Chapter 13
Water Pollution from Construction Industry: An Introduction

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Abstract Water is one of the key natural resources utilized for drinking and other developmental purposes. Water is said to be polluted, when the quality of water is harmful to environment and human health due to unwanted materials entering into the water bodies. Water pollution is a problem that cannot be tolerated even by a construction sector. The pollutants and toxic chemicals generated at the construction sites should be managed well, before discharged into the water bodies. The contaminants like cement, paint, glues, sand, heavy metals, oil, toxic chemicals generated at construction sites enter water bodies due to runoff. Pollutants from construction sites can soak into the groundwater as well, which is more difficult to treat than the surface water. Chemical pollutants especially toxic chemicals, arsenic, lead entering into the water bodies can have a serious human health impact including cancer. Wastewater from the construction sites creates severity to the environment as it can harm or disrupt the entire ecosystem. Managing how much pollution of water can be minimized is a challenging issue to balance between construction business and environment. Hence proper planning is needed to bring the strategies and its implementation in mitigating the water pollution from construction industries.

Keywords Groundwater pollution · Health effects · Strategies · Toxic chemicals · Water bodies

13.1 Introduction

According to sociologist Gideon Sjoberg, the development of the city depends on good environment, fresh climate and water, advanced technology, strong community relation to ensure community steadiness and budget. Construction is an economic

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activity and a part of urbanization facilitating infrastructure which is advantageous to humans in nearly new aspects and damaging in the few other aspects (Muhwezi et al. 2012). These construction activities have global environmental apprehensions emphasizing on water pollution, air pollution, destruction of resources etc. (Hussin et al. 2013). In construction industry, there exist the commercial activities covering constructions and modernization of the city sector including the basic sub-sectors like water source, transportation, schools, medical facilities etc. The construction sector has highest commercial activities; maximum through steel, glass, paint and different material manufacturers for the diverse production of infrastructures, import and export cargo, power generation, industries, houses, complexes and so on (Scott et al. 2013).

Construction sector is one of the big sectors for every growth of the country. It's the main source of income of nearly 30% of the population of the world. Today the construction industry has a wide and diverse range of enterprises globally; however the majority of construction activity is still undertaken by local firms (Gunhan and Arditi 2005). Construction industry provides a job opportunity for a huge sector of people, by hiring from other enterprises, obtaining specialized services by subcontractors, designs by separate professional entities. Though construction activities are a vast throughout the globe, the adverse influence of constructions on the atmosphere and human health is a challenging issue (Garetti and Taisch 2012). In India, construction industry contributes nearly 30% of the waste of the country which includes concrete (65%), bricks and tiles (25%), wood (5%), metals (2%), plastic (2%) and other wastes (1%) (Akhtar and Sarmah 2018). The quantity of waste generation is being increased as many structures are getting deteriorated and have to be demolished due to the age factor. The quantity of the waste is also increasing due to increase in natural calamities like earthquakes, cyclones and floods. The stringent laws are to be implemented in minimizing the damages and pollution due to the construction activities (Wang et al. 2004). Many technological changes are needed in the industry with increasing use of environmental friendly materials. There is also a need for skills training and managerial training for enterprises to adapt to such changes.

The understanding and managing the pollution levels at the construction industry with proper planning and monitoring can reduce the adverse effect on the workers, public and environment. The study in construction sector shows that major contribution of pollution is from water (40%), air (25%) and at the landfill sites (35%) (Yeheyis et al. 2013). The proper strategies to be implemented at construction site to enhance the commercial activities in the city with significant positive impact. Hence this chapter covers the water pollution in the construction industry, sources and characteristics of waste water from the construction industry, environmental and health effects, techniques to control water pollution and strategy for sustainable development of the construction industry.

13.2 Water Pollution at Construction Industries

Construction industry creates enormous water pollution which varies due to different stages of construction activities, type of construction and different construction practices and technology on the site. Compared to other industries, the construction industry creates a huge damage on the environment and also there is a need for strategies to be implemented to minimize these impacts of pollution. Due to over-population in the different cities across the globe, the construction industry is being expanded and creating a huge market and opportunities, hence there is a need for stringent policies and law for curbing the pollution problems (Gan et al. 2015).

The different types of pollution in any industrial activity are air, water, noise and landfill pollution. Water pollution is one such problem, which cannot be neglected by the construction industry. Every industry should have a precautionary measure to manage harmful waste, as it causes irreversible damage to public health and the surrounding. Construction site induced pollution problems could harmfully distress the environment as well as the economic and community of people (Tzoulas et al. 2007). Bequeathing to the environmental protection agency (EPA), construction activity has brought significant variation on the exterior of a land as vegetation is being cleared for many construction projects (Belayutham et al. 2016). This has resulted in the surrounding environment being heavily polluted. Today water contamination due to the construction industry has brought threat to the environment in the world. Among all the industries, the construction industry generates a large amount of water pollutants killing fish and animals or entire ecosystems living in water bodies and in turn affects human health.

