei Ye	1093
A COMPARISON OF CONVOLUTIONAL NETWORKS CAPSULE NETWORK AND TRANSFER LEARNING FOR HEAVY RAINFALL NOWCASTING Cevher Ozden	1103
STUDY ON THE POLLUTION OF COAL MINING ENVIRONMENT FROM COAL SEAM SPONTANEOUS COMBUSTION IN GOAF AND ITS FIRE PREVENTION AND EXTINGUISHING TECHNOLOGY An Zhang, Baoshan Jia	1111
THE EFFECTS SOME PLANT (<i>Coridothymus Capitatus</i> L.) RCHB. F. AND <i>Mentha Pulegium</i> L.) EXTRACTS ON THE CONTROL OF AN INVASIVE WEED (<i>Oxalis Pes-Caprae</i> L.) Sevgin Ozderin, Koray Kacan, Ibrahim Kivrak	1120
THE ADSORPTION PERFORMANCE OF CIPROFLOXACIN HYDROCHLORIDE (CPX) ON POLYURETHANE AND CARBON NANOTUBES FOAMS Qiao Cong, Tingting Zhang, Juanhong Wang, Xing Yuan	1127
QUANTITATIVE STUDY ON FAULT ACTIVITY IN THE NORTHERN MARGIN OF QAIDAM BASIN BASED ON FAULT ACTIVITY RATE Xiaojuan Guo, Jingong Zhang	1138
GEOCHEMICAL CHARACTERISTICS AND GAS PRODUCTION POTENTIAL OF COAL-MEASURE STRATA: A CASE STUDY OF TAIYUAN AND SHANXI FORMATIONS IN QINSHUI BASIN, CHINA Zhenfeng Yu, Jindong Yang, Xinya Song, Jin Qiao	1145

RESEARCH ON THE SPATIOTEMPORAL CHARACTERISTICS MODES AND DRIVING FACTORS OF URBAN CONSTRUCTION LAND EXPANSION IN JIANGXI UNDER RAPID URBANIZATION Chun Fu, Xiaoqiang Tu	1155
APPLIED PEDIGREE SELECTION METHOD TO IMPROVE YIELD AND EARLINESS TRAITS FOR THREESEGREGATING COTTON GENERATIONS Sobhy Gharib Sorou, Abdel Aziz Galal Abdel Hafez, Mohammed Ezzat Abdelsalam, Yaser Mohamed Farag	1172
STUDY ON THE MICRO CHARACTERISTICS OF DEEP-WATER SANDY CLASTIC FLOW AND TURBIDITE SANDSTONE IN CONTINENTAL LAKE BASIN A CASE STUDY OF CHANG 7 MEMBER OF YANCHANG FORMATION IN ORDOS BASIN Kaijun Tan, Yunze Xu, Zhiyong Li, HuiXue, Jianbo Liao, Yuhu Ma	1180
A DIFFERENT APPROACH TO THE MONITORING OF THE QUALITY OF DRINKING WATER WITH DATA MINING TOOLS Derya Camur, Ahmet Altin, Murat Topbas, Huseyin Ilter	1188
NUMERICAL SIMULATION OF MULTIPHASE FLOW AND REACTION IN CATALYST BED OF HYDROGENATION REACTOR Rui Yu, Guangfa Miao	1201
STUDY ON MOLDING PERFORMANCE, COMBUSTION PERFORMANCE AND NO _x EMISSION PERFORMANCE OF BIOMASS COMPOSITE STEAM COAL Zhiying Zhao, Xingwang Dang	1211
THE EFFECTS OF DIFFERENT HORMONE COMBINATIONS ON <i>IN VITRO</i> MICROPROPAGATION OF ARONIA (<i>Aronia Melanocarpa</i> (MICHX.) ELLIOTT) Mehmet Polat, Ilknur Eskimez	1219
TOXIC EFFECT OF SILVER NANO PARTICLES ON <i>Karenia mikimotoi</i> AND MECHANISMS OF ALGAE INHIBITION Yuling Xu, Renjun Wang, Lingling Cui, Lijun Hu, Junfeng Chen	1228
PRESENCE OF <i>Listeria</i> SPECIES IN FRESH SALAD PRODUCTS COLLECTED FROM QUETTA PAKISTAN Nosheena, Abdul Samad, Muhammad Naeem, Hafsa Jamil, Palwasha Farooq, Muhammad Bilal Sadiq, Hafsa Tariq, Farah Sabeen Bugti, Ali Akbar	1234
NEW APPROACH TO ECOLOGICAL STRUCTURE EFFECTS OF MEDICAL AROMATIC PLANT EXTRACT/BORAX ON THE ANATOMICAL STRUCTURE OF WOOD AND HUMAN/ENVIRONMENTAL HEALTH Hatice Ulusoy, Huseyin Peker	1240
KNOWLEDGE DOMAIN AND EMERGING TRENDS IN <i>Lycoris</i> - A SCIENTOMETRIC ANALYSIS - Yuhong Zheng, Pengchong Zhang, Li Fu	1250
RESPONSE OF EGYPTIAN YASMINE RICE CULTIVAR TO DIFFERENT SEEDLING NUMBER PER HILL AND DIFFERENT NITROGEN LEVELS Abd Elhamid Omar, Mahmoud AboYoussef, Abdallah Shoughy, Mohamed Saad Abd El-Aty, Khaled Abdelaal, Yaser Hafez, Mohamed Kamara	1258
RESIDUAL LIFE PREDICTION OF HIGH POWER PROTON EXCHANGE MEMBRANE FUEL CELL FOR VEHICLE USING Xiuqian Sun, Guangqian Zhu	1266
EFFECTS OF CULTIVATION YEARS ON THE GREENHOUSE GAS EMISSION OF GREENHOUSE VEGETABLE SOILS IN A BEIJING SUBURB Wang Xuexia, Li Mengjia, Qiao Dan, Chen Yanhua, Cao Bing, Liu Dongsheng, Wang Jiachen	1278
ASSESSMENT OF THE IMPACTS OF SOIL AND WATER CONSERVATION MEASURES ON BASIN HYDROLOGY WITHIN A SMALL KARST BASIN GUIZHOU PROVINCE CHINA Li Yue, Qi Shi, Li Jingjing	1289
TROPICAL GEOCHEMICAL CHARACTERISTICS OF SOUTHERN TIBET AND ANALYSIS OF WATER POLLUTION IN UTILIZATION PROCESS Haoqing Huang, Qinghua Peng	1308
<u>INVESTIGATION</u> OF FOULING DEVELOPMENT DURING ULTRAFILTRATION OF PURE BACTERIA AND SECONDARY EFFLUENT Xiurong Si, Jianhua Zhou, Xiaofang Wu	1317
RESEARCH ON CONTROL METHOD OF REGIONAL POWER GRID LOAD FREQUENCY IN EXTREME COLD WEATHER ENVIRONMENT Yece Qian, Guoping Shi, Huajie Xu	1324

EXPERIMENTS ON ADSORPTION AND REMOVAL OF PB ²⁺ IONS BY FUNCTIONAL FIBER BAMBOO OF ECO-FRIENDLY BUILDING MATERIALS Endong Wang	1331
EFFECT OF Ca ADDITION ON ALLEVIATING Cd INDUCED CYTO-TOXICITY IN <i>Salix matsudana</i> KOIDZ ROOT-TIP CELLS Jinhua Zou, Jiahui Han, Yuerui Wang, Yi Jiang, Bowen Han, Kongfen Wu, Xiaowen Xu, Xiao Yang, Ziyuan Wang, Yuran Liu	1338
RESEARCH ON THE INFLUENCE OF AIR POLLUTION ON THE STRESS CORROSION OF RAILWAY VEHICLE BODY ALUMINUM ALLOY Yuwei Wang, Feng Yan, Guangxue Yang	1350
EVALUATING IMPACT IN ENVIRONMENTAL IMPACT ASSESSMENT FOR LARGE COMMUNITY DEVELOPMENT USING GM (1, N) MODEL AND MULTIPLE LINEAR REGRESSION Yi-Ti Tung, Tzu-Yi Pai	1360
THE COMPREHENSIVE NUTRITION VALUE EVALUATION OF COMMON FORAGE COMPOSITAE PLANT IN THE KARST AREA Yongkuan Chi, Shuzhen Song, Xiao Hua, Yuansu Wang, Hu Chen	1370
EXOGENOUS APPLICATION OF ASCORBIC ACID AND GIBBERELIC ACID IMPROVED TOLERANCE OF MAIZE TO NaCl STRESS Hira Fatima, Ameer Khan, Muhammad Nadeem	1380
INTERACTION ADSORPTION OF <i>p</i> -NITROPHENOL AND Cu(II) BY CORN STRAW BIOCHAR Jinkui Zhong, Xinzhuo Xie, Bowen Zheng, Jing Li, Qiaozhen Yang	1388
WATER-NITROGEN COUPLING ENHANCEMENT OF YIELD WATER EFFICIENCY AND OUTPUT VALUE COMBINING PRELIMINARY FITTING WATER-NITROGEN COUPLING YIELD MODELING OF FLUE-CURED TOBACCO Danyan Chen, Hao Liu, Ya Liu, Juan Hu, Peizhe Li, Yu Liu, Shilong Li, Jingze Ma, Siyuan Wu, Xiaohou Shao	1397
CHARACTERIZATION AND CONTROL MECHANISMS OF MAJOR IONS HEAVY METALS AND MULTIPLE ISOTOPES IN GROUNDWATER OF COAL-BEARING AQUIFER - A CASE STUDY IN QIANYINGZI COAL MINE Liu Xianghong, Ye Qihong, Chen Kai, Peng Weihua	1407
EXPERIMENTAL ANALYSIS OF PERMEABILITY PERFORMANCE OF MODIFIED RECYCLED CONCRETE Gen Li, Ying Fan	1417
STIMULATION OF RESISTANCE TO <i>Papaya ringspot virus</i> BY BIOTIC AND CHEMICAL SUBSTANCES Mohsen M Elsharkawy, Khloud T El-Ahmer, Samir A Sidaros, Shawky A Elkewey	1427
DIET OF TWO LOCUSTS <i>Oedipoda miniata mauritanica</i> AND <i>Oedipoda coerulescens sulfurescens</i> (ORTHOPTERA ACRIDIDAE) IN THE COAST OF THE TLEMCEEN REGION (ALGERIA) Bessenouci Danoun Meriem, Mesli Lotfi, Benhadji Nadhira	1435
ANALYSIS ON THE TEMPORAL AND SPATIAL CHANGES OF HEALTH FACTORS IN ZHANGJIAJIE FOREST PARK Qing Sun, Jianlin Tian, Qianni Cheng, Yiqiang Xiao	1441
EXPERIMENTAL EVALUATION OF RESERVOIR SENSITIVITY OF TIGHT SANDSTONE GAS RESERVOIRS AND ITS DRILLING FLUID TECHNOLOGY COUNTERMEASURES Hong Guo, Shien Liu, Jinshu Wang, Jing Wang	1450
EXPERIMENTAL COMPARATIVE STUDY ON PORE STRUCTURES OF CONTINENTAL AND MARINE SHALES Li Dong, Xu Zhao	1459
WATER POLLUTION CHARACTERISTICS AND NITROGEN SOURCE APPOINTMENT OF THE MAOBANQIAO RESERVOIR ON THE MAINSTREAM OF THE LONGCHUAN RIVER CHINA Lei Dong, Li Lin, Xiong Pan, Haiyang Jin, Wenliang Zhai, Huiqun Cao	1468
COMPARISON OF SOIL MOISTURE CHARACTERISTIC CURVES IN SALINE-ALKALI LAND UNDER DIFFERENT FARMLAND SHELTERBELTS Haokun Wang	1475
THE AMINO ACID SUBSTITUTION ALA-122-VAL OF ALS CONFERS ALS-INHIBITING HERBICIDE RESISTANCE IN THE <i>Aegilops tauschii</i> COSS POPULATION OF HENAN CHINA Fan-Bin Kong, Gui-Lei Hu, Kun Jiang, Bai-Zhong Zhang	1486
LIQUEFACTION DISCRIMINATION OF THE COASTAL STRATUM OF LLIGAN IN CHINA CODE AND NCEER METHOD Zhang Ming, Xue Ru, Guo Junhui	1495

