Methods and Approaches in Metropolitan Pollution Research

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By

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PREFACE

The study of pollution in environmental issues is a hot topic in the academic community today. This book summarizes some topics related to urban pollution based on decades of work practice with my students and myself, and uses them as an expression of passion and persistence towards environmental protection work. Based on field investigations and research on typical cases, this book dissects some environmental phenomena. Furthermore, it summarizes, judges, and discusses pollutant behavior and factors involved in the process of urban environmental pollution. The main aspects covered include:

    1. Research on urban soil environmental pollution

    2. Research on urban water environment pollution

    3. Research on urban atmospheric environment pollution

    4. Discussion of methods used in urban pollution research

    It should be noted that while the phenomena, laws, and principles described, discussed, and explained in this book may not all be innovative, they offer some fresh perspectives. I hope to engage with colleagues worldwide regarding these matters. Specifically, for the proposed methods, summarized laws, and discussed principles mentioned here, I encourage colleagues working in the fields of environmental science and engineering as well as scholars from other related disciplines to provide suggestions or revisions or even challenge them based on their own work experiences so that we can deepen our understanding of problems, and solve them more effectively. This is the purpose behind writing this book.

    I would like to express my appreciation for my colleagues around the world for their long-term dedication to these areas, and pay tribute to their unwavering efforts and achievements over time!

Zhang Hui
November 2023 Shanghai, China

ABOUT THE AUTHOR

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Dr. Hui Zhang has been working as a PI in the field of behavioral chemistry of environmental pollutants at Shanghai Jiao Tong University in China for a long time. In the research and teaching process of environmental science and engineering, his work interest mainly lies in the study of the behavior patterns of trace metals and persistent organic pollutants in natural and engineering systems (media). In recent years, significant work has been done in the study of regional pollution behavior and evolution of elements such as N, P, and As (migration and transformation mechanisms, evolution trends, isotope timing, and tracing in soil and water), assessment and remediation of soil pollution in farmland and construction sites, and research on eco-friendly control technologies and mechanisms for chemical fertilizer agriculture.

In decades of professional practice, Dr. Hui Zhang has contributed a large number of professional research results (monographs, papers) and provided high-quality academic services to multiple professional journals and conferences (AAAS and ACS etc. members, American Journal of Environmental Sciences etc. journals' associated editor or editorial members, and chair (co-chair) of international conferences).

His main professional contributions include: 1) Revealing the inherent laws among the conditional factors of metal ion release from natural solid particles (rocks, minerals) on the surface of the earth; 2) A research approach was proposed to distinguish the primary background content and post pollution superimposed content of trace metals in soil systems, and its theoretical basis and specific operational plan were explained; 3) A solution for identifying and evaluating the bioavailability of trace metals has been improved and proposed, and an operating procedure has been provided based on experimental work; 4) Based on research practices, proposed a

pollution classification approach in urban soil pollution research, elucidated its mechanism in the cause of formation, and established discrimination reference parameters.

These works have provided inspiration for the understanding of a series of bottleneck issues and exploration of methods in the field of environmental science and engineering research, and have had a significant impact on its research progress.

CHAPTER SUMMARY
(OBJECTIVE AND SCOPE WITH KEY CONCEPT AND TERMS FOR CHAPTERS)

Chapter 1. Introduction

Objective and Scope: In this chapter, a brief overview is given on the research contents of this book. It introduces the research target object and methodology of topics of metropolitan soil, water, and atmosphere environment with cases of urban pollution of two leading cities in economy growth and social development present in Yangtze valley, Shanghai, and Nanjing, China. The real case study content and approaches proposed for urban environmental pollution in this chapter are interpretatively narrated brief and to the point.

Key Concepts and Terms: Urban Soil, Water, and Atmosphere Environment; Metropolitan Pollution; Research Methodology.

Chapter 2. Soil Pollution in Nanjing

Objective and Scope: This chapter provides a comprehensive case research and discussion of urban soil pollution on the behaviors of the trace metals in the development of one of the top-ranking cities in economic development in southeastern China, Nanjing, by means of dissecting different environmental units according to the environmental function in soil of the complex metropolitan region. In these research cases, the studies are carried out on urban soil systems respectively for urban highway, heavy industry factory, and urban garbage dump.

In the case work of the Nanjing section of Nin----Hang highway (highway of Nanjing to Hangzhou), the distribution of the trace metals (V, Cr, Mn, Pb, Co, Ni, Cu, Zn, Sb, As, Cd) in soil affected by the highway are studied along with the distance of the pollution extend perpendicular to highway direction as well as the level of metals in the vehicle fuels and tires respectively. It is suggested in this work that the distribution of the metal speciation in highway soil can be used for roughly recognizing the highway pollution of the metals based on the chemical speciation characteristics of

the metal pollutant in soil caused by urban highway traffic.

In the case work of the Nanjing Alloy Factory, the distribution, the impact scope, the cause of formation, and factors of the trace metals (V, Cr, Mn, Co, Ni, Cu, Sb, Pb, Hg, As, Cd) in the soil are studied, and from this work the distribution of the pollution from production process, extend scope, and control factors is provided with a suggestion for dealing and preventing the pollution of the factory.