Water contamination is the release of unwanted materials into the water bodies, where they interfere with the natural functioning of the ecosystem and in turn have impact on human health. Construction events regularly comprise the use of sediments, cement, toxic chemicals, heavy metals, wood, plastics, oil, solvents, paints and detergents which enter water bodies if not handled properly (Horvath 2004).The sewage from construction sites is created due to the concrete preparations and pouring it in pipes, the hydrostatic tests conducted, domestic wastage due to workers, solid waste discharged into the sewer lines, seepage in pipelines (Morledge and Jackson 2001). These construction pollutants dumped at sites and with surface runoff can soak into the groundwater and in turn strengthen the urban water pollution. The treatment of groundwater is much harder than surface water and it will have an impact on human health.

13.3 Sources and Characteristics of Water Pollution from Construction Industry

Construction industry is one among the most water intensive industries. Water is a vital resource for mixing the concrete, washing the equipment or wetting the dry surfaces and in all stages of the building process. Water gets polluted due to different construction materials at the surface and beneath the ground close to a structure location.

The probable sources of contamination of water from nearby location include erosion of soil, cement working, stockpiles created, lubricants due to maintenance of vehicles and equipment. The sources of contamination also include waste due to demolition and repair work, renovation, land clearing and earth works, concrete material, packing material, wood works, brick wastes, plastic wastes, waste paints and thinners, hazard and toxic materials, electrical wiring, insulation material, sanitary pieces (US EPA 1998; Tang Soon and Larsen 2003). The main source of water pollution from the construction industry is soil erosion and due to runoff and weather conditions it results in sediments (Issaka and Ashraf 2017). Most of the soil surfaces at construction sites are spilled with oil due to diverse events of vehicles and waste paints and solvents.

It is estimated that annually India is generating around 10 million tons of construction waste (Rao et al. 2014). Waste generated from the construction industry can be of the same size or there can be large variation in the size. The waste generated at Tier-I and II cities are bigger in size and in more quantity because of huge buildings and hence more loss of materials (Barbuta et al. 2015). These toxic materials like lead, mercury, arsenic and huge uncontrolled discharge entering water bodies are a threat to human and environment. The huge construction waste generated is transported by the private sectors and hence ends at their need places or at other construction sites for further use (Ponnada and Kameswari 2015). Hence there is a need for policies and guidelines for developers or a contractor for proper handling of waste generated at the site, its transportation regulations and disposal methods. To overcome the water pollution due to the construction industry, the material of concrete is replaced with green materials, which includes inorganic polymer concrete and its being replaced with actual concrete (Bozkurt and İslamoglu 2013). A huge variability of waste from the construction industry is being reused for acquisition of different concrete material requirements and also to upgrade the strength, durability, hardening and resistance.

The appearances of wastewater have a lot of divergence based on the source from the different activities through different sectors like residential area, commercial area, agricultural area, industrial area, which may comprise physical, chemical, and biological pollutants. The strength and composition of waste water depends on the physical, chemical and biological characteristics and to decide the suitable treatment system before the final discharge.

13.3.1 Physical Characteristics

The general physical characteristic of commercial wastewater includes grayish color, odor and settleable solids. The settleable solids by their characteristics, size and shape can be both in the suspended and dissolved form or they are classified as settleable, suspended, dissolved, volatile or nonvolatile. The solids can be organic material plants, fibers, organisms, food waste etc. and inorganic materials like salts, soap, metals, paper, sand, grit etc. (Kumar et al. 2010). In wastewater, the solids are measured in terms of turbidity. Turbidity is quantified by the extent of light being absorbed or scattered through material in water (Kitchener et al. 2017). Both the magnitude and external features or characters of the solid material effect absorption and scattering. The color in the water is an indicator for water being polluted and it is measured on the platinum cobalt scale as per the APHA standards. The color of wastewater continues to change from grayish to dark grey brownish and eventually to black as it passes through a collection system and also as it approaches the anaerobic conditions (Phukon and Bora 2016).