LINE X TESTER ANALYSIS FOR GRAIN YIELD AND YIELD RELATED TRAITS FOR SOME CYTOPLASMIC MALE STERILE AND RESTORER LINES OF RICE	1503
Abd El-Aty Mohamed, Yasser Mazrou, El-Sayed Arafat, Omima Gawish, Mohamed Kamara, Alaa El-Din Omar	
THE EFFECTS OF DRYING ON PHYTOCHEMICALS OF SELF-GROWING PLANT <i>Taraxacum officinale</i> L.	1513
Fatma Ergun	
EFFECT OF DIETARY SUPPLEMENTATION OF SYNBiotics "POWER LAC" ON GROWTH PERFORMANCE, PHENOTYPIC TRAITS AND DIGESTIVE ENZYME ACTIVITIES OF MONOSEX NILE TILAPIA, <i>Oreochromis niloticus</i>	1521
Sheikh Mustafizur Rahman, Ahmed Saud Alsaqafi, Puja Kundu, Abdallah Tageldein Mansour, Yousef A Alkhamis, Roshmon Thomas Mathew, Muhammad Yousuf Ali, Sunuram Ray, Md Golam Sarower	
SALMONELLA DETECTION IN DIFFERENT TYPES OF PACKED RAW POULTRY MEAT BY CULTURE ELISA AND PCR METHODS	1531
Zeki Aras, Gokcenur Sanioglu Golen, Tahsin Onur Kevenk	
EFFECTIVENESS OF SOME MICROBIAL BIOPESTICIDES BASED ON <i>Bacillus</i> AGAINST LESSER MEALWORM <i>Alphitobius diaperinus</i> (COLEOPTERA:TENEBRIONIDAE) UNDER LABORATORY CONDITIONS	1537
Samed Koc, Burak Polat, Aysegul Cengiz, Sevval Kahraman, Ozge Tufan-Cetin, Huseyin Cetin	
LOCAL SCOUR AROUND THE SIDE-WEIR ON COHESIVE BED MATERIAL	1541
Fevziye Ayca Saracoglu, Hayrullah Agaccioglu	
LAND SUBSIDENCE CHARACTERISTICS OF CPEC AS REVEALED BY SBAS-INSAR - A CASE OF GWADAR PORT PAKISTAN	1550
Deliang Chen, Yanyan Lu, Manchun Li, Zhou Zhou	
ESTIMATION OF SOIL ORGANIC MATTER CONTENT BASED ON COMBINED LABORATORY AND FIELD SPECTROSCOPY IN HIGHLAND AGRICULTURAL AREAS: A CASE STUDY ON THE QINGHAI-TIBET PLATEAU, CHINA	1561
Yanan Hu, Xiaohong Gao, Zhenyu Shen, Yunfei Xiao	
ERRATUM	
SYNTHESIS AND CHARACTERIZATION OF CATECHIN LOADED NANOPARTICLES AND THEIR EVALUATION FOR ANTIMUTAGENIC ACTIVITY AGAINST <i>S. TYPHIMURIUM</i> STRAINS	1576
Tulin Arasoglu, Burcu Turkoglu, Ilkgul Akmayan, Banu Mansuroglu, Serap Derman	
STUDY ON THE INFLUENCE FACTORS OF URBAN WASTE RECYCLING FROM THE PERSPECTIVE OF URBAN ENVIRONMENTAL CONVERNANCE	1577
Wenhong Xiao	

SPATIAL AND TEMPORAL VARIABILITY OF TYPICAL AIR POLLUTANT CONCENTRATIONS IN THE URBAN AREA OF QINGDAO, CHINA

Xun Zhang¹, Bin Zhang¹, Yuchai Wan¹, Yanling Xu², Xiansheng Liu^{3,4,*}

¹Beijing Key Laboratory of Big Data Technology for Food Safety, School of Computer and Information Engineering, Beijing Technology and Business University, Beijing 100048, China

²College of Plant Health and Medicine, Qingdao Agricultural University, Qingdao, 266109, China

³Joint Mass Spectrometry Center, Cooperation Group Comprehensive Molecular Analytics, Helmholtz Zentrum Munchen, German Research Center for Environmental Health, Ingolstädter Landstr. 1, 85764 Neuherberg, Germany

⁴Joint Mass Spectrometry Center, Chair of Analytical Chemistry, University of Rostock, Rostock, 18059, Germany

ABSTRACT

Atmospheric pollutants have become a serious concern to the Chinese public in recent years due to the reduction of visibility and severe health risks associated with them. In this study, PM_{2.5}, PM₁₀, NO₂, and SO₂ were measured at a time resolution of 1-hour over the course of a year from January to December 2015 in the urban environment of Qingdao based on the temporal and spatial variations in the concentrations of four air pollutants. We found that (1) seasonal variation exists consistently for all pollutants, with the highest concentration in winter and the lowest in summer. (2) The monthly average of the concentrations of the four air pollutants exhibited U-shaped pattern of “high in autumn and winter but low in spring and summer”, and the double-peak or single-peak impulse-shaped daily variation. PM_{2.5} and PM₁₀ concentrations were lower on weekdays than on weekends while SO₂ concentrations were higher on weekdays than on weekends, indicating a “weekend effect”. (3) PM_{2.5}, PM₁₀, NO₂, and SO₂ factors showed strong correlation and low coefficient of divergence (CD) values at nine sites throughout the year, indicating an even distribution across the urban area. (4) Spatial autocorrelation analysis was used to characterize spatial variability showing that air pollutants in urban areas are not produced in the specific local site. The spatial distribution of annual and seasonal air pollution concentrations simulated by ordinary kriging showed that most parts of urban Qingdao suffer from severe air pollution in winter and pollutant concentrations are higher inland than at coastal sites.

KEYWORDS:

Air pollution, atmospheric pollutant concentrations, spatial-temporal characteristics, monitoring data, Qingdao urban area

INTRODUCTION

Urban areas with a high concentration of people and anthropogenic industrial and transport activities exhibit both the highest pollution levels and the largest targets of impact [1]. Urban and regional epidemiological studies have found a significant correlation between particulate matter (PM) exposure and mortality from cardiopulmonary and lung cancers, especially fine particulate matter and sulfur oxide-related pollution [2-5]. In addition, WHO (2012) [6] has reported that chronic exposure to air pollutants, including particulate matter (PM), causes the death of 7 million people, making it the world’s most important environmental health risk.

Fine particles (PM_{2.5} particles smaller than 2.5 μm in diameter) and coarse particles (PM_{10-2.5}—smaller than 10 μm in diameter but larger than 2.5 μm, CPM) are defined as a modal structure of particle size distributions typically observed in the atmosphere [2]. Fine particles and coarse particles are to be considered as separate classes of pollutants. These two PM size fractions are covered in PM₁₀ (particles smaller than 10 μm in diameter) and can have substantially different sources and sinks [7]. Therefore, the PM source can be analyzed by the ratio of PM_{2.5} and PM₁₀. It is well known that the fine particles originate mainly from combustion processes and gas-to-particle (SO₂, NO₂, HC et al.) conversion processes in the atmosphere. Therefore, in terms of mass concentration, the higher PM_{2.5}/PM₁₀, the higher the contribution rate of the secondary particles; the lower the ratio, the higher the contribution rate of the dust source. Other studies have shown that urban NO₂ mainly originates from mobile pollution sources such as automotive exhaust emissions, while SO₂ mainly originates from fixed sources such as industrial combustion (coal-fired power generation, metal smelting, etc.) [8]. Therefore, the higher the NO₂/SO₂ ratio, the higher the contribution of mobile pollution sources. The lower the ratio, the higher the contribution rate of fixed pollution sources.

Based on these knowledge, the objective of this study are: 1) to show the spatial-temporal characteristics of aerosols in urban cities by combining four indicators of atmospheric pollutants; 2) to explore the trend of atmospheric pollutants in workday and weekend; 3) and to portray the present situation of four indicators of atmospheric pollutants using geo-spatial statistical tools systematically. These estimates may be useful in assessing health impacts through related studies and in communicating with the public and policy makers for potential intervention.