In the case work of the Nanjing Shuige Garbage Dump, distribution, behavior, and current situation of the pollution with the impact scope of the trace metals (V, Cr, Mn, Co, Ni, Cu, Sb, Pb, Hg, As, Cd) in garbage and soil affected by the garbage are studied, and from this work the potential of the metals released from the urban wastes from human daily life is estimated. This result can be used as a prediction of the ecological risks for soil and groundwater systems from the kind of garbage dump discussed in this work.

Key Concepts and Terms: Urban Soil Environment; Urban Highway, Heavy Industry Factory, and Garbage Dump; Trace Metals.

Chapter 3. Water Pollution in Shanghai

Objective and Scope: This chapter provides a case discussion of environmental pollution history on the behaviors and pollution of the trace metals and phosphorus in the development of the top-ranking city in economic development in China, Shanghai. In these cases, the studies are carried out on urban main water systems, urban rivers, and urban lakes respectively. These cases on the pollution of trace metals from the urban water systems are from the Suzhou Creek Shanghai, the Huangpu River Shanghai, and the Dianshan Lake Shanghai. The case on the pollution of phosphorus of the urban water system is from the Dianshan Lake, Shanghai.

In the Suzhou Creek case, the level and speciation of trace metals (Pb, Cd, As, Hg, Zn) in the creek water, suspended particles in water, and the sediment are analyzed and discussed for pollutant behavior and the pollution situation. Based on huge experimental data, the potential ecological risks of Zn, Hg, and Cd alongside obvious higher levels of Zn, Hg, and Cd in the water system of the Suzhou Creek, compared to similar systems in other nations, are pointed out.

In the case of the Huangpu River, Shanghai, the distribution, cause of formation, and their ecological function of the trace metals in the river water system are studied. The level of Cu, Pb, Hg, Cd, and Cr are discussed for their origin and causes. Based on the level change of metals in water systems, the achievement of environmental protection actions for the water

environment of Shanghai is shown from the reduced level of metals compared with the same systems inland and abroad.

In the case study of the Dianshan Lake Shanghai, the distribution, the cause of formation, and the evolution of the trace metals (Cu, Cd, Cr, Pb, Hg, As) and phosphorous in the water system are studied. The behavior and current situation of these above pollutants in the Dianshan Lake are discussed. The close coupling relationships, between the pollutants with the economic and population development in Shanghai, are revealed from the temporal and spatial variation of the pollutants in the sediment of the Dianshan Lake. An important fact offered by this work is that the extent and circle mechanism affected by the natural forces in the system of the lake may be a potential risk for the Dianshan Lake's ecological and economical contribution to Shanghai.

Key Concepts and Terms: Metropolitan Water Environment; The Huangpu River, Suzhou Creek, and Dianshan Lake, Shanghai; The Trace Metals and Phosphorus; Pollution Evolution and Social Development.

Chapter 4. Atmosphere Pollution in Nanjing

Objective and Scope: This chapter provides a comprehensive case research for environmental behaviors of trace metals and their pollution in the atmospheric environment of Nanjing, one of the top-ranking cities in economic development in southeastern China. In this study, it is by means of taking samples from different environmental units, which are divided according to the environmental function in the complex metropolis, that research is carried out systematically on the particle media that are the carrier of the pollutant in urban environments (Nanjing atmosphere).

In the study, the metals (Al, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ba, Sn, Mo, Be, Pb) in the media of atmosphere of Nanjing are studied. It studies respectively the distribution of metals in the media of each kind of urban unit (industry production zone, un-production zone with human daily life, and social action and business consumption zone) and features of the matter phase, morphology, chemical components, and the chemical speciation of metals in the particles from the atmosphere. Based on huge data on metal contents, speciation, and grain size of the particles in the atmosphere, this work discusses the accumulation feature of metals in particles in different size, the relationship of these issues, and factors in the cause of formation associated with the issues to the environment. From this, it is suggested that the function for the metal migration in long distance from the urban atmosphere to the soil and water system of the earth's surface may be an

important factor for the nutrient and pollution contribution of the metals. Another interesting question arising from this study is- what is the grain size partition limit for metal to accumulate?- as some phenomenon show no more accumulation of metals at finer particles than coarse particles, although the general accumulation trend for metals in atmosphere is seemingly to prefer finer particles.

Key Concepts and Terms : Urban Atmospheric Environment; The Environmental Units of Metropolises; Particle Media; Pollution of Trace Metals.

Chapter 5. The Proposal and Discussion on Research Methodology of Urban Pollution

Objective and Scope: In this chapter, the discussion on methodology in metropolitan environmental research is presented. Based on expounded discussion associated with case study the specific procedure and judgement parameter for the methods are put forward. One method suggested is distinguishing trace metals added by human activities from those that existed originally in the geological background in soil, and another is for classification for the urban pollution of trace metals caused by modern metropolis development.

   In the method for differentiating original concentration and added concentration of trace metals in polluted soil systems, the Hazen Probability Ruling Paper used in the method is introduced for figure edits of the samples and the requirement for using this Ruling Paper in the identification. Based on the case study, the method is tested and evaluated by comparing the real environmental meaning of the parameters from this method with the results from known data.

   In the method of classification for urban pollution of trace metals caused by metropolitan development, the judging basis and judgement parameters for the classification are brought up based on the pollutant behavior traces or characteristics in the media of urban environment associated with demonstration and interpretation of real cases.