13.3.1.1 Suspended Solids

The very major cause of water pollution on construction locations is suspended solids as it is the major source of material of construction (Pitt et al. 2007). The soil surface doesn't have any essential component to safeguard it from precipitation and overflow. In absence of vegetation and usage of heavy equipment at the site, the amount of overflow increases and worsens the condition of suspension of soil in water. The machineries working in wet conditions further releases dust elements that are suspended in the shallow water. The construction industry has to take certain steps and precautionary measures to minimize such silt pollution.

13.3.2 Chemical Characteristics

The general municipal or commercial waste water is characterized with 70% organic and 30% inorganic materials. The organic characteristic includes carbohydrates, proteins and fats, which is not found much in construction wastes, while inorganic wastes include heavy metals, alkalinity, sulphur, chlorides, nitrogen, phosphorus, and toxic compounds. Hence a chemical characteristic includes alkalinity, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

The presence of carbonates and bicarbonates of calcium, magnesium, sodium, potassium, or ammonia leads to alkalinity of the water in construction industry waste. This parameter of alkalinity is a significant value of both normal water and wastewater which is measured in terms of pH using a pH probe. The average pH of wastewater should be in the range of 6–9 to protect the organism and alteration in this value needs treatment before the wastewater is discharged. Dissolved oxygen (DO) is to be maintained in the water for the proper respiration and one of the important parameters for assessing the quality of water. The DO level should be in the range of 5–6 ppm, too low or too high DO can harm aquatic life and affect water quality. DO is required for the inhalation of aerobic bacteria and is present as a free oxygen molecule and it can be measured using a dissolved oxygen probe. The DO level gets affected with change in temperature, the increase in temperature decreases the DO (Vega et al. 1998) and hence more stress on water bodies in summer than the other seasons.

Biochemical Oxygen Demand (BOD) is equal to the quantity of oxygen consumed by microorganisms to oxidize carbon-based matter present in the water at a specific temperature. BOD oxidizes all the organics present in wastewater that are biochemically degradable during 5 days' time period at 20 °C. Chemical Oxygen Demand (COD) measures the content of organic matter of wastewater that is oxidized using a chemical agent $K_2Cr_2O_7$. The COD values of waste water are usually higher than the BOD, as it includes the oxygen demand created by biodegradable as well as non-biodegradable substances. The advantage of COD is that the period of digestion is 3 h more than the 5 days incubation period for BOD measurement. Once the correlation has been studied between COD and BOD measurements, the treatment system design can be controlled. Total organic chemical (TOC) is another method to measure the both organic and inorganic content of the waste water. The waste water discharged from the construction industry has high organic content due to the different materials like elements, toxic materials, detergents, cements, sand etc.

13.3.2.1 Hydrocarbons

The source of hydrocarbons on the construction site is from machineries, paints etc. like petrol, diesel, kerosene and oils, paints. These hydrocarbon spillages at site are captivated into the soil and also from improper mapping of pipe networks at construction sites (Chauhan et al. 2010). These hydrocarbons are originated to be in a dissolved phase and hence the treatment remains more expensive. The common treatment is captivating the hydrocarbons through adsorption onto granular activated carbon containers and recovering back the hydrocarbons through desorption. Spillage of hydrocarbons can be minimized at construction sites by providing designated areas for the vehicle cleaning and for filling the fuel. The floating hydrocarbons are generally removed through the flotation process.

13.3.2.2 High pH

The pH is the one of the sources of wastewater on the construction locations due to the wash of building concrete and equipment at the location. The lime stabilization and reuse of the aggregate concrete at the site also increases the pH (Alyafei et al. 2020). The alkalinity of wastewater is much more harmful than the silt or oil, as the alkalinity of concrete waste water is extremely high in the range of pH 12 to 13. Neutralization is an essential treatment process in many industrial manufacturing environments to meet the standards of discharge of wastewater.

13.3.3 Biological Characteristics

In general waste water has a huge quantity of microorganisms, most of which are innocuous to man and microorganisms range from 500,000 to 5,000,000 per ml. However, few microorganisms are harmful and cause disorders in health are also present in wastewater. These microorganisms decompose complex compounds into stable ones with the help of enzymes. Depending upon the respiration, bacteria are classified as aerobic, anaerobic and facultative bacteria. The number of organisms in wastewater is counted using the standard most probable number (MPN) test. It is observed that, construction industry waste water doesn't have the characteristics of biological waste.

13.4 Environmental and Health Effect of Construction Waste

The technology in the construction industry has brought more beauty and creativity due to human intelligence in transferring the design into reality. At the same time, health, safety and environment should be an integral part of any industrial activity like agriculture, manufacturing or construction industry. People should be trained adequately in designing and implementation of a system with due priority with safety, health and environment (Nigam et al. 2007). The surrounding environment of any activity should be free from pollution, as these areas affect the well-being of the public and in turn the rate of production and environment, as safety, health and environment are interrelated (Luhar and Luhar 2019).