MATERIALS AND METHODS

Data collection. In this manuscript, the urban area throughout Qingdao has been used as the study area. PM_{2.5}, PM₁₀, NO₂, and SO₂ concentrations data derived from urban air quality monitoring data of China's National Environmental Monitoring Centre [9]. The observation includes hourly pollutant concentrations at nine monitoring sites in Qingdao in 2015 to characterize the spatial variability of particulate matter concentrations (Figure 1). The detailed description of the monitoring sites is listed in Table 1.

Data preparation. According to Ambient Air Quality Standards (AAQS) of China GB3095-2012,

requirements for the validity of air pollutants concentration data, the data quality control, were conducted. The missing values and the outliers of PM_{2.5}, PM₁₀, NO₂, and SO₂ concentrations in the raw data were excluded using the Bayesian method, which is an important technique in statistics. In addition, the "daily average" refers to the arithmetic mean of the average daily 24-hour concentration; the "monthly average" refers to the arithmetic mean of the daily average concentration in a month; the "seasonal average" refers to the arithmetic mean of the average daily concentration in the calendar quarter; the "annual average" refers to the arithmetic mean of the average daily concentration in the calendar year.

Statistical analysis. Partial Correlation Analysis. The correlation between the concentrations of the two atmospheric pollutants can reflect the characteristics of the origin. When there is a positive correlation, this indicates that the two may have homology; when there is a negative correlation, the concentration of the two has a change characteristic. One may be the precursor of the other, at which point the secondary pollutant generation process is accelerated [10-12]. Therefore, the correlation analysis with Bivariate Correlations Analysis was completed using the Statistical Package of the Social Sciences 18.0 (SPSS 18.0) Software for Windows.



FIGURE 1

Locations of measurement sites in Qingdao (left map, Shandong; right map, Qingdao; 1, Huangdao; 2, Chengyang; 3, Licang; 4, Sifang; 5, Laoshan; 6, Shinan East; 7, Shibe; 8, Shinan West; 9, Yangkou).

TABLE 1
Characteristics of the monitoring sites.

Monitoring sites	Type of station	Local characteristics
Yangkou	Urban background	Few vehicles; many trees, near the sea
Licang	Industrial site	Steelworks; many vehicles, buildings
Shibe	Urban background	Few vehicles, near the park
Shinan east	Business district	Commercial network intensive area
Sifang	Urban background	Few vehicles; near the park
Shinan west	Urban background	Many buildings, near the school, near the sea
Laoshan	Suburban background	Few vehicles; many trees, near the sea
Huangdao	Suburban residential site	Densely populated; many vehicles;
Chengyang	Traffic	Many vehicles, Industry

Coefficients of Divergence. Recent studies shows that the intra urban spatial distributions of atmospheric pollutant concentrations in some study areas are heterogeneous. Coefficients of variation (CV) or a coefficient of divergence (CD) were used to describe the relative heterogeneity of the inter-urban concentration of particles [13]. The CD_{jk} method for identifying the differences of atmospheric pollutant profiles has been described in detail elsewhere [13] (Wilson et al., 2005) and is defined as follows:

$$CD_{jk} = \sqrt{\frac{1}{p} \sum_{i=1}^p \left(\frac{x_{ij} - x_{ik}}{x_{ij} + x_{ik}} \right)^2} \quad (1)$$

where x_{ij} represents the average concentration of i at site j , j and k represent two sampling sites, and p is the number of observations [14]. If the value of CD_{jk} approaches zero, the atmospheric pollutant composition in j and k are similar, and if it approaches one, they are significantly different [7]. Therefore, the CD_{jk} could provide a relative measure of homogeneity in the concentration fields. In addition, a threshold of $CD_{jk} = 0.2$ is used to distinguish homogeneity and heterogeneity between sites (REF) [13] (Wilson et al., 2005).

Spatial Autocorrelation. Observations at different locations may not be independent. For example, measurements made at nearby locations may be closer in value than measurements made at locations farther apart. This phenomenon is called spatial autocorrelation, which can be measured by Moran's I [15,16].

Spatial autocorrelation measures the correlation of a variable with itself through space. Spatial autocorrelation can be positive or negative. Positive spatial autocorrelation occurs when similar values occur near one another while negative spatial autocorrelation indicates dissimilar values. The spatial autocorrelation method for identifying the correlation of atmospheric pollutant profiles was described in detail elsewhere [17]. It covers global spatial autocorrelation (Global Moran's I (GMI)), which is defined as follows.

The global Moran's I statistic is based on cross-products of the deviations from the mean and is calculated for n observations on a variable x at locations j, k as:

$$I = \frac{n}{S_0} \frac{\sum_j \sum_k w_{jk} (x_j - \bar{x})(x_k - \bar{x})}{\sum_j (x_j - \bar{x})^2} \quad (2)$$

where \bar{x} is the mean of the all x variable, w_{jk} are the elements of the weight matrix, and S_0 is the sum of the elements of the weight matrix:

$$S_0 = \sum_j \sum_k w_{jk} \quad (3)$$

In general, Moran's I is similar but not equivalent to a correlation coefficient. Its value varies between -1 and 1, representing negative and positive spatial autocorrelation, respectively. Positive and significant Moran's I values mean that nearby areas have similar spatial patterns, whereas negative values indicate the contrary. If the Moran's I is zero, it means the values are arranged randomly.

Since the Moran's I statistic follows a random distribution or a near-normal distribution, the significance test can be converted into the Z value of the normal distribution statistic. If the Z value at the 5% significance level is greater than 1.96 or less than -1.96, they indicate that there is a spatially significant positive or negative correlation between the observations. Values between -1.96 and 1.96 indicate a non-significant spatial correlation of the study. It is extremely significant when values are greater than 2.58. The standard statistic Z is calculated by the following formula:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}} \quad (4)$$

Where $E(I)$ and $VAR(I)$ are expectation and variance of Moran's I, respectively, and $E(I) = (-1)/(n-1)$. When Z is positive and significant, it indicates that there is a positive spatial correlation, and the observed values are aggregated. On the contrary, Z is negative and significant, indicating that there is a negative correlation, and the observations tend to be discretely distributed. $Z = 0$ means that the observations are randomly distributed.

Due to the continuous spatial distribution of $PM_{2.5}$, the concentration is very important for health impact assessment of $PM_{2.5}$ exposure and other purposes [18]. It has been reported by Global Burden of Disease that fine particulate matter ($PM_{2.5}$) is the seventh largest important death risk factor in the world and the fourth largest important death risk factor in China [19,20]. Therefore, to better reflect the spatio-temporal changes of $PM_{2.5}$ concentrations, the Global Moran's I was employed to identify spatial autocorrelation of $PM_{2.5}$ concentrations in Qingdao. Meanwhile, the analysis of spatial autocorrelation could help to analyze whether sparse ground monitoring sites can meet the requirements.

Spatial distribution estimation of $PM_{2.5}$ concentration. Conventional regression analysis can only provide "average" and "global" parameter estimates, rather than "local" parameter estimates, which vary over space in some spatial systems. Geographically weighted regression (GWR) is a relatively simple but effective new technique for exploring spatial nonstationarity. It allows different relationships to exist at different points in space. Therefore, local rather than global parameters can be estimated and spatial uncertainties examined. To solve the problem that the geographic weighting regression (GWR) model cannot overcome the influence of outliers in the small sample data, spatial distributions

of the average atmospheric pollutant concentrations for 2015 were simulated using ordinary kriging.

Data analysis was performed using the Data Processing System 9.5 (DPS). For the spatial autocorrelation and agglomeration analysis, the GeoDA1.4.0 and Arc GIS 10.2 were used. The results were displayed using ArcView 4.0. The relationships between the atmospheric pollutants concentration were explored by Spearman rank correlation coefficient.

RESULTS AND DISCUSSION

Temporal variation. Seasonal variation. Ordinary season divisions in China are as follows: spring refers to March to May, summer covers June to August, autumn refers to September to November, and winter covers December to February. As the four seasons in Qingdao are clearly classified, one year is divided according to ordinary season divisions to analyze seasonal variation across Qingdao and in diverse regions. Table 2 shows the descriptive statistics of seasonal average atmospheric pollutant concentration averaged over the 9 sites in Qingdao.

The average PM_{2.5} and PM₁₀ concentrations were 51.27 µg/m³ and 97.55 µg/m³, aggregated from 9 monitoring sites for the entire year 2015. These values exceed the Chinese National Ambient Air

Quality Standards (AAQS) Level-2 (35 µg/m³ for PM_{2.5} and 70 µg/m³ for PM₁₀). In addition, NO₂ and SO₂ were also analyzed; their concentrations are 33.34 µg/m³ and 27.52 µg/m³ and are thus below the AAQS Level-2 (40 µg/m³ for NO₂ and 60 µg/m³ for SO₂).

PM_{2.5} and PM₁₀ values in Qingdao showed distinct seasonal variations. In general, the atmospheric pollutant concentrations showed a pattern of “high in spring and winter, while low in summer and autumn”. Seasonal mean values of PM_{2.5} and PM₁₀ concentrations varied from 33.70 µg/m³ and 72.52 µg/m³ in summer to 81.37 µg/m³ and 132.91 µg/m³ in winter with the latter two being 2.41 and 1.83 times of the former two values. For NO₂ and SO₂, the seasonal average concentrations varied from 22.78 µg/m³ and 20.64 µg/m³ in summer to 44.61 µg/m³ and 44.64 µg/m³ in winter with the latter two being 1.96 and 2.16 times of the former two values.

In winter and spring, the atmospheric stratification is relatively stable, and the horizontal diffusion is weakened, so the atmospheric pollutant concentration is high. In summer, due to the influence of the subtropical high in the western Pacific, the atmospheric is diffused and the air pollutants are diluted. In addition, Qingdao is a coastal city located on the south Shandong peninsula facing the Yellow Sea on the southeast. Therefore, under the influence of the ocean current and the southeast monsoon climate, most parts of the city are exposed to an ocean

TABLE 2
Descriptive statistics of seasonal average atmospheric pollutants concentrations (unite, µg/m³).

