



# Causes and Legislative Countermeasures of Rural Soil Heavy Metal Pollution in Hunan Province, China

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## ABSTRACT

In recent years, urban and rural industrial parks have been constructed and widely operated. With the development of intensive agricultural production and accelerated urbanization progress, heavy metals enter rural soil through sewage irrigation, sedimentation of atmospheric soot, and landfill treatment. Heavy metals are not easily degraded and transferred by microorganisms. Restoration and renovation of heavy metal-contaminated rural soil have been difficult. Controlling measures of governing soil heavy metal pollution were proposed to analyse causes of rural soil heavy metal pollution in Hunan Province, China. Based on time series data in Hunan during 2000-2014, this study combined features and analysed causes of rural soil heavy metal pollution in Hunan. The main causes of rural soil heavy metal pollution in Hunan are long-term use of sewage irrigation, stacking of solid waste, large discharge of industrial and traffic waste gases, and great application of chemical fertilizers and pesticides. Rural soil heavy metal pollution in Hunan can be effectively controlled by (1) establishing legislative system for soil heavy metal pollution control, (2) perfecting legal institutions of soil heavy metal pollution, (3) completing supporting law-making stipulations for heavy metal pollution control, (4) optimizing accountability mechanism, and (5) innovating environmental supervisory mechanism of heavy metal pollution control. This study is of positive significance to further and sufficiently recognize causes of rural soil heavy metal pollution. This work is also important in establishing and perfecting laws and regulation system for rural soil environment and resource protection in Hunan Province.

## INTRODUCTION

Rural land is the main source of people's material life and the developmental root of rural economy as well as fundamental requirement of social harmony. Heavy metal belong to one kind of resources. Large quantities of heavy metal elements are contained in industrial raw materials in modern chemical engineering, metallurgy, mining, and other fields. Cr, Mo, and metalloid arsenic are toxic heavy metal elements. Soil heavy metal pollutants first gather at the root parts of crops and then enter and accumulate in human body through the food chain. Finally, soil heavy metal pollutants damage functions of human organs greatly endangering human health. Governance of soil pollution is difficult. Soil pollution even exceeds the scope that soil can bear. Moreover, circulation of pollution and "enrichment" are manifested in the entire ecological system process.

Hunan Province is a large agricultural province in middle China. Basic farmland is the most important natural resource of agriculture and basic element of agroecological system in this province. Protecting basic farmland is a requirement for promoting sustainable agricultural development in Hunan. However, for various reasons, farmlands in some areas in Hunan still suffer all kinds of pollution. Heavy

metal pollution is the most seriously polluting basis causing the largest harm in farmlands of China. Once the farmland suffers heavy metal pollution, it poses extreme threats to agroecological environment, agricultural product quality, and human health if coping measures are not adopted. Basic farmland heavy metal pollution is under severe situation. Soil heavy metal pollution needs urgent countermeasures especially legislative countermeasures. Thus, studying rural soil heavy metal pollution situation and legislative countermeasures can attract attention from all sectors of society to control heavy metal pollution. This issue is also a social focus to facilitate smooth realization of maximum utilization of heavy metal resources and minimization of environmental pollution. As a result, the whole society will be incorporated into circulating state of sustainable utilization of environmental resources. Sustainable utilization of heavy metal resources can be guaranteed only by using legal means to control effectively rural soil heavy metal pollution in Hunan Province.

## EARLIER STUDIES

Considering the current situation of soil heavy metal pollution and legislative governance measures, domestic and foreign scholars conducted several studies on this topic.