Health and safety are still not given the top priority in the construction industries. Construction industry is regarded as one of the highest environment degradation across the world and has caused serious environmental problems and in turn affects the economic condition of the city. The construction activities are enhancing the environmental degradation along with high energy consumption and depletion of natural resources. Through the different sources and discharge of elements from the construction sites affects the water bodies and has implications on human health due to unsafe drinking water which leads to diarrheal, accounting for 70% of death (Schwarzenbach et al. 2010). The significant discharge of suspended materials and toxic substances in water bodies, chunk the gills of fish and seriously disrupt aquatic ecosystems due to lack of dissolved oxygen (Pandey and Madhuri 2014). The metals like lead, arsenic and mercury are highly toxic leading to the depletion of organisms and in turn affect the human systems. The photosynthetic activity of the plants is hindered in water bodies as the hydrocarbon layers block the entry of the sunlight (Carr and Neary 2008). During Heavy showers sediments, paints, lubricants, fuel, solvent, pesticides etc. enter water bodies leading to the reduction of the oxygen in water and in turn damage the marine life and human immunity level (Jain et al. 2016). The construction activities wastewater also destroys the land fertility in nearby areas and adjacent pavements. The groundwater also gets contaminated, which is a source of drinking water through different heavy metals causing health issues like cancer, when consumed (Mahurpawar 2015).Water pollution from construction industry may cause dangerous like cancer, hormonal imbalance, liver and kidney problems, and damage to DNA and reproductive systems.

13.5 Control of Water Pollution from Construction Sites

The enormous quantity of wastewater is generated at the construction sites, as water being one of the key vital components at different stages of a project work. This significant quantity of wastewater generated at a construction site, frequently desires treatment before being recycled or discharged to the natural environment. The water gets polluted due to sewage produced due to different activities by concrete stirring, curing, pouring pipes, hydrostatic test, domestic sewage of construction workers, abundant solid wastes, seepage failure in drain line. These pollutants discarded from the construction locations are connected with surface overflow, which strengthens urban and groundwater pollution.

Water being a key component of a construction project, it must be properly managed to optimize its consumption and to ensure it does not harm the environment. Most countries today have the national and local regulations and standards for discharging the water into the water bodies.If the water quality doesn't meet the standards it cannot be discharged into a public effluent, hence treatment is required. The waste water discharged from concrete construction activities have high suspended solids and pH value (Al-Jumeily et al. 2018). The recent updates in the law, pushes the construction industry to reuse all the waste water generated at the sites and already few of the industries are achieving zero discharge of waste water.

The general waste water treatment systems consist of pH adjustment, coagulation-flocculation, decantation, flotation, sedimentation etc. This primary treatment system needs more space, relatively complex equipment, more chemical additives etc. In addition, the sludge obtained must be treated and managed as waste before discharge. Because of these difficulties, most of the planned solutions of construction industries intended at reusing the water rather than the treatment of construction industry effluents. There are number of treatment studies shown by different researchers, like 2 stage treatment method of sedimentation and neutralization (Tsimas and Zervaki 2011), coagulation and sedimentation (De Paula et al. 2014), adsorption followed by electrochemical techniques, to minimize the turbidity and COD in the effluents (Alyafei et al. 2020).

Biological treatment is of much significance as it treats wastewater from either domestic, commercial or industrial wastes. The biological treatment process is considered to have a cheaper and safer operating process compared to conventional physical and chemical methods. The aerobic activated sludge process is well practiced across the globe for any commercial waste water. The biological treatment includes both aerobic and anaerobic processes. Aerobic treatment, in presence of oxygen, converts organic matter through microorganisms into carbon dioxide, water and biomass. The anaerobic treatment in the absence of air converts organic matter into methane and carbon dioxide (Kolade 2018). The change in stringent discharge standards by the concerned has forced the application of a different advanced biological treatment processes in current years (Shivaranjani and Thomas 2017).

Today's construction projects are causing enormous environmental pollution. Researchers are concentrating on survey of green materials and its suitability in the construction industry as it minimizes the environmental pollution. Green construction is focusing to facilitate the sustainable development of industry and also to protect the ecosystem (Gupta and Vegelin 2016). Green constructions are trying to attempt towards saving energy, water wastage, reducing material cost etc. In recent years substantial water wastage has been reduced in few of the construction locations due to the technological advancement in different usage of water fixtures, water harvesting, water audits, and leak detection machines.