		PM _{2.5}	PM ₁₀	NO ₂	SO ₂
Full year	Min	43.28	81.18	16.68	18.82
	Max	59.97	118.24	42.22	37.41
	Median	45.81	93.98	31.62	23.47
	Mean	51.27	97.55	33.34	27.52
	S.D.	5.54	13.20	7.81	6.31
Spring	Min	28.95	69.38	12.99	11.20
	Max	63.07	147.03	53.34	43.35
	Median	45.81	99.11	37.30	22.79
	Mean	46.32	101.77	33.39	23.02
	S.D.	5.44	12.24	12.07	7.16
Summer	Min	22.71	48.45	6.27	10.80
	Max	41.06	94.42	43.05	44.03
	Median	34.03	72.23	24.86	20.50
	Mean	33.70	72.52	22.78	20.64
	S.D.	3.91	11.68	8.31	6.04
Autumn	Min	20.17	46.84	3.81	10.57
	Max	69.14	119.12	50.57	38.28
	Median	45.49	80.47	29.30	21.18
	Mean	43.14	83.00	32.21	21.45
	S.D.	5.71	16.34	9.78	4.77
Winter	Min	60.19	99.16	15.51	26.96
	Max	126.73	192.67	65.19	71.35
	Median	76.38	130.00	46.78	41.05
	Mean	81.37	132.91	44.61	44.64
	S.D.	9.91	17.65	9.65	11.42

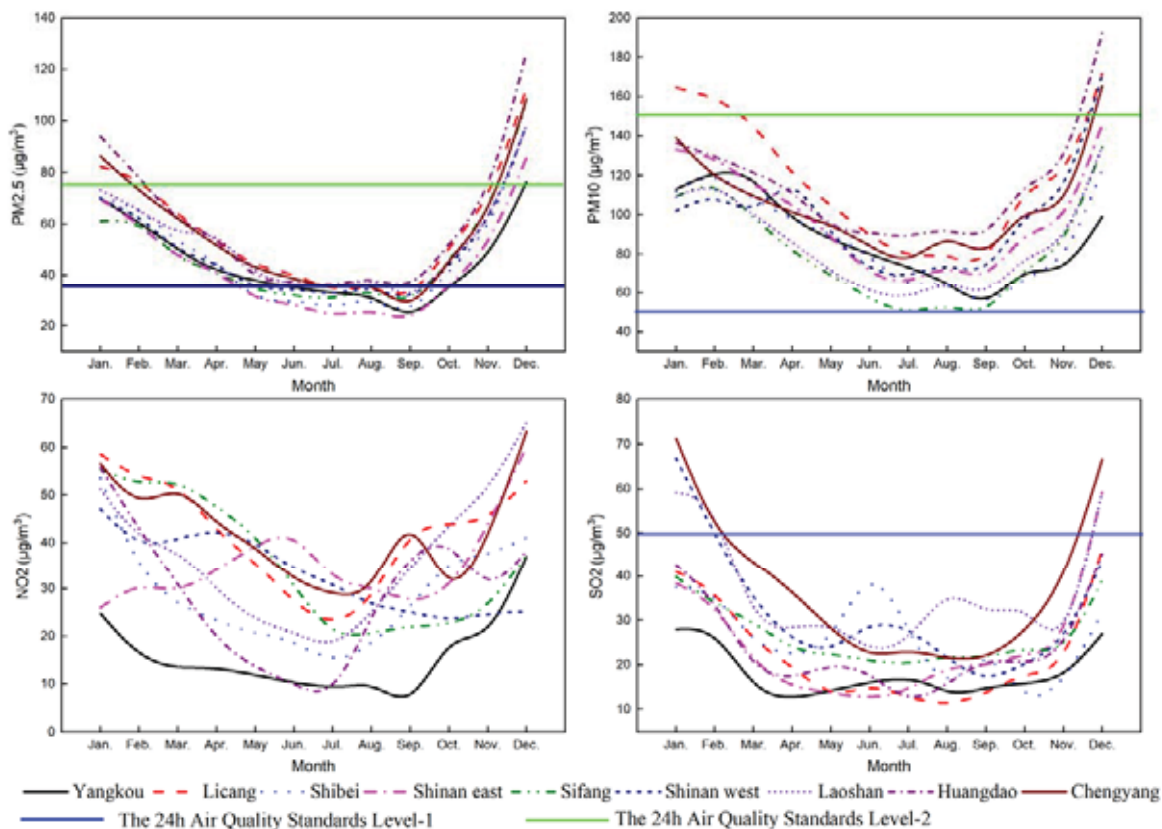


FIGURE 2
Monthly variations of atmospheric pollutants in 9 different regions of Qingdao.

climate with high humidity and abundant precipitation in summer [21]. So the atmospheric pollutants deposit and diffuse more easily in summer due to abundant rainfall and the strong air convection. In winter, however, the low temperature and insufficient photochemical promotion contribute a dominant downdraft, resulting in insufficient air diffusion and stronger emissions of primary particles [22]. At the same time, the coal combustion affects Qingdao in winter, leading to a seasonal high of the PM in Qingdao.

Monthly variation. The monitored monthly variations of four atmospheric pollutant concentrations at urban sites are presented in Figure 2. As can be seen, the four atmospheric pollutant concentrations showed a U-shaped pattern of “high in autumn and winter but low in spring and summer”, especially PM_{2.5}, PM₁₀ and SO₂. Furthermore, according to AAQS (GB 3095-2012), only a few sites exceeded the 24h Air Quality Standards Level-2 for atmospheric pollutants (75 µg/m³ for PM_{2.5}, 150 µg/m³ for PM₁₀, 80 µg/m³ for NO₂ and 50 µg/m³ for SO₂) in a few months. It's worth noting that NO₂ concentrations were below the 24h Air Quality Standards Level-1 (80 µg/m³).

As shown, the monthly averages were similar among the different regions. There were two important time inflections that should be followed in January and September. There was a downward

trend after January, which was basically stable, but a slightly decreasing trend from June to September and an apparently increasing trend after September. For PM_{2.5}, the lowest monthly average concentration was observed in September in Shinan east (20.17 µg/m³), reaching the air quality of the 24h Air Quality Standards Level-2 and the highest value was found in December in Huangdao (126.73 µg/m³). For PM₁₀, the lowest monthly average concentration was observed in September in Sifang (46.84 µg/m³), reaching the air quality of the 24h Air Quality Standards Level-1 and the highest value was found in December in Huangdao (126.73 µg/m³). For NO₂, the lowest monthly average concentration was observed in September in Yangkou (3.81 µg/m³), reaching the air quality of the 24h Air Quality Standards Level-1 and the highest value was found in December in Laoshan (65.19 µg/m³). For SO₂, the lowest monthly average concentration was observed in September in Shibe (10.57 µg/m³), reaching the air quality of the 24h Air Quality Standards Level-1 and the highest value was found in January in Chengyang (71.35 µg/m³).

Combined with Qingdao's monthly average PM_{2.5}/PM₁₀ in 2015, the ratio of each monitoring point reached a peak on the time scale from December to January, indicating that the “Heating” contributed significantly to PM_{2.5}, during the winter heating process. In addition to generating atmospheric particulate matter, a large amount of gaseous pollutants

such as SO_2 are emitted simultaneously, which contributes to the formation of secondary $\text{PM}_{2.5}$. For the NO_2/SO_2 ratio, the peaks and valleys of the monitoring points on the time scale are not exactly the same. For the entire city, the higher ratios are October, November and May. This period is during the tourist season, and the traffic volume has increased significantly, resulting in a large amount of nitrogen dioxide emissions; the lowest proportion is from January to February, which is the winter heating period. When coal is burnt a large amount of sulfur dioxide is produced, which reduces its proportion.

Brunekreef and Holgate (2002) [22] pointed out that meteorological effects could affect monthly variation, because climate changes can affect the accumulation, diffusion, sedimentation, and chemical conversion of pollutants in the atmosphere. Studies have shown that the differences in physical properties between surface water and land will cause local atmospheric movements, forming weather phenomena with significant daily changes such as sea and land breeze, lake and land breeze, and river breeze [24-27]. The existence of such local atmospheric movements will cause changes in wind direction, wind speed in the area, and affect the distribution of

air pollutant concentrations in the area. The urban area of Qingdao is in the typical East Asian monsoon climate zone. The weather and climate are influenced by the sea and land and have the transitional characteristics between continental and oceanic. In general, the concentration of pollutants at coastal monitoring sites is lower than that at inland monitoring sites.

Daily variations. The monitored daily variations of four atmospheric pollutant concentrations at urban sites are presented in Figure 3. In order to compare changes in short-term variation in different regions, this section has also used the Min-Max Normalization method to standardize 0-1 concentrations of four atmospheric pollutants in each region (Figure 3 a, b, c and d). As shown in the figures, the daily average of the four atmospheric pollutant concentrations showed cyclical and pulse-like changes in different urban sites of Qingdao in 2015. For $\text{PM}_{2.5}$, the daily minimum value was detected on August 09th at $4.77 \mu\text{g}/\text{m}^3$ in Shibei, while the maximum was detected on December 24th at $376.46 \mu\text{g}/\text{m}^3$ in Huangdao. For PM_{10} , the daily minimum value was observed on July 22th at $16.17 \mu\text{g}/\text{m}^3$ in Shinan west,