Korre combined traditional statistical method, namely, principal component analysis and geostatistics, to conduct evaluation of heavy metal pollution status in soil in Greece waste mine lot (Korre 1999). Ersoy utilized geostatistical method to conduct spatial analysis of soil heavy metal on England pasture and proposed suggestions for controlling heavy metal pollution risk and restoration of polluted soil in this area (Ersoy et al. 2004). Imperato studied contents of heavy metals (e.g., Cu, Cd and Pb) and their morphologies (Imperato et al. 2003). McGrath conducted statistical analysis and risk evaluation of Pb content in soil and provided very useful reference information for decision makers in soil environmental quality evaluation (McGrath et al. 2004). Considering background value of soil in Beijing as basis, Chen evaluated soil heavy metal environment quality in metropolitan park in Beijing (Chen et al. 2008). Zhang used auxiliary data, namely, environmental variable data, to improve prediction accuracy of heavy metal contents at county level (Zhang et al. 2008). Wei used geological accumulation index method to evaluate heavy metal pollution status in Chinese cities, urban road dusts, and farmland soils (Wei & Yang 2010). Delgado analysed space variation of heavy metals at estuary of Guadiana River and indicated that pollution in this area was related to acid wastewater discharge from mine (Delgado et al. 2010). Guariglia evaluated the American Act of Liability Exemption for Environmental Pollution of Small Enterprises and Revitalization of Brownfield (Guariglia et al. 2002). Fakoyade analysed soil heavy metal pollution problems in Guinea and Nigeria (Fakoyade & Onianwa 2002). Ye analysed legislative governance measures of America for soil heavy metal pollution and proposed suggestions for China's land heavy metal pollution (Ye et al. 2007). Qin analysed how Germany regulated soil heavy metal pollution by law and analysed specific legislative countermeasures adopted by Germany to govern soil heavy metal pollution (Qin 2007). Liu believed that soil heavy metal pollution can be effectively reduced through implementation of the Code of Primary Product Quality Security and establishment of agricultural standardized production (Liu et al. 2006). As seen from existing research literature, the main causes of rural soil heavy metal pollution were pollution discharge in chemical industry, inappropriate utilization of pesticides and fertilizers in agricultural production, pollution discharge of transportation tools, and so on. Meanwhile, relevant legislative countermeasures were not complete. Management of relevant polluting enterprises was not in place. Moreover, production operators lacked self-consciousness of public environment protection. Thus, analysing rural soil heavy metal pollution situation and legislative governance countermeasures in Hunan exerts regulating effect of legal means, prevents

and governs rural soil heavy metal pollution problems, enhances people's awareness of environmental safety, and accelerates legal construction of soil environmental safety in Hunan during the process of developing and utilizing heavy metal resources.

## FEATURES OF RURAL SOIL HEAVY METAL POLLUTION IN HUNAN

Hunan is a large traditional agricultural province. However, this province is experiencing rural soil heavy metal pollution because of industrial development. Heavy metal pollution is a negative product during rural economic development process. This pollution is obviously different from other pollutants with its own following features:

**Enrichment pollution:** Different from biodegradability of other organic compound pollutants, after soil is polluted by heavy metals, they will gradually accumulate in polluted soil. Heavy metal elements are absorbed by crops from soil. Then, toxic properties of heavy metals will be amplified through the effect of food chain. Finally, enrichment by thousand and even 10 thousand times will occur inside high living bodies. Thus, high-toxicity compounds will be transformed. These compounds will change with the changing surroundings. Heavy metal pollutants accumulated in soil can not only generate underground water pollution by virtue of rainfall, leaching or permeation but also generate entrainment effect together with fuel gas and dust in air. However, heavy metal pollutants in any environment will be possibly restored to soil through natural sedimentation or permeation and then, circulation proceeds. Those polluted environments can form new pollution sources. Thus, secondary heavy metal pollution occurs.

**Surface-aggregation pollution:** Most heavy metal pollutants in soil leave in and accumulate in soil plough layer. Under normal conditions, only a few migrate to low layer of soil. The main reason is because large quantities of organic colloids, inorganic colloids, and organic-inorganic composite colloids are contained in soil. These colloids can generate adsorption, replacement, and biological effect on heavy metals. In case heavy metals enter soil, these colloids can be dissolved in soil solution and react with organic and inorganic matters in the soil. These pollutants are stored in soil minerals after soil colloids are rapidly adsorbed and fixed on the surface of heavy metals. Then, these pollutants experience sedimentation with other compounds in soil. Heavy metals exhibit strong adsorption and chelating abilities in soil colloids. These characteristics form a limitation on transfer ability of heavy metals in soil. Consequently, heavy metal pollutants will aggregate in soil plough layer in large quantities.