Key Concepts and Terms: Methodology Research; The Original Geological Background and Added Content of Trace Metals; Identification for the Origin of Trace Metals in Polluted Environment; Classification of the Pollution in Metropolitan Development.

CHAPTER 1

INTRODUCTION

With the progress of human society to this day, environmental issues are occurring and developing rapidly along with the swift development of the social economy. Especially with the advancement of human technology and capabilities, the intensive utilization, impact, and transformation of nature has had a serious and profound impact on the human living environment. Some of these are unexpected and very worrying. From the perspective of environmental elements, the impact of human activities on the environment is mainly reflected in their impact on the atmosphere, soil, water, and organisms. Many of these issues have become hot topics in current scientific research. In the specific field of environmental science and engineering research, there has been a lot of work on the above-mentioned environmental elements, and they are currently developing in an endless trend. This is a comforting thing that is conducive to the sustainable development and progress of human society. In research, with the increasing breadth and complexity of problems, it is often necessary for people to make comprehensive judgments and propose methods and measures that help solve specific problems as reasonably as possible. The current reality is that there is too much research on a single problem in a certain aspect, and there is relatively little exploration of integrated research or solutions for comprehensive problems. In reality, problems are often complex and intertwined with multiple factors, intertwined in the same time and space. A typical manifestation in this regard is urban environmental issues (Larsen, Hoffmann and Maurer 2016, 928-933).

In today's highly industrial civilization and large-scale modern production, various forms of urban pollution are closely related to human activities, whether viewed from the situation of various functional units or media in the city. On the one hand, under the interference of human activities, the pollutant content in natural media exhibits abnormal distribution. On the other hand, the amount of pollutants that appear and form under the interference of human activities increases continuously in the medium with the increasing interference of production and life on natural media. In urban pollution research, whether it is river, lake, road, factory, garbage dump, or

the atmospheric environment, the stable recording medium - pollutants in the environment such as soil, sediment, or atmospheric particulate matter - tends to increase with increasing human interference (Livesley, McPherson, and Calfabietra 2016, 119-124). Especially the increasing trend, coupled with artificial chemicals and other substances related to production and daily life in time and space, as well as the spatial distribution characteristics of pollutant speciation, reveals the widespread problem of human activities leading to their superposition and dissemination into natural media from the perspective of material records (Baensch Baltruschat, Kocher, and Reifferscheid 2020, 733). Although the increase in the content of these pollutants has slowed down due to environmental protection measures in some areas, some pollutants still exhibit an increasing trend under certain circumstances (Yuan, Xue, and Han 2021, 217-226). These situations all indicate that people must take effective measures to control and prevent urban pollution based on in-depth understanding and objective evaluation. In addition, on the basis of in-depth understanding and practical response to specific urban environmental issues, the exploration of urban pollution research methods is also indispensable. For example, urban pollution classification is an important link in urban pollution research and control, which can provide clear and targeted work references for in-depth understanding and effective prevention and control of pollution. It can provide a basis for the complex and intricate urban pollution research work and play a crucial role in effective prevention and control of pollution, etc.

In the research content of this book, based on actual pollution cases in the development of typical cities in contemporary China, some pollution phenomena that appear in specific environmental elements in modern urban pollution research are proposed, as well as some understanding perspectives on the relationship between these phenomena and urban development. The problem of pollution classification in urban pollution research is explored, as well as the identification and differentiation of human and natural material sources in pollution assessment, from the perspective of pollution causes. This includes identifying, evaluating, and analyzing the causes of pollution issues in urban soil, water, and atmospheric environments, as well as predicting development trends and discussing research methods. This emphasizes the causal connection and factor analysis of the problem. It mainly covers the following four aspects: research on urban soil environment, research on urban water environment, research on urban atmospheric environment, and discussion on some methods in urban pollution research.

1. 1 Research on Urban Soil Environment

Taking Nanjing, one of the rapidly developing leading cities in the lower reaches of the Yangtze River in China, as a case study, a systematic study was conducted on the trace metal pollution caused by transportation, industry, and daily life in the soil environment.

The Nanjing region of China, as an important industrial and agricultural economic region, has always been the political and economic center of the middle and lower reaches of the Yangtze River with superior natural conditions. Nowadays, in the new situation of rapid development of national economic construction, it has developed at an unprecedented scale and speed, forming a light and heavy industry supporting system led by chemical engineering, machinery, automobile manufacturing, metallurgy, electricity, etc. Its absolute industrial output value ranks among the top among similar cities in the country. Correspondingly to the rapid development of industry, the transportation industry has developed rapidly, and the transportation networks of railways, highways, and waterways are becoming increasingly perfect and sound. The construction of transportation infrastructure has developed unprecedentedly in terms of capital investment and scale effectiveness. The development of production and transportation is bound to bring huge human impacts to the environment, especially heavy industrial factories and water and land transportation arteries, which are sources of trace metal pollution. The harm they bring to the environment is bound to intensify, and these are topics that require timely and in-depth research and response.