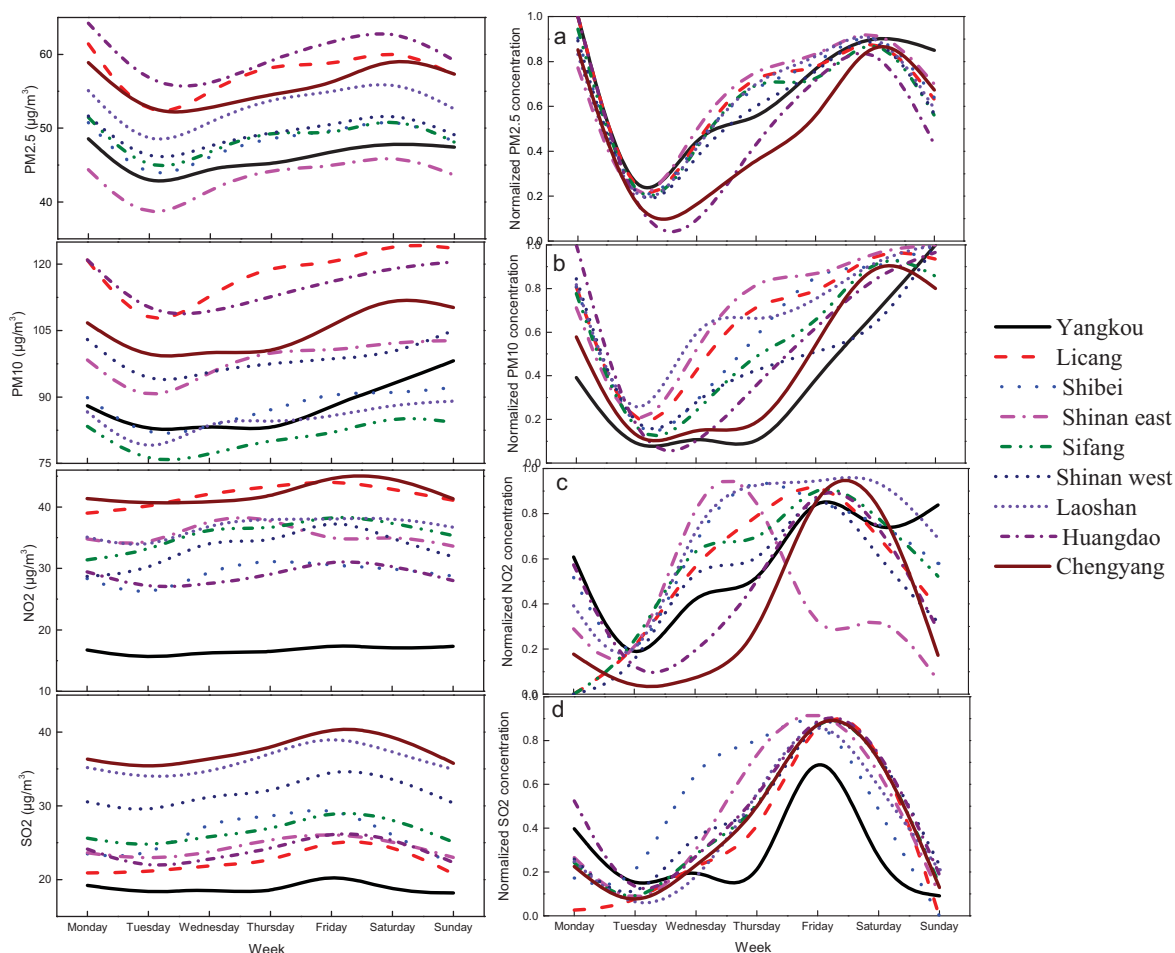


FIGURE 3
Daily variations of atmospheric pollutants in 9 different regions of Qingdao (a, b, c, d are standardized concentration for $\text{PM}_{2.5}$, PM_{10} , NO_2 and SO_2 in each region).

while the maximum value was also observed on December 24th at $478.58 \mu\text{g}/\text{m}^3$ in Huangdao. For NO_2 , the daily minimum value was found on June 22th at $1.65 \mu\text{g}/\text{m}^3$ in Huangdao and the maximum was found on February 11th at $242.11 \mu\text{g}/\text{m}^3$ in Sifang. For SO_2 , the daily minimum value was detected on June 23th at $1.38 \mu\text{g}/\text{m}^3$ in Huangdao, while the maximum value was detected on January 09th at $184.03 \mu\text{g}/\text{m}^3$ in Laoshan. However, based on the average of the four pollutant concentrations in 2015, there were more days of excellent quality in summer in Qingdao, followed by autumn, and spring, while the fewest days of good quality took place in winter. Combined with Qingdao urban average Air Quality Index (AQI), summer witnessed better air quality reaching a standard of 87, followed by autumn (77 days), spring (71 days). Winter was the worst season in terms of air quality reaching the standard of 51 days. The region with a slight pollution was Huangdao, obviously, where 20 heavily and 22 moderately polluted days were observed in 2015.

Diurnal variations. In order to compare the diurnal variations of different regions, the values of the four atmospheric pollutant concentrations were summarized by every hour and were 0-1 standardized using the Min-Max Normalization method for each region and the results are presented in Figure 4. Compared with monthly variations of four atmospheric

pollutant concentrations, diurnal variations of $\text{PM}_{2.5}$ and NO_2 shared great resemblance with bimodal pattern in different regions though the degree of change varies greatly. Generally, the extent of the variation was greater during daytime than during the night. Moreover, there was an apparently increasing trend after 5:00 am, occurring during the early morning rush hour. The peak in the morning appears around 9:00 am, which is due to enhanced anthropogenic activity during the rush hour. Then they have been falling, which may be due to the higher sea breeze frequency after 13:00 pm, which is conducive to reducing the concentration of atmospheric pollutants. For $\text{PM}_{2.5}$ and NO_2 , most monitoring sites showed second highest peaks around 19:00 to 21:00 pm, similar to those observed in Beijing and New York City [28,29]. For PM_{10} and SO_2 , most monitoring sites showed concentrations in a unimodal pattern with a significant peak between 5:00 and 10:00 pm.

Weekend effect. Intense human activities can affect weather and climate in many ways. The more typical is the weekend effect, defined as the average concentration for Saturday through Monday minus the average concentration for Wednesday through Friday [30,31]. Szulejko et al. (2018) [32] analyzed the hourly data of NO , NO_2 , O_3 and CO using the data acquired in the Yong-San district of Seoul, Korea from 2009 to 2013 and found the weekend effect.

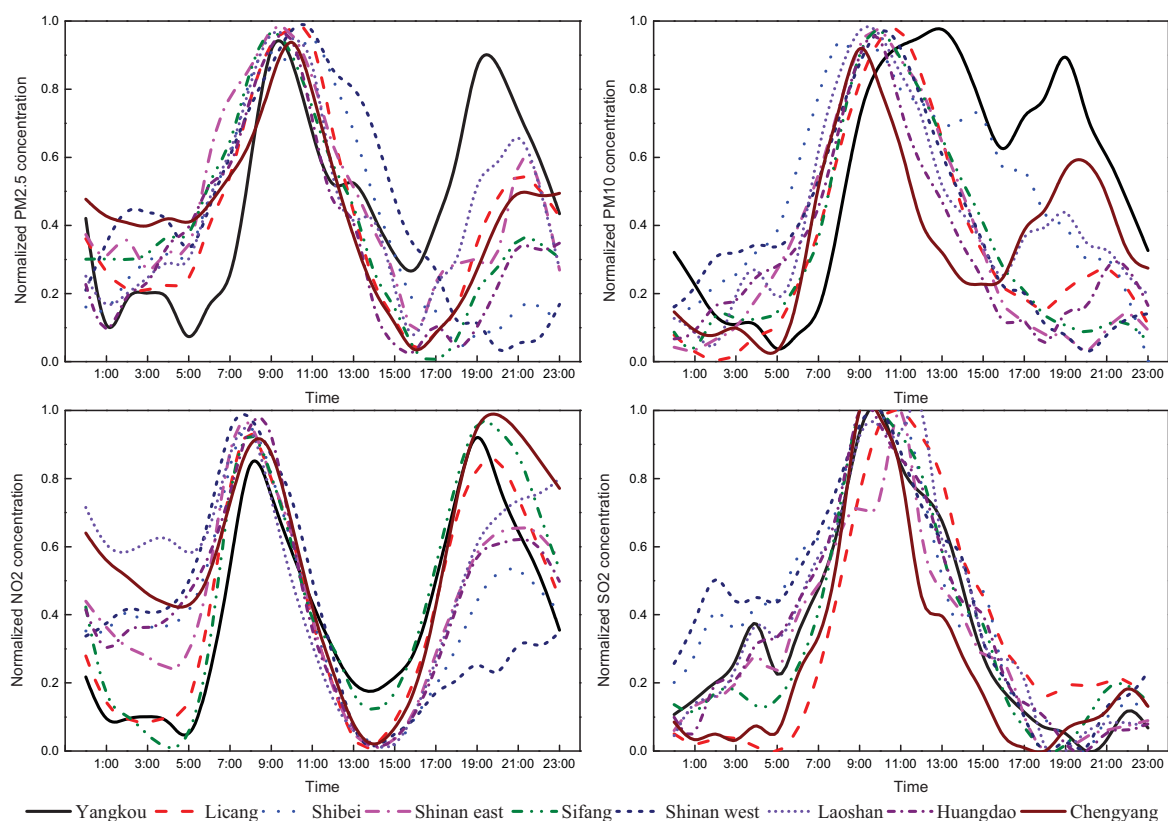


FIGURE 4
Diurnal variations of atmospheric pollutants in 9 different regions of Qingdao (Beijing time).

TABLE 3
Weekday and weekend differences in PM_{2.5}, PM₁₀, NO₂ and SO₂ concentrations at nine stations.