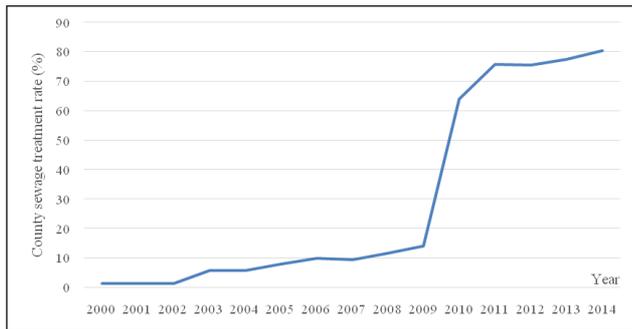


Fig. 1: Sewage disposal rate in Hunan counties.

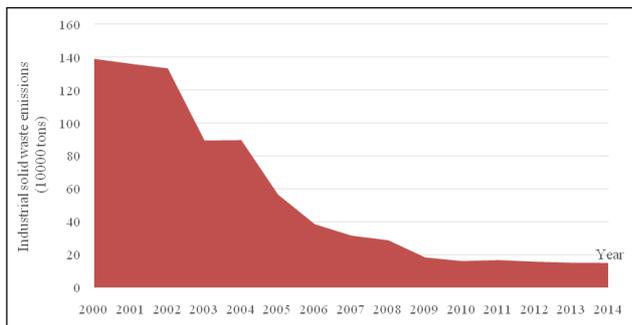


Fig. 2: Discharge quantity of industrial solid wastes in Hunan Province.

**Disguised pollution:** Soil heavy metal pollution is colourless and flavourless. This pollution cannot be sensed by human sensing organs. Moreover, this pollution will possibly appear after plants enter the food chain and experience reaction through accumulation to a certain degree. Atmospheric sedimentation, water flow, and other ways are the main approaches for heavy metal elements in soil to migrate and transform. Human beings absorb polluted agricultural products and water and even polluted air. All these factors can cause heavy metal accumulation. In human body, when concentration of accumulated heavy metal elements develops to a certain degree, reaction of one human organ or change of one function will possibly be generated. At the same time, heavy metal pollution in soil can be reflected in one form.

**Irreversible pollution:** For heavy metal pollutants, soil exerts two effects-medium for migration and transformation and final end. After heavy metal pollution is formed, heavy metals will be probably and continuously accumulated in the environment. When heavy metals exceed pollutant limiting value, which can be contained by soil, soil heavy metal pollution naturally happens. To degrade heavy metal pollution is difficult when heavy metal pollutants in soil are continuously accumulated. Then, restoring radically polluted soil will be complicated. Meanwhile, restoration of

polluted soil is not feasible without large quantities of capital and techniques as guarantee. This restoration work may take a very long time. Moreover, target of complete restoration can hardly be realized despite unremitting efforts.

### CAUSES OF RURAL SOIL HEAVY METAL POLLUTION IN HUNAN PROVINCE

Heavy metal pollutants in Hunan farmlands enter farmland soil mainly through four approaches, namely, irrigation sewage, atmospheric sedimentation, stacking and permeation of solid wastes, and through fertilizers and pesticides. Causes resulting in heavy metal pollution of basic farmland in Hunan are mainly long-term sewage irrigation, unreasonable disposition of solid wastes, discharge of industrial waste gases, and traffic waste gas and utilization of fertilizers and pesticides in large quantities.