As a representative modern city, the terrain of Nanjing's urban area is open and undulating, with well-developed soil and vegetation. The functional division of the urban area is relatively clear, and the research on trace metal soil pollution caused by urban development has good representativeness. Due to Nanjing being one of the fastest growing cities in China since the 1980s, significant changes have occurred in the content and distribution of trace metals in its soil environmental media during urbanization, resulting in significant toxic effects of trace metal pollution. For example, certain characteristic diseases (such as lung cancer, respiratory diseases, and skin corrosive reactions) are significantly more common among some factory employees than normal conditions, and trees growing in soil contaminated with household waste wither and grow slowly with a tendency towards a single plant species, etc. The accumulation of soil pollution has reached a level that cannot be ignored. This study selected environmental units such as factories, highways, and garbage dumps in the Nanjing area to study the environmental behavior and pollution of trace

metal elements in their soil environment. Based on the specific characteristics of each environmental unit, specific work was carried out on the pollution situation in its soil. The location of the research area is shown in Fig. 1-1.

The above-mentioned situation of trace metal pollution in the Nanjing area of China is a hot topic in the current research field of environmental science and engineering, which focuses on the behavior patterns of trace metals in surface media caused by natural and human factors (including the superposition of original background content and later human factors). Conducting in-depth research on this topic has increasingly demonstrated its importance in sustainable socio-economic development (Trujillo Gonzalez and Torres Mora 2016, 636-642). Moreover, there is an urgent need to conduct comprehensive research on the pollution superposition characteristics (distribution, distribution, migration, and enrichment mechanisms) of urban trace metal pollution sources in the Nanjing area, which is a great opportunity and of great significance for the development, planning, and protection of human health of the entire city. This research work aims to understand the laws and mechanisms of urban trace metal pollution, and it has enlightening significance in the exploration of comprehensive pollution control methods and other aspects.

This study conducts specific research on the geochemical background of environmental media in the study area, the distribution (content distribution, form distribution) characteristics and migration patterns of trace metal elements, population lesions or environmental effects, regional socio-economic development history, and trace metal behavior processes, pollution status, causes, and mechanisms. On this basis, we will discuss and evaluate the pollution, effects, origins, and development and evolution trends of trace metals in the research area. Based on experimental data, we will summarize the general environmental behaviors of trace metals controlled by their chemical properties and geochemical habits.

In the study, the soil environment of highways (Nanjing section of the Nanjing to Hangzhou Highway), factories (Nanjing Ferroalloy Factory), and domestic waste disposal sites (Nanjing Shuige Waste Dump) were selected as specific research objects.

1. 1. 1 The study on trace metal pollution in the Nanjing section of the Ning (Nanjing)—Hang (Hangzhou) Highway

It focuses on studying and discussing the distribution characteristics of trace metal elements (V, Cr, Mn, Pb, Co, Ni, Cu, Zn, Sb, As, Cd) in the soil of this section affected by the highway. The content changes and speciation

characteristics along the vertical direction of the highway are analyzed and demonstrated in combination with the trace metal content in automotive fuel, tires, and traffic flow characteristics, the spatial impact and impact limits of road factors on trace metal pollution in soil systems, as well as the causal mechanism of the distribution characteristics of metal speciation in road pollution, were proposed, and their significance in pollution identification was discussed.

1. 1. 2 The research on trace metal pollution in Nanjing ferroalloy factory

It focuses on the pollution and chemical forms of trace metals (V, Cr, Mn, Pb, Co, Ni, Cu, Zn, Sb, As, Cd) in the factory area. Anatomical research was conducted on the influence range, genetic mechanism, and limiting factors of trace metal distribution characteristics in the factory area, and pollution was identified and evaluated. The possible impact range and factors of trace metal pollution in factories in space were proposed, and the metal speciation distribution pattern of trace metal pollution formed by factories with thermal processes as the main production process was revealed. Suggestions for the direction of controlling trace metal pollution in factories were given.

1. 1. 3 The study on trace metal pollution in Nanjing Shuige garbage dump

It focuses on the distribution characteristics, behavior patterns, and pollution status of trace metals (V, Cr, Mn, Pb, Co, Ni, Cu, Zn, Sb, As, Cd) in the garbage and soil system of the urban garbage dump. The potential parameter of trace metal release from urban household waste to the environment under natural factors was proposed, and the speciation characteristics of trace metal pollution from urban household waste and its potential ecological risks to soil and groundwater ecosystems were pointed out.

1. 2 Research on Urban Water Environment

Select the waters within Shanghai, China as the case study of urban water environment for this work.

Shanghai is one of the regions with the fastest socio-economic development in China and even the world today. The rapid development of the social economy is bound to bring serious, even overloaded, negative

impacts to the environment. The wide distribution of rivers, lakes, and the sea, and the interweaving of water systems are significant geographical features of Shanghai. And the water environment is a direct place to absorb surface pollutants, so the water pollution situation in Shanghai is a good representation of urban water pollution. Especially the current development scale, speed, industrial characteristics, and interference or impact on the natural environment of Shanghai all have typical representative significance in the environmental impact of modern urban development.