Stations	Weekday (µg/m ³)				Weekend(µg/m ³)				Weekend (%)			
	PM _{2.5}	PM ₁₀	NO ₂	SO ₂	PM _{2.5}	PM ₁₀	NO ₂	SO ₂	PM _{2.5}	PM ₁₀	NO ₂	SO ₂
Yangkou	45.6	84.63	16.81	19.3	48.0	93.02	16.9	18.5	5.25	9.91	0.92	-3.86
Licang	57.4	117.5	43.33	23.2	59.9	123.1	40.9	22.1	4.22	4.76	-5.43	-4.76
Shibei	48.2	87.21	30.61	28.9	50.2	90.93	29.0	23.8	4.03	4.27	-5.13	-
Shinan East	43.7	99.04	36.95	25.1	44.9	101.1	34.6	23.9	2.57	2.15	-6.22	-4.80
Sifang	48.5	79.60	37.35	27.3	50.5	84.53	34.7	26.3	3.99	6.20	-7.04	-3.66
Shinan West	49.2	97.37	35.87	32.8	51.0	102.5	31.7	31.6	3.76	5.32	-	-3.75
Laoshan	53.3	85.02	37.82	37.1	54.8	88.00	36.7	35.7	2.86	3.50	-2.98	-3.59
Huangdao	58.9	112.5	29.29	24.5	62.3	120.2	29.3	24.0	5.85	6.80	0.13	-1.95
Chengyang	54.3	102.0	42.47	38.3	58.8	110.0	42.5	37.2	8.18	7.89	0.28	-2.80

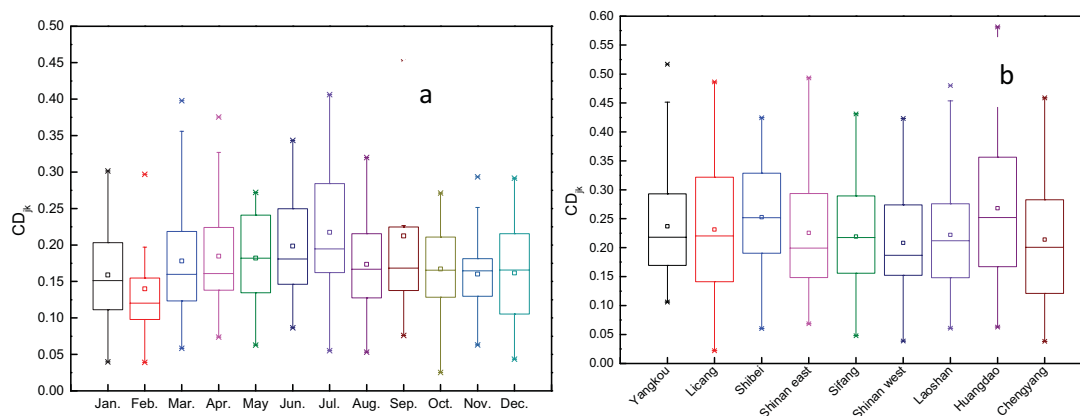


FIGURE 5

Coefficients of divergence for atmospheric pollutants (a, calculated across all urban sites pairs by month for the entire study (Jan.—Dec. 2015); b, calculated across all months pairs by different urban sites). Whisker-box plot as described previously.

From the weekly variation of PM_{2.5} and PM₁₀ (Figure 3 a, b), it can be seen that the PM_{2.5} and PM₁₀ concentrations at each site began to accumulate on Wednesday, reached their maximum on the weekend and rapidly decreased on Monday. However, for NO₂ and SO₂, the concentrations reached their maximum on weekdays and declined on weekends. The main reason is that these urban sites are located in urban areas where human activities are concentrated. The traffic flow on working days is large and frequent. On weekends, the traffic flow is reduced drastically and the emissions of automobile exhausts are declining. Combined with the definition of the above mentioned weekend effect, $WE = (C_{\text{weekend}} - C_{\text{weekday}}) / C_{\text{weekday}}$, this paper has calculated the weekend effect of atmospheric pollutants from 9 stations in Qingdao (Table 3). As shown in Table 3, the trends

for PM_{2.5}, PM₁₀, and SO₂, at these sites are consistent with visible weekend effects. Clearly, the concentration of SO₂ on weekends is higher than on working days, and the concentration of NO₂ on weekends is significantly reduced. It is speculated that the change of motor vehicle emissions on weekends and working days may be the main reason for the PM_{2.5} weekend effect.

Spatial variation. Coefficients of Divergence (CD) calculations for atmospheric pollutants. The coefficient of divergence can be used to measure the spread of the data points for two datasets. The monthly CD_{jk}s were calculated across all urban site pairs for the whole daily data of the study (Figure 5). The median CD_{jk} values ranged from 0.120 to 0.195

suggesting a homogeneous-to modestly heterogeneous distribution of atmospheric pollutants for the 9 sites. With the exception of February, May and July, the range between the 1st and 3rd quartiles was approximately 0.16. The median CD_{jk} values during the summer and winter seasons were 0.179 and 0.145, respectively. Furthermore, the average median CD_{jk} value of all urban sites was 0.165 during the whole year, proposing spatial homogeneity (Figure 5a). This suggests that exposures to the four atmospheric pollutants in the urban core sites may be well-estimated using a central monitoring site at least for 24-h-based concentrations. Moreover, as seen from Figure 5, the CD_{jk} values did not seem to change significantly in each season (average CD_{jk} values were 0.196 and 0.154 for summer and winter, respectively).

In order to compare the monthly variations within one site, the regional CD_{jks} were calculated across all months' pairs (Figure 5b). As shown in the Figure 5, the conversion range is quite large between different months, especially Licang ($CD_{min} = 0.022$, $CD_{max} = 0.486$) and Hunagdao ($CD_{min} = 0.062$, $CD_{max} = 0.581$). And the median CD_{jk} values greater than approximately 0.2 were indicative of a relatively heterogeneous temporal distribution, which can further explain Figure 2.

Spatial autocorrelation analysis. Moran's I scatter plots of the $PM_{2.5}$ concentrations in Qingdao using GeoDA are presented in Table 4. Results showed, that for $PM_{2.5}$ Moran's I was greater than 0 for hourly, annual, seasonal, and monthly values in 2015, except for April, August, September, October, and December, which were close to 0 indicating no significant spatial autocorrelation. The remaining months ranged from 0.114 to 0.423 and the hours ranged from 0.115 to 0.315, suggesting a significant but less strong positive spatial autocorrelation of $PM_{2.5}$ concentrations in Qingdao. The hourly and monthly average $Z(I)$ values were 1.61 and 1.53, which did not exceed 1.96, indicating a non-significant spatial correlation. Therefore, the pollution of Qingdao could be comprehensively reflected showing no significant spatial heterogeneity among the sites. This further verified the analysis of section 3.2.1. In addition, these results indicated that the $PM_{2.5}$ pollution source was not generated by individual sites, but there were many sources of pollution widely distributed throughout the urban area, or sources of pollution from outside the city. It can be concluded that air pollutants in urban areas are not produced at specific local sites.

TABLE 4
Spatial autocorrelation index of $PM_{2.5}$ concentrations in Qingdao in 2015.

Hourly	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h
Moran's I- $PM_{2.5}$	0.257	0.16	0.20	0.16	0.16	0.11	0.11	0.11	0.14	0.21	0.24	0.173
P	0.043	0.09	0.06	0.08	0.08	0.12	0.13	0.13	0.11	0.06	0.05	0.089
Z	1.896	1.40	1.64	1.48	1.46	1.23	1.21	1.20	1.33	1.71	1.82	1.482
Hourly	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Moran's I- $PM_{2.5}$	0.179	0.21	0.12	0.13	0.13	0.13	0.22	0.28	0.31	0.26	0.24	0.268
P	0.081	0.04	0.11	0.10	0.09	0.08	0.05	0.03	0.03	0.04	0.05	0.039
Z	1.531	1.79	1.29	1.40	1.41	1.43	1.86	2.11	2.22	1.91	1.84	1.959
Monthly	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Moran's I- $PM_{2.5}$	0.264	0.17	0.2	-	0.37	0.42	0.31	0.05	0.06	0.09	0.11	0.081
p	0.027	0.09	0.07	0.43	0.01	0.00	0.01	0.19	0.17	0.14	0.12	0.156
Z	2.143	1.52	1.64	0.08	2.48	2.76	2.44	0.89	0.92	1.12	1.21	1.109
Seasonal	Sprin	Sum	Au-	Win	An-							
Moran's I- $PM_{2.5}$	0.303	0.28	0.11	0.17	0.25							
P	0.044	0.03	0.13	0.08	0.03							
Z	2.120	2.08	1.22	1.61	1.89							

Spatial distribution of atmospheric pollutants concentrations in urban of Qingdao. Because monitoring sites are clustering in the urban areas of Qingdao, the four pollutant concentrations are able to reflect the distribution of pollutants in the urban areas of Qingdao. Spatial distribution of average atmospheric pollutant concentrations in 2015 were simulated using Ordinary Kriging. The research of Liao et al. (2006) [33] showed that their investigation of GIS approaches for estimating daily mean geocoded location-specific air pollutant concentrations supports the use of a spherical model to perform lognormal ordinary kriging on a national scale. Zongwei Ma et al., (2014) [34] successfully applied this approach for simulating the spatial distribution of PM_{2.5} using satellite remote sensing in China. And Lü and Tian (2007) [35] found that during the period 1990 to 2003, ambient air NO₂ concentrations were significantly enhanced in urban observatories as a result of anthropogenic influences.

In this study, PM_{2.5} was used as an example to simulate the concentration change in urban areas. The results of Ordinary Kriging are shown in urban areas covered by monitoring sites (Figure 6). As shown in the Figure 6, the concentrations of pollutants in inland areas are high, while they are lower near the seashore. Furthermore, it is obvious that most parts of urban Qingdao suffer from severe air pollutions in winter, especially the buffer of Huangdao, Chengyang and Licang.

Correlation between PM and gaseous pollutant. It has been found that the correlations between

PM and gaseous pollutants could indicate the source types of particulates: positive correlations indicate the same sources, whereas negative correlations imply different sources, or the gaseous pollutant(s) may be the precursors or oxides in the process of particulate nucleation and growth [36,37]. Partial correlation coefficients between particulates and gaseous pollutants are shown in Table 5. All coefficients shown have gone through the test of significance. SO₂ mainly derived from stationary pollution sources that originate mainly from heating emission sources and other industrial emission sources [38-40]. Unlike SO₂, NO_x has its main source in mobile pollution referring to on-road mobile sources, especially heavy duty diesel vehicle emissions [41,42]. CO could be seen as kind of mixed pollution source. Because it emits directly from incomplete combustion such as biomass and fossil fuel burning, or indirectly from the oxidation of methane and volatile organic compounds (VOCs) [43]. And O₃ is known as a product from the photochemistry reaction of NO_x, CO and VOCs [44,45].