**Long-term utilization of sewage irrigation results in heavy metal pollution of farmlands:** Long-term utilization of sewage irrigation is the main reason of heavy metal pollution in basic farmlands in Hunan. This factor is especially the chief culprit of Cd pollution. Rural sewage disposal technology in Hunan is low. Sewage disposal rate is at low level as shown in Fig. 1. Sewage from some enterprises in towns and villages are even directly discharged without any disposition. Consequently, irrigation water quality seriously exceeds standard. A number of heavy metals, such as Cd, As, Hg, Zn, Cu, and Pb, are mixed in farmlands resulting in increased load of soil heavy metals. In addition, long-term irrigation will easily give rise to soil heavy metal pollution. Sewage irrigation will acidize soil. Sewage irrigation also activates Cd, Cr, Pb, and other heavy metals in soil. Thereafter, these heavy metals can be easily absorbed by plants. Some pesticides, herbicides, and rust removers used in agricultural production contain As, Pb, and other heavy metal elements. Extensive use of pesticides, herbicides, and rust removers causes soil heavy metal pollution. Utilization of phosphate fertilizers in agricultural production especially utilization of imported phosphate fertilizers containing high content of Cd is one of the main approaches for Cd to enter soil environment. This process is also one of the main causes for soil Cd pollution in farmlands. As solid wastes including industrial waste residues, municipal wastes, and sludge are rich in nutrient substances needed by plants and organic matters needed by soil, they are applied to soil through farm-oriented compost. Heavy metals also enter soil environment through this method. Thus, soil heavy metal exceeds standard.

**Stacking of solid wastes causes heavy metal pollution in farmlands:** Solid wastes giving rise to soil heavy metal pollution in farmlands mainly include industrial solid

wastes, such as slag, electronic disassembling waste, sludge, and agricultural solid wastes (e.g., agricultural films and excrements of livestock). Industrial solid wastes are the main source resulting in heavy metal pollution in farmlands as shown in Fig. 2. For example, slag contains large quantities of heavy metal pollutants. These pollutants are easily dissolved under rainfall effect, thereby permeating in soil. This phenomenon directly results in soil heavy metal pollution centering on stacking place, especially in areas with lower terrain than stacking place. Then, safety of underground water is seriously endangered. With fast development of modern agriculture, more and more agricultural solid wastes are rapidly increasing. A considerable number of these wastes directly retain in soil giving rise to soil pollution. Meanwhile, agricultural films contain large quantities of heat stabilizers rich in heavy metals, such as Pb and Cd. These films are hard to recycle once they are used. Many of them are left in soil and hard to be degraded. Heavy metal industries that surround villages exert great influence on environmental destruction. These industries are mainly lead-storage battery manufacturing, electronic parts and component manufacturing, chemical raw materials and chemical manufacturing, metal-surface treatment and heat-treatment processing, heavy non-ferrous metal metallurgy, and other industries that are involved in heavy metal pollution. At present, these enterprises lag in technology. These establishments lack specialized facilities and techniques to govern pollution. Thus, heavy metal pollutants generated after their operations are discharged outward in forms of “the three wastes”. As a result, Pb and Zn contents in farmland soil surrounding these enterprises stay high.

**Industrial and traffic waste gases give rise to heavy metal pollution in farmlands:** Waste gas floating dust discharged by factories especially metal smelting factories is one of the main causes of soil heavy metal pollution in farmlands. Discharge quantity of industrial waste gases in Hunan is shown in Fig. 3. Waste gas floating dust generally contains large quantities of heavy metal elements, such as Cd, Pb, Zn, and Cu. The scope of influence can reach up to 10 km in prevailing wind direction and scope of severity is approximately 1100 m. Wastewater and waste residues illegally discharged by heavy metal pollution enterprises that surround villages pose serious threat to the environment. Pb and Cd pollution in farmlands at nearby two sides of arterial traffic is an important factor resulting in heavy metal pollution of foods, such as vegetables. Pb and Cd mainly come from automobile tail gas. Automobiles run mainly by relying on burning gasoline (diesel), whereas gasoline is a kind of explosive and combustible liquid. To prevent explosion, people always add a kind of antidetonant-lead tetraethyl in gasoline. Pb content in farmland soil and Pb content in crops at two

sides of arterial traffic are obviously higher than those in areas that are far from two sides of arterial traffic.