Shanghai is located at the mouth of the Yangtze River and the coast of the East China Sea, with a crisscrossing river network and scattered water bodies. It has the characteristics of having both a relatively vast land space and a well-developed water system of rivers and lakes. Due to Shanghai being a leading region in China's economic development, the basic attributes of a large population, high urbanization level, and significant industrial ratio determine the special and prominent characteristics of the pollution load it brings to the environment during development. Especially in the nearly forty years since China entered the era of rapid development, the evolution of material components in the natural environment caused by economic development in Shanghai has the characteristic of reflecting the typical environmental effects of human interference in natural systems such as water, soil, the atmosphere, etc. (Chen, Zhang, and Wang 2022, 841). This research focuses on the relationship between pollution evolution and human interference factors. Surface water bodies with wide distribution coverage and stable pollution records, including Shanghai Dianshan Lake, the Huangpu River, and Suzhou Creek, were selected as the main objects to study the trace metals and P in their water and sediment, as well as their behavior and distribution patterns in the medium. The location of the research area is shown in Fig. 1-2. The main content includes the following:

1. 2. 1 Study on Trace Metal Pollution in Shanghai Water Environment

The main and larger water bodies in Shanghai's land area include Dianshan Lake, the Huangpu River, and Suzhou Creek, as shown in Fig. 1-2. In addition, numerous small lakes and rivers are also developed. The research on trace metal pollution has selected Dianshan Lake, the Huangpu River, and the Suzhou Creek as the objects.

1. 2. 1. 1 The study on pollution of Dianshan Lake in Shanghai

It focuses on the environmental behavior and pollution status of trace metals (Cu, Cd, Cr, Pb, Hg, As) in the sediment of Dianshan Lake. Based on the analysis and discussion of their respective causes, the obvious spatiotemporal coupling relationship between the various pollutants mentioned above has been revealed, confirming that the main source of trace metals in Dianshan Lake is human production and living activities. The coupling relationship between nitrogen, phosphorus, and trace metals in the sediment of Dianshan Lake is an objective record of the impact of human activities on the natural environment. The abnormal input of these substances has interfered with the normal material exchange cycle between water, sediment, and even organisms in nature. Based on a large amount of experimental data and analysis and comparison of domestic and foreign data, the fragility and potential ecological risks of trace metals, P, and other pollutants cycling in the Dianshan Lake water system, which is an important water source in Shanghai, under changing natural conditions were pointed out. It was emphasized that its potential environmental hazards are very important and urgent environmental protection tasks that require strong measures should be taken.

1. 2. 1. 2 The research on pollution of the Huangpu River in Shanghai

It focuses on the distribution, causes, and evolution of pollutants in river water and sediment. The correlation between the changes in the content of Cu, Pb, Hg, Cd, and Cr in water systems and human life and production emissions was analyzed and demonstrated, and their causes and evolutionary trends were discussed. On the basis of experimental data and comparison with similar rivers in the world, the practical role of Shanghai's environmental protection measures in effectively controlling the trace metal content in the water quality changes of the Huangpu River was demonstrated, and the important impact of daily sewage discharge on the current water quality changes of the Huangpu River was pointed out.

1. 2. 1. 3 The pollution research of the Suzhou Creek in Shanghai

It focuses on the content and speciation of trace metals (Pb, Cd, As, Hg, Zn) in river water, suspended solids, and sediments. The behavior of trace metals in the Suzhou Creek system was discussed, and the pollution and evolution trends of trace metals in the Suzhou Creek were analyzed and evaluated. The causes and influencing factors of pollution were demonstrated.

Based on experimental data, potential hazards in the ecological risks of Zn, Hg, and Cd in the Suzhou Creek were pointed out, and a warning opinion was proposed that the content of trace metals Zn, Cu, and Hg in the Suzhou Creek system is significantly higher than that of urban rivers in developed countries both domestically and internationally, as well as data on the migration and accumulation behavior of trace metals in the Suzhou Creek system.

1. 2. 2 Study on phosphorus pollution in Shanghai water environment

The study of phosphorus polluted water environment takes Dianshan Lake in Shanghai as the object, and the location is as shown in Fig. 1-2.

Nowadays, under the increasing influence of human activities, phosphorus and its behavior in the water environment have become important environmental issues faced by humans. The phenomenon of eutrophication in water bodies, which is closely related to it, has emerged worldwide and is gradually increasing in evolutionary momentum. Some have already affected normal production and life in the region. Especially in the urban water environment, with the continuous improvement of people's living standards and content, the pollutants entering the urban water environment are rapidly increasing, especially the large and continuous addition of phosphorus and other nutrients, which has greatly accelerated the evolution process of the urban water environment from poor nutrition to rich nutrition. Research has shown that Lake Erie in North America completed the eutrophication process in just 25 years from 1950 to 1975 under the combined action of natural and human factors, which is equivalent to the natural historical evolution effect of the past 15,000 years (Ostrom, Ostrom and Henry 1998, 162-179). During a considerable period of time in the late 1980s in the middle and lower reaches of the Yangtze River in China, most lakes exhibited levels of moderate (or higher) eutrophication (Shu, Huang and Wu 1996, 193-200; Jin, Tu 1990, 10-14), and some lakes experienced National Environmental Protection (Bureau of China 2000; Liu 1990). The level of phosphorus content in water bodies is an important indicator of water environmental quality, and its content and evolution have always been highly valued. Dianshan Lake was once a water source in Shanghai, but it is still one of the main water sources in Shanghai. Its socio-economic and ecological significance in the entire development of Shanghai are very important. At present, with the acceleration of China's economic construction in recent decades, the pollutants discharged into Dianshan Lake are increasing with development, and the overall water quality is showing a

trend of deteriorating year by year. Therefore, the study of the evolution trend and influencing factors of its water quality is an important and urgent environmental issue.