As shown in Table 5, the correlations between PM and SO₂, NO₂ were positive, indicating that throughout the year, PM originated mainly from direct sources such as stationary and/or mobile emissions. PM_{2.5} and PM₁₀ were strong positively correlated with CO ($p < 0.01$) in all months, suggesting strong contributions of mixed combustion sources to fine and coarse particulates. PM_{2.5} was negatively correlated with O₃ in several months and throughout the year. Because O₃ plays an important role in the growth of ultrafine particulates, like photochemistry

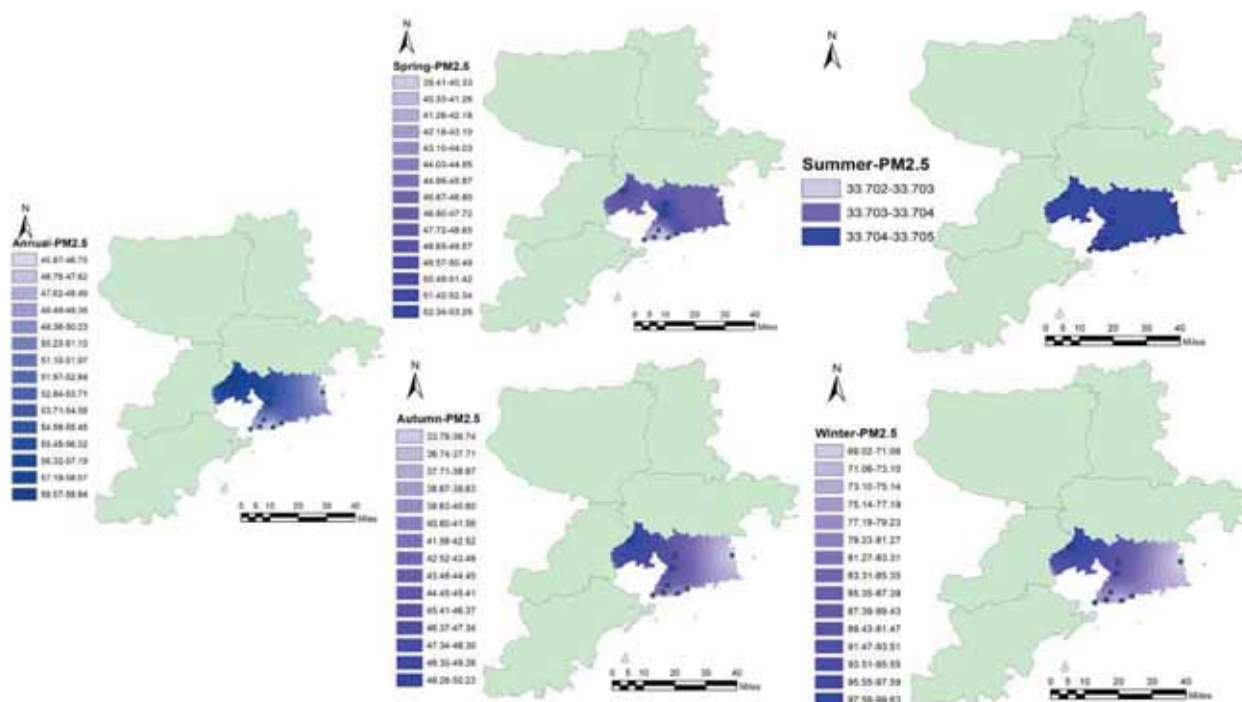


FIGURE 6
Spatial distribution of average PM_{2.5} concentration in annual, spring, summer and winter (2015) (unit: µg/m³)

TABLE 5
Correlations between PM and gaseous pollutants.

TIME	Index	SO ₂	NO ₂	CO	O ₃ -8h	Index	SO ₂	NO ₂	CO	O ₃ -8h
Jan.		0.580**	0.599**	0.949*	-		0.577*	0.601*	0.902*	-
				*	0.484**		*	*	*	0.505**
Feb		0.475**	0.552**	0.778*	-0.116		0.404*	0.363*	0.570*	-0.068
				*			*	*	*	
Mar		0.531**	0.499**	0.853*	0.225		0.452*	0.443*	0.843*	-0.005
				*			*	*	*	
Apr		0.484**	0.375**	0.755*	0.478**		0.352*	0.322*	0.256	0.529**
				*			*	*		
May		0.415**	0.372**	0.799*	0.619**		0.357*	0.418*	0.828*	0.704**
				*			*	*	*	
Jun		0.339**	0.346**	0.762*	0.716**		0.286*	0.385*	0.833*	0.784**
				*			*	*	*	
Jul	PM _{2.5}	0.229**	0.228**	0.765*	0.849**	PM ₁₀	0.113*	0.200*	0.794*	0.891**
				*			*	*	*	
Aug		0.257**	0.190**	0.822*	0.764**		0.187*	0.292*	0.874*	0.814**
				*			*	*	*	
Sep		0.431**	0.421**	0.848*	0.594**		0.334*	0.436*	0.831*	0.608**
				*			*	*	*	
Oct		0.267**	0.257**	0.875*	0.468**		0.330*	0.382*	0.833*	0.31
				*			*	*	*	
Nov		0.411**	0.502**	0.797*	-0.172		0.492*	0.549*	0.791*	-0.069
				*			*	*	*	
Dec		0.511**	0.590**	0.965*	-0.361*		0.569*	0.562*	0.979*	-0.427*
				*			*	*	*	
Annual		0.471**	0.474**	0.924*	-		0.425*	0.471*	0.801*	0.016
				*	0.211**		*	*	*	

Significant correlation at the *P < 0.05 and **P < 0.01 levels.

process [46]. Therefore it promotes the transformation of fine particles to large particles. PM₁₀ was positively correlated with O₃ in most months, indicating opposite sources of fine particulates, such as direct exhaust rather than homogeneous or heterogeneous reactions.

CONCLUSION

In general, the four atmospheric pollutant concentrations in Qingdao had an apparent U-shaped pattern of “high in autumn and winter but low in spring and summer”, and the double-peak or single-peak impulse-shaped daily variation. Their annual average concentrations in 2015 across Qingdao were 51.27 µg/m³ (PM_{2.5}), 97.55 µg/m³ (PM₁₀), 33.34 µg/m³ (NO₂) and 27.52 µg/m³ (SO₂), reaching the national Grade II standard, respectively.

The four atmospheric pollutant concentrations changed significantly in both long-term and short-term scales. Their pollution level varied greatly in different seasons. In winter, their concentrations were the highest, followed by those of autumn and spring, both reaching the national Grade II standard, whereas their concentrations in summer were the lowest, at the national Grade I standard, except PM₁₀.

Monthly variations were similar at different monitoring sites, showing U-shaped patterns. The monthly average PM_{2.5} concentration reached a minimum in September and a maximum in December, the same was true for PM₁₀. For NO₂ and SO₂, the lowest monthly average concentrations were observed in July and August, reaching the air quality of the 24h Air Quality Standards Level-1. The highest values were found in January.

However, daily variation shared the same bimodal or unimodal pattern regardless of seasonal change. Throughout the day, the four atmospheric pollutant concentrations were highest around 08:00-10:00 am and lowest around 14:00-18:00 pm. For PM_{2.5} and PM₁₀, the daily peak during the year happened on December 24th in Huangdao (376.46 µg/m³, 478.58 µg/m³), while the minimum value appeared on August 09th in Shibei (4.77 µg/m³ for PM_{2.5}) and July 22th in Shinan west (16.17 µg/m³ for PM₁₀). For NO₂ and SO₂, the daily minimum value was detected on June 22th and 23th in the year in Huangdao (1.65 µg/m³, 1.38 µg/m³), while the daily peak was detected on February 11th in Sifang (242.11 µg/m³ for NO₂) and January 09th in Laoshan (184.03 µg/m³ for SO₂). Air quality in Qingdao City was worse on weekends than on weekdays. PM_{2.5} and PM₁₀ concentrations were lower on weekdays than on weekends while SO₂ concentrations were

higher on weekdays than on weekends, indicating a "weekend effect".

The spatial correlation theory was used to study the spatial correlation of air pollutants at nine environmental monitoring points in urban areas of Qingdao. After calculating the Moran index, it was found that the spatial correlation of pollutants at each monitoring point was not strong, showing that air pollutants in urban areas are not produced in the specific local site. The spatial distribution by Ordinary Kriging displayed that most parts of urban Qingdao suffer from severe air pollutions in winter and the concentrations of pollutants in inland areas are higher than in seaside sites, especially the buffer of Huangdao, Chengyang and Licang.

ACKNOWLEDGEMENTS

Author Contributions: Data curation, Y.X.; Funding acquisition, X.Z. and Y.W.; Investigation, X.L.; Methodology, X.L.; Project administration, X.Z.; Software, X.L.; Supervision, X.L.; Visualization, Y.W.; Writing—original draft, X.Z. and Y.W.; Writing—review & editing, X.L.

Funding: The work is funded by National Natural Science Foundation of China (42101470), the Research Project of the Ministry of Science and Technology of China (2019YFC0507800), the Germany Federal Ministry of Transport and Digital Infrastructure (BMVI) as part of SmartAQnet (19F2003B), the Support Project of High-level Teachers in Beijing Municipal Universities in the Period of 13th Five - year Plan (CIT& TCD 201904037).

We would like to acknowledge Beijing Key Laboratory of Big Data Technology for Food Safety for providing a research grant to conduct this work. We express gratitude to the editors for the editing assistance. Lastly, we would like to thank the reviewers for their valuable comments and suggestions on our paper.