**Utilization of fertilizers and pesticides in large quantities results in heavy metal pollution in farmlands:** Application of fertilizers and pesticides in large quantities can result in obvious accumulation of soil heavy metal elements as shown in Fig. 4. Zn, Ni, Cu, Pb, Cd, Cr, and Hg in main commercial organic fertilizers in Hunan exceed standards. Inorganic pesticides containing As and Pb were used in agricultural production in large quantities. Large quantities of heavy metals are unavoidably left in soil. Organic pesticides can be divided into organophosphorus, organochlorine, organonitrogen, organic-sulphur, organic-metal, and organic pesticides containing nitril, amide, nitrile, s-triazine, and other perssads. However, the one used in large quantities is organochlorine pesticide. These compounds are of stable properties. These pesticides take several years and even dozens of years for them to be degraded in soil. Meanwhile, some organic metal pesticides, such as organomercurial fungicide, are of stable properties. Residual toxicity of degradation product is serious greatly affecting rural soil.

## LEGISLATIVE COUNTERMEASURES FOR SOIL HEAVY METAL POLLUTION

**Constructing legislative system of soil heavy metal pollution control:** Establishment of a legal system for soil heavy metal pollution control in Hunan Province not only needs formulation of specialized soil pollution control law and detailed rules and regulations of soil heavy metal pollution control but also cooperation of relevant periphery laws. Problem of soil heavy metal pollution control can be legislatively and effectively solved only when specialized legislation and periphery legislation compensate, coordinate, and integrate each other from two aspects, namely, governance of polluted soil and control of pollution source and pollutants. Control of soil heavy metal pollution should persist in comprehensive legislation and specialized legislation, equal attention of urban and rural governance, and implementation of uniform legislation for rural and urban lands to save cost. However, the causes of “agricultural type” soil pollution and those of “urban type” soil pollution are different; thus, they should be distinguished in specific countermeasures and legal stipulations. A systematic and specialized Soil Pollution Control Law coping with soil pollution should be formulated. System framework in legal field for soil pollution control should also be established. Based on this framework, specific control system for heavy metal pollution can be set up to form legal system for soil heavy metal pollution control combining guidance of legal principles and operable specific rules. Legislative orientation

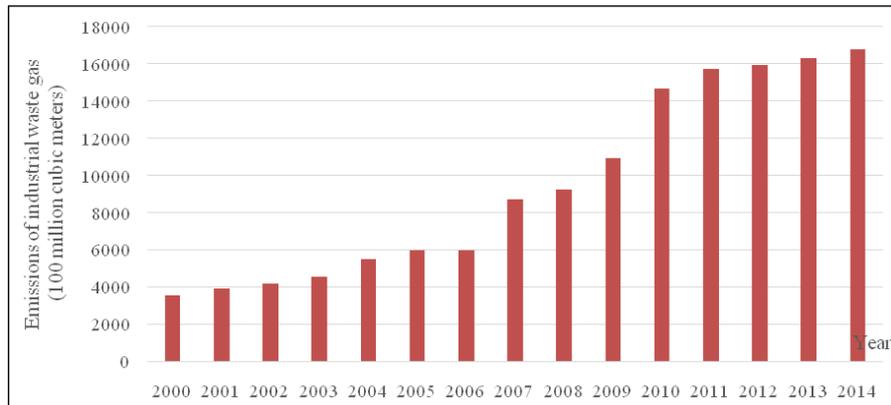


Fig. 3: Discharge quantity of industrial waste gases in Hunan Province.

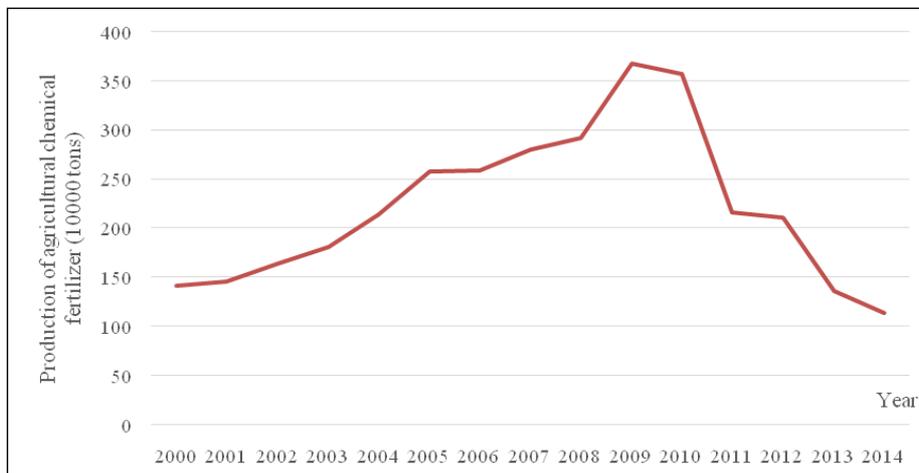


Fig. 4: Yield of agricultural fertilizers in Hunan Province.