The study of sediment has become one of the hot topics in the geochemical behavior of phosphorus, a nutrient element in lakes. Sediments are the destination of nutrients in river basins and play an important role in the entire ecological evolution process and geochemical cycling of lakes. After phosphorus in the water enters the sediment, it usually undergoes significant speciation transformation and re migration, accompanied by the mineralization of organic matter in the sediment and degradation. During the sedimentary burial process, the profile distribution characteristics of sediment phosphorus will be modified due to the influence of early diagenesis. The different speciation and contents of phosphorus elements in sediments have different effects on the phosphorus exchange ability at the sediment water interface, the phosphorus content level in overlying water, and the eutrophication of lakes (Sondergaard, Windolf, and Jeppesen 1996, 992-1002). At the same time, lake sediment is also a more stable carrier for recording the temporal and spatial evolution of phosphorus compared to water bodies. By studying the accumulation of phosphorus elements at different depths in sediment, we can understand and predict their evolution trends, providing scientific support for environmental protection decision-making.

This study analyzed and discussed the changes in total phosphorus and various forms of phosphorus content in the sediment of Dianshan Lake. We hope to understand the evolution law of the eutrophication factor phosphorus in Dianshan Lake through this work, explore the migration and transformation behavior characteristics of phosphorus elements in sediment of Dianshan Lake, reveal the impact of human activities on the phosphorus cycle in the lake during urban development, and the relationship between phosphorus input and urban water quality degradation, providing reference to the phenomenon of nutrient pollution in the urban water environment and corresponding research work, providing scientific support for predicting the trend of water quality changes, and promoting urban water environment protection and management planning.

1. 3 Research on Urban Atmospheric Environment

The metal pollution in the atmospheric environment of Nanjing, China was selected as the research object. The geographical location and sampling situation are shown in Fig. 1-3.

Urban air pollution is an environmental pollution problem closely related to soil pollution and water pollution. Based on the previous research content of this work, atmospheric pollution closely related to soil and water pollution is selected for research. Air pollution is not only constrained by the surface soil environment and water environment, but also has an impact on the environmental conditions of surface environmental elements. Especially urban air pollution, due to its complex and variable pollution sources, intensity, and significant spatiotemporal distribution uncertainty, has complex and diverse attributes on the surface environment and its effects. The comprehensive study of air pollution and soil pollution, due to their consistent spatiotemporal characteristics, makes it convenient to comprehensively grasp and judge the observation and understanding of problems, and is expected to draw more relevant research conclusions. It is conducive to understanding the connection and mutual influence between different environmental media pollution, and can enlighten a deeper understanding of the problem.

Due to the complexity of pollution sources, diverse types of pollutants, and the instantaneous and uncertain spatiotemporal distribution, research on urban air pollution has always been a headache in the field of environmental science and engineering (Diener and Mudu 2021, 796). The particles in the atmosphere have relatively stable characteristics in reflecting changes in their environmental quality compared to other phases. Trace metals, atmospheric particulate matter, is their main carrier. Therefore, studying trace metal pollution in the atmosphere and the situation of atmospheric particulate matter is an important reference factor, and also an important research direction in the atmospheric environment research of the environmental science community. In recent years, research in this field has deepened from the monitoring of physical indicators such as the total amount of particulate matter per unit time or volume of air, particle size changes, etc., to the chemical composition, its transformation, and influencing factors. This study, based on the division of urban environmental functional zones, focuses on the distribution and pollution of trace metal elements in the atmospheric environment, as well as the role and contribution of trace metal distribution and pollution in other surface media, and explores this from a geochemical perspective. In attempting to comprehensively evaluate the characteristics of urban atmospheric trace metal pollution through these works, exploring and revealing the relevant mechanisms and laws of modern urban atmospheric trace metal pollution is necessary.

As mentioned earlier, the urban development speed of Nanjing is fast, and the urban terrain is open with undulations. The wind direction pattern is obvious, and the soil vegetation is well developed in Nanjing. The

functional division of the urban area in Nanjing is clear. Due to these features of Nanjing, the research on the composition of atmospheric particulate matter caused by urban development has good representativeness in Nanjing. In the study, the distribution characteristics of metal elements (Al, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ba, and Pb) in urban atmospheric particulate matter in different functional units were mainly studied and discussed. On the basis of the research on the phase, morphology, composition, and metal speciation of particles, the composition and structural characteristics of the emission sources of urban productive zoning (concentrated distribution area of large industrial enterprises), non-productive daily activity zoning (government agencies, cultural and educational departments, residential areas, etc.), and urban marketplace type zoning (leisure, entertainment, shopping, and other large businesses, consumer service institutions, small commercial stalls) are summarized. Combining speciation analysis data and metal content characteristics of different particle sizes, the aggregation patterns, genetic relationships, and influencing factors of trace metals in atmospheric particulate matter were analyzed and demonstrated. The fact that trace metal elements mainly aggregate in fine particles and major metal elements mainly aggregate in coarser particles has been revealed. Based on the study of urban soil pollution, the relevant parameters of the contribution of urban atmospheric particulate matter to trace metal pollution and remote impacts in the ground environment are proposed, and their environmental significance is pointed out. A possible particle size boundary, which requires further in-depth research, for the enrichment of trace metal elements in urban atmospheric particulate matter, was discovered.

