Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 18 | No. 2 | pp. 445-450 | 2019

Original Research Paper

Open Access

Environmental Pollution Generated by Architectural Engineering Construction and Environmental Management and Control Measures

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-03-2019
Accepted: 15-04-2019

Key Words:
Architectural engineering
Engineering construction
Environmental pollution
Environmental management

ABSTRACT

Rapid urbanization in China has driven prosperous development in the building industry. Resource consumption is enormous, given the lack of effective environmental management and reasonable planning in the building construction process, thereby causing severe environmental disruption. Building construction activities are one of the main production activities that destroy environmental resources and pollute the environment. In this study, environmental pollution types generated by the architectural engineering construction were analysed, environmental management and control features in the construction process were summarized, and environmental management and control measures for pollutants arising out of construction projects were proposed. Site operation is the phase that requires the longest time in the entire construction project. It features long duration, considerable resource consumption, and high quantity waste generation. Atmospheric, water, noise, and waste pollution are mainly generated in the architectural engineering construction. Environmental management and control in the building construction are characterized by integrality, durability, dynamics, and diversity. Environmental pollution caused by architectural engineering construction can be effectively relieved through various measures, such as strictly controlling the discharge of atmospheric pollutants generated in the construction, avoiding arbitrary wastewater treatment, controlling continuous noise pollution, and optimizing waste treatment processes and flows. The study results have provided policies and suggestions to implement effective management and reasonable planning of the architectural engineering construction environment, thereby effectively reducing environmental pollution degree through reasonable management and assessment of building projects and leading to the formulation of building management systems that control and reduce environmental pollution.

INTRODUCTION

With the acceleration of industrialization and urbanization in China, industrial energy consumption continues to increase and emission quantities of industrial wastewater, exhaust gas, smoke dust, and garbage have far exceeded the environmental bearing capacity. Thus, conflicts among economic, social, and natural factors have gradually aggravated, and the environmental management problem has started to become an issue that draws extensive concern in all sectors of society. Economic globalization and China's pace in participating in international competition have continuously accelerated and its contact with the international engineering market has continuously deepened. Thus, quality, occupational health, and safety and environmental problems in the implementation process of construction projects have become hot issues in the community. Environmental management can not only save cost and control construction quality but also protect the life and health safety of workers.

As a pillar industry in China, the building industry has played a significant role in China's economic construction and enjoyed swift development in recent years with continuous increase in output value, as shown in Fig. 1. Meanwhile, the building industry leads to high environmental pollution. It should have created an artificial environment that satisfies the material and spiritual lives of human beings. However, traditional construction activities have caused a series of environmental problems, such as excessive consumption of natural resources, arbitrary construction waste disposal, and severe wastewater pollution in the process of providing people with production and life facilities. Therefore, environmental management of construction projects has become the top priority. Construction projects will generate destruction and pollution of surroundings from project approval to final scrapping and demolition and will consume a large amount of resources. Especially during the construction process, generated environmental problems not only directly endanger life and health safety of human beings but also affect the sustainable development of social and economic construction. Environments generated in the construction phase of a construction project are diversified, and environmental pollution becomes complicated, e.g., on-road flying dust on the construction site, exhaust emission

brought by waste paint coatings, solid wastes abandoned in the construction, noise pollution, wastewater pollution, radioactive contamination, and light pollution. Therefore, environmental management in the construction phase of construction projects is the key to completing quality objectives and realizing sustainable development.