of “centre on governance and combine preventive control” should be set because sources of soil pollution are diverse. These pollution sources include sedimentation of polluted air entering soil surface layer causing soil pollution, sewage polluting soil through industrial discharge and agricultural irrigation, inappropriate treatment, and disposal of solid wastes resulting in permeation of heavy metal elements into soil causing soil heavy metal pollution.

**Establishing perfect legal system for preventive control of soil heavy metal pollution:** Legislative innovation for preventive control of soil heavy metal pollution not only needs to establish legal system for preventive control of soil heavy metal pollution but also needs to establish perfect legal system for preventive control of soil heavy metal pollution. Soil pollution survey aims at determining soil pollution status, designating governance area of soil pollution, and adopting effective countermeasures or technical

means to eliminate soil pollution by hazardous substances. Soil survey system should be determined, including initiation of soil survey, subject of duty of soil survey, establishment of soil survey institution, collection of soil survey funds, and degree of soil survey. Soil heavy metal pollution monitoring system and soil survey system are different in approaches but equally satisfactory in results. This method also aims at figuring out pollution degree, distribution, and category of soil heavy metal pollution to take measures in restoring and governing polluted soil. Uniform monitoring specifications and monitoring technology standard should be formulated. Second, regular inquiry and routine monitoring method should be adopted to meter timely real-time data of soil heavy metal pollution in various areas. To establish soil heavy metal pollution monitoring network and pollution data monitoring database in Hunan is necessary. Conventional environmental monitoring station and heavy

metal pollution source monitoring centre should be set up in key planned areas. Regional environment and conventional health monitoring should also be implemented.

**Perfecting supporting legislative stipulations for preventive control of soil heavy metal pollution:** Standard system of preventive control of soil heavy metal pollution is an important constituent of legal system for preventive control of soil heavy metal pollution. This system is also an important basis for implementation of relevant laws and regulations. However, present industrial discharge standard in Hunan is far from meeting environmental protection standard. Moreover, this standard cannot cope up with the demand for environmental health. We should perfect heavy metal standard of soil pollution and test method, test technology, heavy metal discharge standard, and test standard in water body and air. Issuance and technical study of relevant technical standards and technical specifications of soil heavy metal pollution should also be accelerated. Perfecting stipulations on preventive control of agricultural land soil pollution is good to guarantee effectiveness and operability of legislation of soil heavy metal pollution control. According to laws of soil heavy metal pollution control, we should formulate and perfect legislation and relevant technical standards and specifications of soil pollution control in agricultural lands. Discharge of heavy metal pollutants in living environments mainly comes from household garbage and electronic trash generated by cosmetics, electronic products, leather and chemicals, tobacco, traditional Chinese medicinal materials, edible mushrooms, and other products. Thus, we should actively carry out issuance of limit and technical standards of heavy metals in relevant products, such as cosmetics, electronic products, tobacco, traditional Chinese medicinal materials, and edible mushrooms, as well as studies on detection method and detection techniques. Moreover, we should provide considerable attention to supervisory implementation of classification and recycle of rural household garbage, technological innovation, improvement of public awareness, etc.