REFERENCES

- [1] Almeida, S. M., Pio, C. A., Freitas, M. C., Reis, M. A., and Trancoso, M. A. (2005). Source apportionment of fine and coarse particulate matter in a sub-urban area at the Western European Coast. *Atmospheric Environment*. 39(17), 3127-3138.
- [2] Wilson, W. E., and Suh, H. H. (1997). Fine particles and coarse particles: concentration relationships relevant to epidemiologic studies. *Journal of the Air & Waste Management Association*. 47(12), 1238-1249.
- [3] Pope III, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., and Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Jama*. 287(9), 1132-1141.
- [4] Perez, L., Medina-Ramón, M., Kunzli, N., Alastuey, A., Pey, J., Pérez, N., and Sunyer, J. (2009). Size fractionate particulate matter, vehicle traffic, and case-specific daily mortality in Barcelona, Spain. *Environmental Science & Technology*. 43(13), 4707-4714.
- [5] Zanobetti, A., and Schwartz, J. (2009). The effect of fine and coarse particulate air pollution on mortality: a national analysis. *Environmental Health Perspectives*. 117(6), 898-903.
- [6] WHO (2012) IARC: Diesel Engine Exhaust Carcinogenic, I.A.f.R.o.C. (IARC) (Ed.), Lyon, France.
- [7] Pakbin, P., Hudda, N., Cheung, K. L., Moore, K. F., and Sioutas, C. (2010). Spatial and temporal variability of coarse (PM_{10-2.5}) particulate matter concentrations in the Los Angeles area. *Aerosol Science and Technology*, 44(7), 514-525.
- [8] Wang, S., and Hao, J. (2012). Air quality management in China: Issues, challenges, and options. *Journal of Environmental Sciences*. 24(1), 2-13.
- [9] China National Environmental Monitoring Centre (CNEMC) (2015). National Air quality. <http://www.cnemc.cn/en/>. (Accessed January.2020).
- [10] Kim, C. S., Adachi, M., Okuyama, K., and Seinfeld, J. H. (2002). Effect of NO₂ on particle formation in SO₂/H₂O/air mixtures by ion-induced and homogeneous nucleation. *Aerosol Science & Technology*. 36(9), 941-952.
- [11] Holmes, N. S. (2007). A review of particle formation events and growth in the atmosphere in the various environments and discussion of mechanistic implications. *Atmospheric Environment*. 41(10), 2183-2201.
- [12] Kong, L. D., Zhao, X., Sun, Z. Y., Yang, Y. W., Fu, H. B., Zhang, S. C., and Chen, J. M. (2014). The effects of nitrate on the heterogeneous uptake of sulfur dioxide on hematite. *Atmospheric Chemistry and Physics*. 14(17), 9451-9467.
- [13] Wilson, J. G., Kingham, S., Pearce, J., and Sturman, A. P. (2005). A review of intraurban variations in particulate air pollution: Implications for epidemiological research. *Atmospheric Environment*. 39(34), 6444-6462.
- [14] Krudysz, M., Moore, K., Geller, M., Sioutas, C., and Froines, J. (2009). Intra-community spatial variability of particulate matter size distributions in Southern California/Los Angeles. *Atmospheric Chemistry and Physics*. 9(3), 1061-1075.

- [15] Moran, P. A. (1948). The interpretation of statistical maps. *Journal of the Royal Statistical Society. Series B (Methodological)*. 10(2), 243-251.
- [16] Geary, R. C. (1954). The contiguity ratio and statistical mapping. *The Incorporated Statistician*. 5(3), 115-146.
- [17] Xu, G., Jiao, L., Zhao, S., and Cheng, J. (2016). Spatial and temporal variability of PM 2.5 concentration in China. *Wuhan University Journal of Natural Sciences*. 21(4), 358-368.
- [18] Du, Y., and Li, T. (2016). Assessment of health-based economic costs linked to fine particulate (PM 2.5) pollution: a case study of haze during January 2013 in Beijing, China. *Air Quality, Atmosphere & Health*. 9(4), 439-445.
- [19] Cohen, A. J., Ross Anderson, H., Ostro, B., Pandey, K. D., Krzyzanowski, M., Künzli, N., ... and Smith, K. (2005). The global burden of disease due to outdoor air pollution. *Journal of Toxicology and Environmental Health, Part A*. 68(13-14), 1301-1307.
- [20] Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., and Aryee, M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*. 380(9859), 2224-2260.
- [21] Zhang, R., Wang, M., Sheng, L., Kanai, Y., and Ohta, A. (2004). Seasonal characterization of dust days, mass concentration and dry deposition of atmospheric aerosols over Qingdao, China. *China Particology*. 2(5), 196-199.
- [22] Chai, F., Gao, J., Chen, Z., Wang, S., Zhang, Y., Zhang, J., and Ren, C. (2014). Spatial and temporal variation of particulate matter and gaseous pollutants in 26 cities in China. *Journal of Environmental Sciences*. 26(1), 75-82.
- [23] Brunekreef, B., and Holgate, S. T. (2002). Air pollution and health. *The Lancet*. 360(9341), 1233-1242.
- [24] Avissar, R., and Pielke, R. A. (1989). A parameterization of heterogeneous land surfaces for atmospheric numerical models and its impact on regional meteorology. *Monthly Weather Review*. 117(10), 2113-2136.
- [25] Porson, A., Steyn, D. G., and Schayes, G. (2007). Sea-breeze scaling from numerical model simulations, Part I: Pure sea breezes. *Boundary-Layer Meteorology*. 122(1), 17-29.
- [26] Crosman, E. T., and Horel, J. D. (2010). Sea and lake breezes: A review of numerical studies. *Boundary-Layer Meteorology*. 137(1), 1-29.
- [27] Choi, S. Y., Lee, Y. H., Cho, C., and Kim, K. R. (2015). Analysis of local wind induced by surface heterogeneity and sloping terrain near Nakdong river. *Asia-Pacific Journal of Atmospheric Sciences*. 51(3), 249-257.
- [28] DeGaetano, A. T., and Doherty, O. M. (2004). Temporal, spatial and meteorological variations in hourly PM_{2.5} concentration extremes in New York City. *Atmospheric Environment*. 38(11), 1547-1558.
- [29] Zhao, X., Zhang, X., Xu, X., Xu, J., Meng, W., and Pu, W. (2009). Seasonal and diurnal variations of ambient PM_{2.5} concentration in urban and rural environments in Beijing. *Atmospheric Environment*. 43(18), 2893-2900.
- [30] Gong, D. Y., Guo, D., and Ho, C. H. (2006). Weekend effect in diurnal temperature range in China: Opposite signals between winter and summer. *Journal of Geophysical Research: Atmospheres*. 111(D18).
- [31] Xia, X., Eck, T. F., Holben, B. N., Phillippe, G., and Chen, H. (2008). Analysis of the weekly cycle of aerosol optical depth using AERONET and MODIS data. *Journal of Geophysical Research: Atmospheres*. 113(D14).
- [32] Szulejko, J. E., Adelodun, A. A., Kim, K. H., Seo, J. W., Vellingiri, K., Jeon, E. C., ... and Brown, R. J. (2018). Short and Long-Term Temporal Changes in Air Quality in a Seoul Urban Area: The Weekday/Sunday Effect. *Sustainability*. 10(4), 1248.
- [33] Liao, D., Pequet, D. J., Duan, Y., Whitsel, E. A., Dou, J., Smith, R. L., and Heiss, G. (2006). GIS approaches for the estimation of residential-level ambient PM concentrations. *Environmental Health Perspectives*. 114(9), 1374-1380.
- [34] Ma, Z., Hu, X., Huang, L., Bi, J., and Liu, Y. (2014). Estimating ground-level PM_{2.5} in China using satellite remote sensing. *Environmental Science & Technology*. 48(13), 7436-7444.
- [35] Lü, C., and Tian, H. (2007). Spatial and temporal patterns of nitrogen deposition in China: synthesis of observational data. *Journal of Geophysical Research: Atmospheres*. 112(D22).
- [36] Zhang, R., Khalizov, A., Wang, L., Hu, M., and Xu, W. (2011). Nucleation and growth of nanoparticles in the atmosphere. *Chemical Reviews*. 112(3), 1957-2011.
- [37] Sun, K., Tao, L., Miller, D. J., Pan, D., Golston, L. M., Zondlo, M. A., and Zhang, Y. (2017). Vehicle emissions as an important urban ammonia source in the United States and China. *Environmental Science & Technology*. 51(4), 2472-2481.
- [38] Huang, Q., Cheng, S., Perozzi, R. E., and Perozzi, E. F. (2012). Use of a MM5-CAMx-PSAT modeling system to study SO₂ source apportionment in the Beijing Metropolitan Region. *Environmental Modeling & Assessment*. 17(5), 527-538.

- [39] Lee, H. D., Yoo, J. W., Kang, M. K., Kang, J. S., Jung, J. H., and Oh, K. J. (2014). Evaluation of concentrations and source contribution of PM10 and SO2 emitted from industrial complexes in Ulsan, Korea: Interfacing of the WRF–CAL–PUFF modeling tools. *Atmospheric Pollution Research*. 5(4), 664-676.
- [40] Fioletov, V. E., McLinden, C., Krotkov, N., and Li, C. (2015). Lifetimes and emissions of SO2 from point sources estimated from OMI. *Geophysical Research Letters*. 42(6), 1969-1976.
- [41] Lu, Q., Zheng, J., Ye, S., Shen, X., Yuan, Z., and Yin, S. (2013). Emission trends and source characteristics of SO2, NOx, PM10 and VOCs in the Pearl River Delta region from 2000 to 2009. *Atmospheric Environment*. 76, 11-20.
- [42] Lu, X., Yao, T., Li, Y., Fung, J. C., and Lau, A. K. (2016). Source apportionment and health effect of NOx over the Pearl River Delta region in southern China. *Environmental Pollution*. 212, 135-146.
- [43] Buchholz, R. R., Paton-Walsh, C., Griffith, D. W., Kubistin, D., Caldow, C., Fisher, J. A., ... and Krummel, P. B. (2016). Source and meteorological influences on air quality (CO, CH4 & CO2) at a Southern Hemisphere urban site. *Atmospheric Environment*. 126, 274-289.
- [44] Miller, M. B., Fine, R., Pierce, A. M., and Gustin, M. S. (2015). Identifying sources of ozone to three rural locations in Nevada, USA, using ancillary gas pollutants, aerosol chemistry, and mercury. *Science of The Total Environment*. 530, 483-492.
- [45] Park, K., and Rhee, T. S. (2015). Source characterization of carbon monoxide and ozone over the Northwestern Pacific in summer 2012. *Atmospheric Environment*. 111, 151-160.
- [46] Li, L., Chen, Z. M., Zhang, Y. H., Zhu, T., Li, S., Li, H. J., and Xu, B. Y. (2007). Heterogeneous oxidation of sulfur dioxide by ozone on the surface of sodium chloride and its mixtures with other components. *Journal of Geophysical Research: Atmospheres*. 112(D18).

Received: 21.02.2021

Accepted: 19.03.2021

CORRESPONDING AUTHOR

Xiansheng Liu

Joint Mass Spectrometry Center,
Cooperation Group Comprehensive Molecular
Analytics,
Helmholtz Zentrum München,
German Research Center for Environmental Health,
Ingolstädter Landstr. 1,
85764 Neuherberg – Germany

e-mail: xiansheng.liu@helmholtz-muenchen.de