The samples for this study include total dust and air-borne dust. The air-borne dust here refers to the particles of particle size 10μm -100μm (10μm < the particle diameter <100μm, atmospheric dust fall) in the atmosphere, which can directly settle to the surface of the earth through gravity in the atmosphere under normal circumstances. These particles are the most directly related material forms to the surface material components in the atmosphere corresponding to the spatial location of the atmosphere. The characteristics of pollutants in air-borne dust (atmospheric dust fall) have important indicative significance for surface material sources and are also a reflection of surface material composition in the atmosphere. The total dust refers to particles with a diameter less than 10μm (the particle diameter <100μm) in the atmosphere. These particles are atmospheric particles that cannot directly settle to the surface under normal weather conditions due to the action of gravity. The following work has been mainly carried out on these two media:

1. 3. 1 Research on the phase and morphology of particulate matter

By using methods such as electron probe, scanning electron microscopy, and X-ray phase analysis, morphology and phase analysis were conducted on two types of particulate matter, namely total dust and air-borne dust. The phase characteristics of particulate matter can provide useful information for determining the source of particulate matter, and infer its possible source from the indicative significance of phase and composition for its source. The morphology characteristics of particles have indicative significance for their migration process. A comprehensive analysis of the phase and composition of atmospheric particulate matter, combined with the morphological characteristics of particulate matter, is conducted to analyze and demonstrate the source and approximate process of atmospheric particulate matter in the atmosphere, supporting the judgment of the causes of urban air pollution.

1. 3. 2 Research on the content and speciation of trace metals in particulate matter

The ICP-AES analysis method was used to analyze the total and speciation content of trace metals in two types of atmospheric particulate matter mentioned above. The content and chemical speciation of trace metals in atmospheric particulate matter are key parameters for atmospheric trace metal pollution. By analyzing the changes in trace metal content and morphological characteristics in atmospheric particulate matter at different time and space, we can determine the causes of atmospheric trace metal pollution and understand its contribution to urban air pollution.

1. 3. 3 Comparative study on characteristics of different seasons and special weather conditions

Comparative study of atmospheric particulate matter under different seasons and special weather conditions. Analyzing and comparing from several aspects such as phase, morphology, chemical composition, and chemical speciation, through this systematic comparison, summarize the changes in atmospheric particulate matter under these different conditions, and infer the role and contribution of climate conditions to urban air pollution.

On the basis of the above work, the possible correlation between trace metals in the atmosphere and trace metals in surface soil and water bodies

was discussed, their causes were analyzed and demonstrated, and their mutual influence and role in sustainable development of human society were explored.

1. 4. Discussion on Some Methods in Urban Pollution Research

The research on urban pollution research methods mainly focuses on the differentiation method between the original background content of pollutants in environmental media and the superimposed content of later human activities, as well as the classification method of urban pollution. Based on actual cases researched, the problems were explored and discussed.

Cities are highly concentrated human settlements on Earth, and are also important sources of pollutants released into the environment due to human factors. They are one of the main sources of pollution spread in the human environment (Zhang 2019, 345-358). Especially in today's highly industrial civilization and large-scale modern production, the diffusion scale and intensity of various urban pollution sources are increasing day by day, resulting in increasingly complex and serious environmental pollution problems (Xue, Wang, and Zhang 2022, 826). A large amount of research has shown that these issues are universal (Larsen, Hoffmann, and Maurer 2016, 928-933). Even due to environmental protection efforts, some pollutants may experience a slowdown or cessation of pollution growth locally. Due to the special nature of the minimum limit law of environmental issues, as long as there is still pollution from pollutants in the environment, the ultimate evolutionary result of such a trend is to worsen environmental quality, thereby affecting human health and sustainable social development (Liang, Wang, and Li 2019, 237). Therefore, the accumulation trend of pollutant content in urban environmental media displayed by material records preserved in environmental media is a serious implicit ecological environment proposition that people face, and it is a warning to the evolution of natural media material composition (Muller, Osterlund, and Viklander 2020, 709). Stopping or responding to this trend is a challenge facing humanity and a heavy task (Qian, Chakraborty, and Leung 2022, 819-860).

Roughly speaking, the current exploration and research on environmental issues in this field roughly includes two aspects of work. On the one hand, it is aimed at studying the amount of pollutants in natural systems, mainly environmental factors, and their behavioral effects. On the other hand, it focuses on the study of the amount, behavior, and effects of pollutants in biological organisms. Actually, these are two aspects of the same problem.

The first aspect of work is to address where pollutants come from, where they go, and how they go into the inorganic environment. The work level also mostly focuses on the behavioral effects of pollutants in environmental media before and during their entry into organisms, which belongs to the category of environmental science that focuses on research. The second aspect of work is to address the biochemical behavior and magnitude effects of pollutants in organisms. The work mainly focuses on the interaction between organisms and pollutants, as well as the actual effects of these effects in life processes, which belongs to the scope of biomedical research. Due to the fact that these two aspects of work have the same research object - pollution and pollutants, sometimes intertwined naturally or unnaturally - it is difficult to distinguish them. In the research and exploration of these issues, overlapping situations are frequent or fundamental. However, overall, it is still hierarchical.

