1.0 INTRODUCTION

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With the advent of rapid industrialization, Indian economy had progressed; however people had little awareness that the industrial boon providing employment to a large population would also spread their deadly tentacles and engulf the environment, eventually becoming a major cause of air, water and land pollution. Accordingly, the concerns had been raised by many regulatory bodies including central pollution control board (India), World Health Organization (WHO), World Bank, Indian Standard Institution, Indian Council of Medical Research, etc and the contribution of industries towards pollution is clearly understood in the recent times. The pollutants from industrial discharge and sewage besides finding their way to surface water reservoirs and rivers are also percolating into ground to pollute ground water sources. The polluted water contributes to undesirable taste, color, odour and most importantly may contain toxic chemicals that may disturb the ecosystem and pose deadly effects on human and animal health. They also subdue plant growth and most annoyingly the toxicants easily enter the food chain. Hence, the past four decades had witnessed a number of treatment technologies to overcome such pollution problems, especially water pollution.

Environmental pollution has been considered as a side effect of various industries. Nowadays, environmental preservation has become a key issue in a society because it is often linked to quality of life. So, increasing awareness on the environment in both developed and developing countries has initiated more studies of
possible solutions for controlling pollution. The impacts of pollution on the environment have led to an intense scientific investigation.

Organic compounds are the major water pollutants, among which phenol and its analogous has been the subject of great concern, as they are toxic in nature and induce adverse effect on receiving bodies. Phenol is a type of organic pollutant which can be dreadfully hazardous to human health. The origin of phenol in the environment is both industrial and natural. The presence of phenol in water imparts carbolic odor to receiving water bodies and can cause toxic effects on aquatic flora and fauna. Phenols are toxic to human beings and affect several biochemical functions (Nuhoglu and Yalcin, 2005). Thus, phenol is recognized as priority pollutants by “US Environmental Protection Agency” (EPA) (1979). The World Health Organization (WHO) recommends the threshold permissible phenolic concentration of 0.001mgL\(^{-1}\) in portable waters and threshold concentration of phenol in drinking water below 1.0 \(\mu\text{g}/\text{L}\). While Ministry of Environment and Forests (MoEF), Government of India, have set a maximum concentration level of 1.0 mgL\(^{-1}\) of phenol in the industrial effluents for safe discharge into surface waters. Thus, the treatment of phenol is necessitated which is done either by conventional or biological techniques.

The treatment technologies for the removal of phenol from wastewater include adsorption, solvent extraction, activated carbon adsorption, chemical oxidation and biodegradation (Marrot et al., 2006). But methods such as solvent extraction, activated carbon adsorption and chemical oxidation often suffer from serious drawback including high cost and formation of hazardous byproducts (Naresh et al., 2012). Favorably, biological degradation is generally preferred as it has advantages of lower
costs and possibility of complete mineralization; therefore do not give rise to any hazardous byproducts. Harnessing the potential of microbes to degrade phenol has been an area of considerable study to develop bioremediation approaches which has been considered as a “green option” for treatment of environmental contaminants. (Vojta et al., 2002).

The removal of phenol from industrial effluents has attracted researchers from different field. Biological treatment of phenol has therefore been an increasingly important process in pollution prevention. Phenol biodegradation studies with the bacterial species have resulted in bringing out the possible mechanism and also the enzyme involved in the process. There are reports on many microorganisms capable of degrading phenol through the action of variety of enzymes. Among various enzymes phenol hydroxylase, laccase and catechol 2, 3 dioxygenase are involved more in the biodegradation of phenol (Leonard and Lindley, 1999a; Hublik and Schinner, 2000).

Environmental biotechnology relies on the pollutant-degrading capacities of naturally occurring microorganisms such as bacteria, fungi and microalgae. Industrial effluents containing different organic and inorganic pollutants require proper treatment prior to discharge into the environments. Among various methods available, biodegradation is environmental friendly and cost effective method. The organic pollutants are used as sole source of carbon and energy for various microorganisms. It is suggested that the microorganisms may adapt themselves to the current environmental conditions by altering their kinetic parameters and has the ability to
adapt to restricted availability of food, depending on the growth conditions of a microorganism.

Biodegradation process generally employs microbes like fungi, bacteria etc. Bacteria offers higher advantage over other organisms as it has faster rate of multiplication and they are easier to handle. Hence, there is always a search of bacteria that can degrade phenol effectively and as a consequence of which plenty of literature is available. Many researchers have isolated the bacteria from phenol contaminated site which gives higher probability of acquiring a phenol degrader as the bacteria isolated from such areas usually gets acclimatized to the phenol contaminated environment and may possess excellent machinery to combat higher concentration of phenol and degrade them. Thus, a number of both aerobic and anaerobic phenol degrading microorganisms have been isolated and characterized (Chen et al., 2004; Santos et al., 2001).

A number of microbial species possess enzyme systems that are applicable for the decomposition of various aliphatic and aromatic toxic compounds. Intensive efforts to screen species with high-degradation activity are needed to study their capabilities of degrading phenol and phenolic derivatives. Most of the current research has been directed at the isolation and study of microbial species of potential ecological significance (Krstanov et al., 2013). However, many reports suggest that bacteria degrade phenol through the action of variety of enzymes such as oxygenases hydroxylases, peroxidases, tyrosinases and oxidases. Oxygenases include monoxygenases and dioxygenases. Nonetheless, the mechanism of degradation is generally decided by phenol concentration and nature of the organism of choice.
Additionally, several physical factors such as temperature, pH, oxygen availability etc and chemical factors such as the nutrient source like carbon, nitrogen or trace elements can also limit the rate of biodegradation of phenols.

When new microorganisms have been isolated with biodegradation efficiency, their biochemical versatility has been found to be immense. However, the isolation of those microbes will often require a targeted intelligent approach to screen the biosphere for its presence (Wackette and Hershberger, 2001). The mechanism of phenol biodegradation is generally decided by the nature of the organisms, type of the enzyme and the external factors affecting biodegradation. These factors may include temperature, pH, oxygen content and availability, substrate concentration and physical properties of contaminants. Each of these factors should be optimized for the selected organism for the maximum degradation of phenol.

Biotechnology for hazardous waste management involves the development of biological systems that catalyse the detoxification, degradation or decontamination of environmental pollutants. In future technologies, microbial systems might be the potential tools to deal with the environmental pollutants. Biodegradation of phenol by many microorganisms has been studied in order to understand the nutrient requirements, environmental physico-chemical factors, and complex biochemistry involved that may assist in bioremediation of this toxic compound.
1.2 **Aim and objectives**

This study thus focuses on the phenol biodegradation ability of a newly isolated bacterium followed by optimization of physical and chemical parameters for achieving maximum biodegrading ability. Thus the main aim of this study is to investigate the ability of newly isolated bacteria to degrade phenol with the following specific objectives:

1. To isolate, screen and identify potential phenol degrading microorganisms from industrial effluent contaminated soil.
2. To optimize physical parameters of aerobic phenol biodegradation in batch cultures by potential strains.
3. To optimize chemical parameters of aerobic phenol biodegradation in batch cultures by potential strains.
4. To study the various immobilization techniques of aerobic phenol biodegradation in batch cultures by potential strains.