**Optimizing accountability mechanism for soil heavy metal pollution:** Besides fund guarantee, governance of soil heavy metal pollution mainly lies in determination of liability subject and selection of imputation method. Thus, optimization of accountability mechanism for soil heavy metal pollution is obviously significant. We should establish relatively perfect accountability mechanism for soil heavy metal pollution and then establish and optimize complete accountability mechanism with reference to those from developed countries. Liability subject determination of soil heavy metal pollution becomes an intractable and unavoidable problem because of difficulty in governing soil heavy metal pollution and high cost of restoration. Thus, generating and dis-

charging of hazardous wastes should be the principal liability subjects for soil heavy metal pollution. Considering the particularity of soil heavy metal pollution, pollution doers should bear final responsibility. Other responsible people can also claim compensation from pollution doers after bearing their own liabilities. Moreover, time difference exists between polluting behaviour and consequences because soil pollution lasts for a long term and is of elusive feature. We should lengthen prescribed period for litigation in compensation for damage caused by soil heavy metal pollution. Fund system should also be established for soil heavy metal pollution governance and environmental pollution liability insurance system of heavy metal enterprises to realize socialization of civil liabilities for pollution governance.

**Innovating environmental supervisory mechanism for soil heavy metal pollution control:** We should innovate environmental supervisory mechanism and implement environmental supervisory mechanism of "centre administrative organization for environmental protection conducts macrocoordination, whereas local governments implement microcontrol." The Ministry of Environmental Protection should make macrocoordination of environmental protection and governance, and be responsible for formulation of policies and laws, issuance of environmental standards and information, execution of environmental monitoring, etc. Chief executives at provincial, municipal, and county levels should bear comprehensive responsibilities for pollution control tasks. Chief executives should also be directly responsible for the Ministry of Environmental Protection to realize coordination and integration of macro and microgovernance measures. With reference to environmental supervisory patterns, diversified environmental supervisory means or tools in western countries, such as America and Japan, our environmental supervision should be based on governmental leading, adopting benefit incentive. In addition, supervising subjects should provide service, announce environmental information, set incentive measures, guarantee measures, and other flexible means to reach supervising goal and realize coordination and integration of multiple supervising tools. Meanwhile, environmental supervision needs effective participation. Supervision of the general public and social organizations should also guarantee the right to know and participation of the general public. The government should also guide and improve environmental awareness and participation ability in environmental supervision of the general public. We should promote development of non-governmental environmental organizations, comprehensively rely on social force to facilitate environmental supervision, guide the general public to become hard core of environmental supervision construction, and realize coordination and integration of supervi-

sory law enforcement and general public's participation in law enforcement.

## CONCLUSIONS

Hunan is a large traditional agricultural province. Rural soil is one of the natural resources wherein social economy survives in Hunan. Rural soil is also an important constituent part of ecological environment. With elevation of modern agricultural production level, rural soil environment suffers increased pollution and damage. Heavy metals enter rural soil through sewage irrigation, atmospheric soot sedimentation, landfill treatment, and other approaches. Degradation and migration by microorganisms are difficult for soil heavy metals. Thus, heavy metals continuously accumulate and enter agricultural products through the food chain. As a result, quality safety of agricultural products is affected and human health is endangered. This study combined the features and analysed causes of rural soil heavy metal pollution to propose further countermeasures for governing heavy metal pollution based on time series data during 2000-2014 in Hunan. Rural soil heavy metal pollution in Hunan exhibits four features, as follows: enrichment, surface aggregation, elusive property, and irreversibility. Long-term utilization of sewage irrigation, stacking of solid wastes, discharging of industrial waste gases and traffic waste gases in large quantities, and a large amount usage of fertilizers and pesticides are the main causes of rural soil heavy metal pollution in Hunan. Rural soil heavy metal pollution in Hunan can be effectively controlled by establishing legal system for soil heavy metal pollution control, perfecting legal institutions of soil heavy metal pollution, completing supporting law-making stipulations for heavy metal pollution control, optimizing accountability mechanism, and innovating environmental supervisory mechanism of heavy metal pollution control. As this study only uses time series data at provincial level to analyse causes for rural soil heavy metal pollution in Hunan and proposes specific legal countermeasures for preventive control of soil heavy metal pollution, in-depth analytical investigation on special correlation between different cities in soil heavy metal distribution is suggested. With this investigation, we can explore

trans-regional united law enforcement on rural soil heavy metal pollution and formulate specialized laws appropriate for rural soil heavy metal pollution in Hunan.

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