PAST STUDIES

Domestic and foreign scholars have carried out a large number of studies on environmental pollution generated by architectural engineering construction and reasonable environmental management measures, thereby enjoying abundant achievements. Many studies have indicated that because comprehensive socio-economic development has driven the development of the building industry, the present mainstream development tendency is that building construction and follow-up services can save as many resources as possible, can reduce consumption of resources and energies, and can remit generation of pollutants. Andersen et al. (1967) analysed the relationship between internal building material type and indoor air pollution. Cole et al. (1992) suggested that energy consumption of buildings represented the current scope of environmental auditing and summarized environmental assessment-related key issues, namely, material production and use in the building construction process. Morledge et al. (2001) believed that the UK building industry was the most common pollution source in industrial pollution, accounting for 22% of water-related pollution events, which were already verified in the industry. Crawley (2004) studied the environmental problems of architectural engineering construction projects in the scrapping and demolition phase and suggested that these demolition activities also brought about environmental pollution. Cheng et al. (2006) used the decomposition method in input-output (I-O) analysis and sensitivity analysis to simulate the influence of pollution in the Japanese building industry at different levels on the Japanese economy. The influence of pollution on the economy needs to be relieved to improve the department's efficiency. Zou et al. (2007) sought for risk management strategies from angles of project stakeholders and life cycle by combining China's architectural culture. The development of safe, highly efficient, and high-quality construction activities could effectively reduce environmental pollution. Sharrard et al. (2008) evaluated the influence of construction projects on peripheral environments using I-O-based hybrid life cycle model. Collyer et al. (2009) believed that architectural engineering construction projects were under environments with dynamic changes, and the environmental influencing factors generated would also affect other construction projects. In the aspect of reasonable management and control measures of building construction, Yip (2000) proposed that time, quality, and cost management in the building construction should be elevated. He also discussed the significant pollution problems in an island environment caused by building constructions in Hong Kong. Shen et al. (2002) considered that the implementation of construction environmental management contributed directly to environmental protection. He also analysed the environmental management profile of the Hong Kong construction industry and put forward that contractors should effectively distribute resources in their companies to adjust their environmental management policies. Li et al. (2002) proposed a quantitative construction pollution control method based on balance of construction resources. This effective tool can be used by the project manager to reduce the building pollution level in specific time periods when other control methods become ineffective. Kartam et al. (2004) introduced the current situation of the waste disposal system in Kuwait building industry, pointed out potential problems caused to the environment, human beings, and economy, and highlighted the main advantages and bottlenecks of the recovery apparatuses. Azadeh et al. (2008)

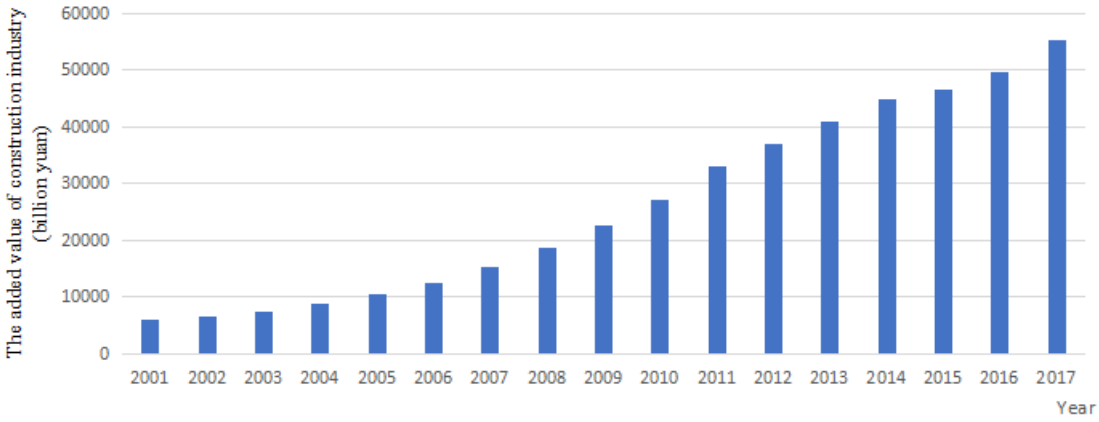

Fig. 1: Values added in China's building industry in 2001-2017. [Data from China State Statistical Database http://data.stats.gov.cn]

believed that executing HSE integrated management system was conducive to the effective environmental management of architectural engineering construction projects. Kofoworola et al. (2009) believed that construction wastes became the main waste source in volume and weight in Thailand. He suggested that effective recovery of construction and demolition wastes should be enhanced in Thailand and that all construction wastes generated within Thailand territory should be counted and checked to evaluate the feasibility of large-scale recovery of construction and demolition wastes. Robichaud et al. (2010) summarized the cost and development tendencies of green buildings and used these study results to propose suggestions for green project management practice in the building industry. Existing studies indicate that the site construction phase occupies the longest time in the entire construction project, featuring long cycle, great resource consumption, and enormous wastes. Reducing pollution generated in building constructions is a major task in the current building industry. Related construction units and departments need to focus on environmental management in the site construction process and formulate feasible and reasonable site construction management measures to effectively realize coordinated development of building industry and environment.