13.6 Strategy for Sustainable Development of Construction Industry

Accomplishment of sustainable development of the construction industry needs a high standards technology and design with green materials to have a clean and ecofriendly environment. The sustainability in the construction industry is in terms of energy, water, air, green space etc. Environmental Impact assessment (EIA) of construction projects emphases on reducing the adverse impact on the environment examining both positive and negative impact of the project and provides different predictions and options for decision makers (Shah et al. 2010).

The building construction project falls under 8(a) category of EIA notification 2006 (as amended) by the Ministry of Environment and Forests (MoEF). The MoEF has made it obligatory to get environmental clearances for construction projects with area greater than 20,000 m^2 (Gupta et al. 2015). It is required to prepare an EIA report on the basis of a guidance handbook and then submit it to the suitable authority. These impact studies in the construction industry include all factors relevant in having impact on the environment, natural resources and also cost-effective projects. Hence these impact studies require a multidisciplinary approach towards all factors involved and come out with feasibility stages of the project.

The Environmental Protection Agency (EPA) guides in protecting the environment as first priority at the beginning of any construction work. All the contract workers should be aware of the rules and the company should safeguard the environment critically. There are many materials and chemicals used at some stage of construction work and these materials may have an impact on employees and the environment if not taken care in handling them properly. Hence EPA proposes proper execution of the effective pollution hindrance and management procedures safely during the construction work (Petraru and Gavrilescu 2010). Also, energy star programs are generated by EPA along with the energy department for using energy efficient materials and buildings across the world. The research process has been developed to use eco-friendly materials in the construction procedure that can save 250 metric tons of CO_2 emissions yearly. Another proposal of EPA is a recycling program initiated at construction garbage which helps to study the impact on the environment and to recycle all the materials on the site.

Good construction site practice can overcome and minimize pollution. Have proper design systems to reduce the release of contaminants and avoid erosions. Depending on the location and structure of construction the soil stabilization process should be implemented based on local rules and regulations. All the construction materials must be kept safe and secure, to avoid runoff due to rains and other waterways. All the roads and footpaths near the construction site must be kept neat and clean. The regular examination of spillages at the site, use of nontoxic paints, and nonhazardous materials at all possible areas of location at construction sites will reduce the pollution. All these practices at the construction site reduce pollution and implementation of these strategies leads to sustainable development in the construction industry.

13.7 Reduce, Reuse and Recycle of Construction and Demolition of Wastes

Construction industry is trying to minimize or reduce the wastage at the source itself by preserving or optimizing the existing buildings instead of the new construction. Adopt construction methods or technology in the system such that it can be disassembled or reused with different techniques for the better savings in terms of economics and environment. The concept of minimizing the waste (reduce), using items more than once (reuse) and using the product to the new use (recycle) in the construction industry is the need of the hour. Recovering the valuable materials like concrete, rubber, wood, metals, steel, brass from the construction site is a very effective approach to save money and protect the natural resources (Hussin et al. 2013). The construction industry can adopt different technology and design parameters to discharge less waste, avoid too many materials, and incorporate safe and secure storage areas and weather proof conditions.

Currently industry should preserve the good materials and store them in harmless places for further use on the same site or different site. Different materials like bricks, tiles, paint, inert materials, wood, plaster, packing materials, glass, plastics, metals can be reused. Paybacks of reducing disposal of construction materials, 3Rs concept creates services and increases in monetary benefits in recycling industries. The 3Rs concept increases commercial openings within the local community, and minimizes the environmental effects with potential to turn 100 percent of materials back into the construction location (Jain 2012). Hence presenting an effective waste management in the launch of the design systems at construction locations avoids enormous landfilling, thereby improving the recycling process.

13.8 Conclusion

Construction activities are one of the significant sources accountable to devastate the environment and natural ecological units. Any country cannot stop the construction site activities as it is the backbone of the economic status of the particular place. Therefore, there is a need to implement advanced technologies and methods following sustainable construction to bring down the pollution level at the sites. Water being one of the key components of the construction site, can pollute the environment and hence use of recycled water streams in construction areas is the need of the hour. The enormous quantity of water wherever possible can be reused from greywater and rainwater harvested at construction sites. Today energy savings and green buildings are getting popularized in the construction industries in order to save water and energy. Sustainability is being achieved in construction industries with environmental friendly approaches and move towards economic feasibility with comfort and safety of the residents. The changing technology of the construction industries are minimizing the consequence on the environment, improving safety and health of workers, reduction in disposal costs with accomplishment of environmental goals. Hence water pollution in the construction industry can be minimized with more environmentally friendly approaches and awareness, favorable government policies and continuous education for efficient water use.

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