The prerequisite for studying these issues and achieving effective solutions is to clarify which or how much of the pollutants naturally exist in the medium, which or how much are superimposed into the medium due to human activities in the later stage, and the impact of human activities on the process of pollutant behavior. This involves the distinction between the natural background content and artificially superimposed content of pollutants in the medium, as well as the classification problem in pollution research. This issue is most prominent and typical in trace metal pollution. This research selects the situation of trace metals in urban soil media in Nanjing, China as the research object. Through practical cases, it explores the differentiation method between the original background content and later human activities' superimposed content of pollutants in environmental media, as well as the urban pollution classification method, and discusses its theoretical basis and application effects. The content includes:

1. 4. 1 Study on the differentiation between the original background content and later artificial superimposed content of pollutants in environmental media

Regarding the distinction between the original background content and the later superimposed content of pollutants in environmental media, trace metal pollution was chosen as the starting point, and trace metal pollution in soil media in Nanjing was taken as a specific case. We specially selected the Nanjing factory environmental unit with known soil background content and its parent material to study the method of distinguishing background content and artificially superimposed content, in order to explore the determination method of trace metal background content in environmental research.

Because the specific object of the problem is substances such as trace metals, regardless of levels of the problem, it is inevitably influenced or constrained by the natural properties of trace metals themselves. Firstly, the background content of trace metals objectively exists in natural media, but people do not have a comprehensive understanding and mastery of the background data of trace metals in various media. In regions where background content research has been conducted, it can be considered that the background content of trace metals is known. However, due to the complex genetic properties of trace metal background content itself, these data materials, which are often macroscopic in nature, may not be accurate enough to solve specific environmental problems. Secondly, in areas where pollution has already occurred or has been discovered, it is often difficult to obtain trace metal background content data and make accurate judgments about the causes of pollution, especially in modern cities, through simple sampling, testing, and other work. Furthermore, the specific process of the formation of trace metal pollution in cities is complex and diverse, with diverse time, space, and causes, including the interaction, interference, and superposition of natural factors, human factors, time, space, components, and processes. When facing problems, it often makes people feel confused and unable to start.

The above problems may exist to varying degrees in all cases of trace metal pollution, but they are particularly prominent in urban trace metal pollution and are more difficult to solve. But these are fundamental issues that will inevitably be encountered and need to be addressed in the study of trace metal pollution in cities. From the perspective of pollutant characteristic attributes, one of the main characteristics that distinguish trace metals from other pollutants is their background content in environmental systems (atmosphere, water, soil, biological systems) without exception. The fundamental reason for this phenomenon is that trace metals themselves are the basic material components that make up the Earth's crust. Therefore, in the process of natural material circulation, trace metal elements will naturally migrate, combine, and distribute according to their respective chemical and geochemical habits, as well as the physical and chemical conditions of the environmental system they are in. This is a manifestation of geochemical laws, and this manifestation often has strong natural inertia. Correspondingly to the above situation, the reason why the content range of trace metal elements in environmental systems or units exceeds the allowable limits for normal and healthy development and growth of organisms is no more than the combination of background content and human factors.

The main type of human trace metal pollution is urban trace metal pollution. This fundamental attribute determines the high intensity and

sustainability of trace metal pollution in cities, the complexity of pollution sources, and the importance of the problem. In fact, it is a situation where human activity factors are superimposed on urban environmental media with native background content. This research work starts with specific cases and explores the definition and differentiation of geochemical primary background and pollutant content in soil media through the investigation of specific problems, and explains and discusses the solutions and ideas. A method for distinguishing the primary background content of trace metals from the later artificially superimposed content in soil pollution research, the Hazen probability grid paper method, was proposed. The specific requirements and sample data processing steps of this method were emphasized. The environmental significance of the relevant parameters obtained using this method was studied, verified, and analyzed through practical application research.

1. 4. 2 Research on urban pollution classification

The classification of trace metal pollution in cities plays an important role in the research and prevention of urban pollution. Distinguishing pollutants from different causes or sources in the medium and classifying complex and diverse urban pollution can make the complex and disorderly urban pollution problems methodized, which is not only conducive to a deeper understanding of the problem, but also conducive to making the complex, disorderly, and intertwined urban pollution problems concrete and convenient for practical research and governance operations. It can provide targeted work references for in-depth understanding and effective prevention and control of pollution, enabling a basic judgment and grasp of intricate problems, in order to objectively understand problems and effectively prevent and control pollution in practical work. This study takes urban trace metal pollution as the starting point, and analyzes and discusses the causes and processes of pollution, pollutant combination characteristics, and quantity changes. Based on the actual situation of pollution phenomena, it analyzes and judges them, and classifies them accordingly.

In urban trace metal pollution, various and complex factors play their respective roles in their processes, and trace metals themselves will inevitably leave traces of action in the medium, reflecting the behavioral characteristics of trace metal elements. These traces and features are closely related to the entire process and influencing factors. Therefore, these traces and features are the external manifestations of the essential content related to the formation process and factors of trace metal pollution. From the revelation of these traces and features, it is possible to find ways to distinguish