ENVIRONMENTAL POLLUTION TYPES GENERATED BY BUILDING CONSTRUCTION

Atmospheric pollution: Some dust-raising materials, such as lime and yellow sand, are used in several urban construction projects. When these materials are left unused in the construction process, they float toward various corners of the city on windy days. Some tiny molecules are inhaled by humans due to their presence in the atmosphere, thereby causing respiratory diseases. Therefore, when these dust-raising and dispersible materials are not being used, they should be sealed and covered to avoid secondary atmospheric pollution. Some vehicle washing tools should be arranged on the construction site to prevent vehicles that transport lime and micromolecular building materials from carrying dust into the city, thereby causing urban dust pollution. Moreover, construction sites should not be located near schools and hospitals. Students and patients can be infected with respiratory diseases more easily in the presence of atmospheric pollution. The former can easily get sick due to incomplete immune system development and low immunity. The atmospheric pollution will aggravate the diseases of patients, leading to severe conditions. Some abandoned coatings and pipelines must not be burnt in the construction site to avoid creating smoke that pollutes the environment; they should be disposed in a green manner.

Water source pollution: All developments in a modern city require water. Clean water sources are extremely important to guarantee human survival. Water resource pollution is unavoidable in the sites of construction projects, thereby affecting residential water quality to a certain degree. Special attention should be provided to water pollution in the construction and discharge process on the construction site. If these sewages are directly discharged without treatment, then they will affect the urban water-cycling system and cause irreparable consequences. In daily life, water is as important as oxygen. Sewages can be recycled twice or more only through precipitation and then filtering before being discharged. Sewage pipes should be cleared in the inspection process to prevent substances precipitated on the pipeline from being discharged and pollute water resources. Water pollution classification should be conducted on the construction site similar to garbage classification, and sewage treatment modes are different. Domestic sewages by constructors on the construction site can be treated, whereas some other sewages containing chemicals should be strictly treated to truly ensure that sewage discharge will not result in water resource pollution.

Noise pollution: Building construction sites are generally located in suburbs or outside the city centre. However, unlike first-tier cities with high economic development levels, most second-tier and third-tier cities will expand urban housing area at one outer circle of the city centre, namely, in the middle circle, which is called the "city-in-city" phenomenon. Some of these areas have many communities and schools. Thus, noise pollution is an unavoidable problem. During the construction period, community residents should be informed in advance to avoid conflicts caused by noise. Night-time construction is currently allowed. China has rigorous stipulations over noises on the construction site. Some transport vehicles also generate some noises, which affect residential surrounding communities. The quantity of used construction machinery is large with night-time construction phenomenon because the construction period is generally long. These features directly cause severe noise pollution and affect daily residential life.

Waste pollution: The total quantity of annual discharged construction wastes in China reaches over 1.5 billion tons because of the change in building construction design, inappropriate material procurement, material damage in storage and transportation processes, leftover bits and pieces generated by on-site material machining, inappropriate construction operation, and insufficient attention to construction waste management. Acceleration of urbanization progress has driven infrastructure construction. Thus, the quantity of construction wastes has grown, and the energy consumption in the entire building industry has continuously increased, as shown in Fig. 2. Meanwhile, restricted

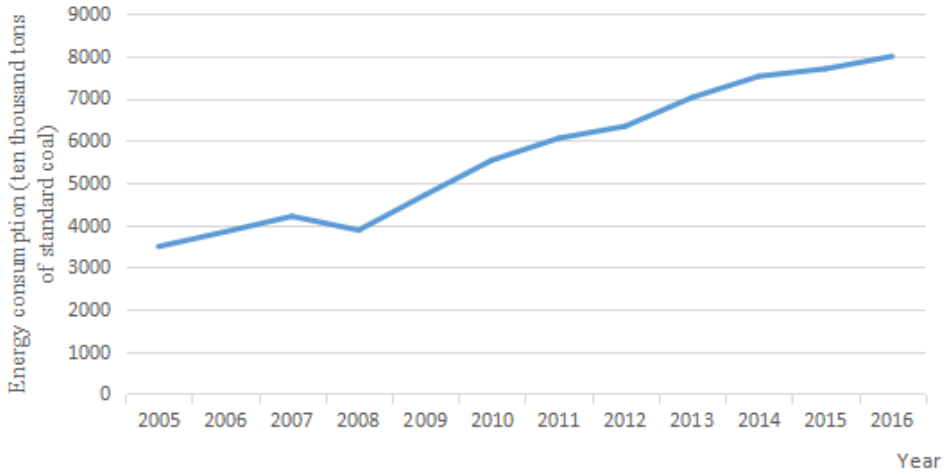

Fig. 2: Energy consumptions in China's building industry in 2005-2016.
[Data from China State Statistical Database http://data.stats.gov.cn]

by urban landfills, the urban solid waste disposal system is faced with enormous challenges. Construction waste digestion sites in various cities in China have problems of unreasonable site selection, lack of planning, and great distance from the construction site. Thus, the transportation cost is high. Construction units illegally dump wastes by taking risks, because they are driven by interests to reduce waste disposal cost. This disposal method not only occupies land resources but also results in wastage of natural resources. It is the least feasible method and results in the greatest environmental pollution. However, governmental departments have ineffectively supervised illegal dumping activities, and most people and some building enterprises do not have sufficient environmental awareness. Therefore, this traditional solid waste disposal method is still very common.

ENVIRONMENTAL MANAGEMENT AND CONTROL FEATURES IN THE BUILDING CONSTRUCTION

Integrality: Environmental management of architectural engineering construction projects is a comprehensive system consisting of multiple environmental management factors and an organic whole. The activities of constructors on the construction site include various factors of subprojects. Therefore, influencing factors in various aspects or potential influencing factors should be comprehensively considered in the recognition and evaluation process of environmental management when environmental management of architectural engineering construction projects is carried out. However, these influencing factors should not be recognized in one aspect or separated from each other. For instance, to analyse on-road flying dust control problem on the construction site, we should not only be aware of dust pollution generated by on-road flying dust but also focus on sewage pollution from sewage created in the construction site when the construction road is watered. Therefore, feasible preventive measures can be formulated only through an integrated research and management of environmental pollution caused by the construction phase of the project.

Long lasting: The construction phase of a project has the longest duration in a construction process with a relatively long construction period. Thus, the number of uncertain factors also increase. Environmental management of the construction phase should restrict the formulation scope of the environmental management measures to this phase, because various factors are interconnected in this construction process. Moreover, environmental problems in the construction phase affect the environmental issues when final construction products are established in the construction process upon completion of the construction project. Given that construction products are immovable, their long-lasting feature should be considered in the management process. Pollution prevention or formulation of environmental management measures in the full life cycle of the construction project should be considered in the environmental management process.

Dynamics: The construction process of a project is under a social environment with dynamic changes. Hence, environmental problems generated in the construction phase in the ever-changing process are variable; they undergo continuous changes as the construction progresses. Development vision is required in the environmental management of the construction phase and in the full life cycle. Environmental problems, which may be generated in construction phases in the construction project, should be studied and explored, and their induction factors or change laws should be discussed. The features of environmental influence factors at

different layers and times should be analysed. Moreover, the influences they generate must be classified into direct or indirect, short-term or long-term, and reversible or irreversible influences.

Diversity: Environmental influencing factors generated in the construction process are diversified. They continuously change as the construction progresses, and this change results in the greater diversity of influencing factors. Some coatings used for wall painting generate some chemical gases, which cause atmospheric pollution. After wall painting, solid waste pollution occurs if coating tanks are arbitrarily abandoned but not reasonably disposed. Meanwhile, coatings provide some radioactive substances, which cause radioactive pollution. Another example is concrete, which may leak on the construction site because of inappropriate pouring or due to the presence of extremely large gaps in template binding during the concrete pouring process. If concrete is left at the construction site, then it will cause solid waste pollution. Wastewater is generated when the concrete mixer is washed, thereby causing wastewater pollution of the construction site and surroundings. Therefore, construction of different subprojects in the construction phase is accompanied by appearance of different types of environmental influence factors, whereas different environmental influencing factors generate different influences on the environment, all of which give rise to diversity of environmental management means in the construction phase.

REASONABLE ENVIRONMENTAL MANAGEMENT AND CONTROL MEASURES IN THE CONSTRUCTION PROCESS

Strict control emission of air pollutants in the construction process: Soils on the working face and excavated soil should be sprayed in advance for dry ground surfaces in the foundation pit excavation process to maintain a humid state. Meanwhile, excavated soils should be timely transported out of the construction site to avoid severe dusts due to long-term stacking or windy weather. Transport vehicles should not be fully loaded when transporting waste soil or gravels in the construction process, and certain measures should be observed to prevent transported goods from scattering on the road. The scattering phenomenon on vital urban communication lines affects urban environment and city appearance. Meanwhile, the road for transportation should be sprayed with water to prevent the increase of road dust due to vehicle's back and forth movement. Waste soil and gravel scattered on the road should be cleared immediately. Construction materials required in the construction process should be reasonably managed. Materials that easily cause dust, such as gravel and cement, should be uniformly stacked and managed, and re-handling or re-handling distance should be reduced as much as possible. Meanwhile, construction materials to be re-handled should be gently handled by constructors to avoid dust generation due to high-altitude throwing. Liquid materials containing chemicals and used in the construction process including coatings, paints, and bitumen should be uniformly covered and disposed after use. Special attention should be provided to decoration materials that are abandoned after use, because the chemicals they contain cause atmospheric pollution after volatilization, thereby affecting the health of constructors and surrounding residents. Fences should be set before construction to reduce dust accumulation in the construction site and to prevent dust particles from being blown by wind, thereby influencing the surroundings. Moreover, under windy weather in the construction process, environmental administrators on the construction site should timely remind operating personnel to cover materials, which may generate flying dusts. Furthermore, roads on the construction site and large and spacious places should be sprayed with water.

Avoid arbitrary wastewater treatment in the building construction process: Sewers must be constructed for wastewater generated on the construction site before the construction is started, and they must be unobstructed. Sewers must pass through main wastewater discharge sites to prevent discharged wastewater from polluting the environment. Cleaning of construction materials, concrete curing and stirring, and cleaning of construction machinery and concrete mixers are necessary. These activities cause the formation of sewages, which should be uniformly managed. Concrete mixers and construction machinery should be cleaned outside the construction site as far as possible, and sewer lines must be provided in the cleaning place. Residual wastewater from the cleaning of construction materials should be poured by constructors at a designated place. Domestic sewage of staff is the main source of wastewater pollution in the construction site. Drainage pipelines should be set in the living area of the constructors to timely discharge their domestic sewage into sewage treatment tanks or designated treatment plants. Sewages generated by staffs in bathrooms and toilets considerably influence the construction site. The sewers must be kept unobstructed and regularly cleaned and checked to ensure sanitary conditions of their living environment.

Control persistent noise pollution: Construction procedures should be reasonably arranged, and night-time construction especially construction of large-scale machinery (such as piling construction) should be avoided. Meanwhile, constructors should be trained to know about stipulations over the range of noise decibels and strictly implement rules. Transport vehicles used in the construction site should not arbitrarily whistle, and transportation of construction mate-

rials should be carried out during the daytime. When concrete mixers operate at night-time, whistling should be controlled. If the living area of the staffs on the construction site is close to the residential quarters, then the staffs should avoid making loud noises.

Optimize waste treatment process and flow: Scattered construction materials in the construction site should be cleared immediately and uniformly stacked at the designated place. Recyclable materials should be recycled in a timely manner to avoid wastage of resources. Packing bags of construction materials used on the construction site shall not be arbitrarily abandoned. Packing bags of construction materials completed the same day should be recycled after the construction. Environmental administrators on the construction site should conduct inspection before the construction is completed each time. Household garbage of staffs on the construction site is also a source of solid wastes. The staff must enhance environmental protection of the living area and set garbage cans for recycling and disposal. Wastes on the construction site must be cleared and transported to the designated waste treatment plant, but they should not be stacked for a long time to avoid decomposition. Meanwhile, recyclable wastes should be classified and collected.

CONCLUSION

As an important pillar of China's national economy, the building industry has provided a healthy and comfortable living environment for the survival of human beings. Many severe environmental problems arise because the building industry consumes a large quantity of resources during the construction process. Environmental pollution control in the construction phase, which is a critical link in the full life cycle construction process of construction projects, becomes the emphasis of environmental management of construction projects. Environmental pollution types generated in the architectural engineering construction were analysed, environmental management features in the construction were summarized, and reasonable environmental management measures for pollutants generated by construction projects were proposed. The study results indicated that architectural engineering construction has the following properties: requires a long duration to complete, leads to great consumption of resources, and generation of a high amount of waste. Construction mainly causes various pollution types, namely, atmospheric, water resource, noise, and waste pollution. Environmental management in the building construction is characterized by integrality, durability, dynamics, and diversity. Studies on continuous field monitoring of concrete environmental pollutants on the construction site show that reasonable management of the entire construction process in the building industry and formulation of a building management system aim to control and reduce pollutant discharge. Selection of actual construction project cases, as well as comparison of their contribution to environmental pollution, must be conducted in the future.

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