Biodegradation of polymer effluent and its reutilization for growth of ornamental plant

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ABSTRACT

One of the most challenging current problems arising with rapid industrialization, is the proper disposal of waste products. Polymer effluent released from polymer industry is one of the major sources of environment pollutants as the concentration of harmful materials in the waste water was extremely high. Bioremediation offers a simpler, cheaper and more environment friendly option to traditional methods of remediation. Bioremediation is the microbial clean-up approach. Hence the present study was carried out to analyse Physico-chemical parameters like colour, odour, pH, EC, TSS, TDS, BOD and COD of untreated polymer effluent and was degraded using bacteria. The results of the analysis of the physico chemical parameters revealed that untreated polymer effluent was yellow in colour with pungent odour. pH was alkaline with high organic load such as EC, TSS, TDS, BOD and COD which were higher than the permissible limits of CPCB (1995) for its disposal indicating high pollution potential of the waste. Since the untreated polymer effluent has high organic load, disposal of such waste water into the environment without proper treatment pose hazards to environment. Hence Escherichia coli was used to degrade the untreated polymer effluent for a period of 96 hrs in a laboratory scale study. Results of analysis of degradation of the effluent revealed that colour and odour of 100% untreated sample has changed to almost colourless and odourless nature. pH has changed from alkaline to neutral and also showed marked reduction (12.35% - 99.5%) of parameters in biotreated sample using Escherichia coli. The biotreated sample was reused for the growth of ornamental plant, Impatiens balsamina. The results of the growth study revealed that growth rate of the plant was increased in biotreated sample than in untreated sample.

Key words: Biodegradation, Impatiens balsamina, Physico-chemical characterization, Polymer effluent, Reutilization.

INTRODUCTION

Pollution is the process that makes nature’s resources such as land, water, air or other parts of the environment unsafe or unsuitable to use. Anything added into the environment results in producing harmful or poisonous effect on living things is called pollution. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Environmental pollution can take the form of chemical substances or energy, such as noise, heat or light.

Water pollution is the contamination of water bodies (lakes, rivers, oceans, aquifers and ground water). Water used by people and its disposal into a receiving water body with altered physical and chemical parameters is defined as waste water. Pollution of water with various toxic minerals is considered dangerous because of the potential toxic effects on aquatic life as well as to other animals, plants and human beings.

Industrial pollution is a global concern. Among the major different industries, the polymer industry is a notorious polluting industry of the environment. The polymer industry manufactures various plastic products (polymers). A polymer is a large molecule or macromolecule composed of many repeated subunits. Polymer is a high molecular mass formed by the combination of large number of molecules into simple molecules, called monomers. The process by which the measures get combined and transformed into the polymer is known as Polymerization. Polymers range from familiar synthetic plastics such as polystyrene to natural biopolymers such as DNA and proteins (Harinee et al., 2018). The polymer effluent is the waste water generated after the production of polymer by the industry which pollutes soil and ground water. Polymer industry generate significant amount of effluent (Noorjahan, 2017). It appears as pale yellow colour with pungent odour. Polymer effluent is among the most hazardous industrial pollutants due to its huge organic and inorganic load, which exhibit very high value for pH, conductivity, DO, TDS, TSS, BOD and COD in the water stream which is highly toxic to human life and environment. It affects the resources, health and livelihood of thousands of people and also causes decline of trees. Some of the plastic products cause human health problems because they mimic human
hormone. Hence polymer effluent with high pollution load should be treated before its disposal (Harinee et al., 2018).

The treatment of industrial waste varies with its character, quantity and the nature of receiving media and the dilution available. There are different methods of waste water treatment such as Physical method, Chemical method and Biological method.

Physical and chemical methods of waste water treatment are invariably cost intensive and cannot be employed in all industries especially in developing and under developed countries. Biological treatment or Bioremediation are based on the process and potentials of almost all types of life forms viz., Plants (Phytoremediation), microbes (Microbial remediation) and animals (Zoo remediation). Compared with chemical/physical methods, Biological treatment method have received more interest because of their cost effectiveness, lower sludge production and environmental friendliness.

Bioremediation is defined as a spontaneous or managed process which utilizes biological organisms, mostly microorganisms. It employs biological agents to render hazardous wastes to non-hazardous or less hazardous wastes. Micro organisms have a number of vital functions in pollution control. Microbes can acclimatize themselves to toxic wastes.

Srinivas Gidhamaari et al. (2012) reported that certain bacterial species such as Pseudomonas putida, P. fluorescens, Klebsiella pneumoniae, Escherichia coli, Staphylococcus aureus and Bacillus subtilis showed great results to treat various industrial effluents.

It is well known that water of good quality and free of pollutants are primary requirements for agricultural practice. After degradation the treated water could be used for crop cultivation, irrigation and aquaculture purpose. The literature survey revealed that several studies were carried out on various aspects of Impatiens balsamina such as flowering pattern, seed germination and pollen germination etc. (Harinee et al., 2018)

Taking into consideration of all the above said investigations carried out by many researchers, research pertaining to degradation of polymer effluent using microbes especially bacteria was meagre. Hence an attempt has been made to analyse physic-chemical parameters of untreated polymer effluent, to degrade the untreated polymer effluent using Bacteria Escherichia coli and to reuse the biotreated water for the germination and growth of ornamental plant, Impatiens balsamina.

MATERIALS AND METHODS

Untreated polymer effluent was used as the material in this study. The untreated sample was collected in polythene containers (10 litres capacity) from the point wherein all the effluent from different stages of processing are discharged together from polymer company situated in Chennai, Tamil Nadu, India. They were brought to the laboratory with due care and stored at 25°C for further analysis.

The physico-chemical parameters such as colour, odour, pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of untreated polymer effluent were determined by following the Standard Methods outlined by APHA (1995).

Pure culture of bacteria, Escherichia coli for biodegradation of polymer effluent was obtained from Microbiology laboratory, Chennai, Tamil Nadu, India. The culture was maintained in nutrient agar broth for substantial growth to use for biodegradation of polymer effluent.

Population of $10^4$ cells/ml of E. coli were transferred to 1000ml of 100% untreated polymer effluent in a conical flask. Conical flask with effluent and bacteria (E. coli) were incubated at 30 ± 0.5°C for 96 hours laboratory scale study in rotary shaker at 2000 rpm. After incubation, the samples were centrifuged at 5000 rpm for 20 minutes. Control (conical flask with untreated polymer effluent without bacteria) was also run simultaneously. The procedure for degradation process was carried out by following the procedure of (Durga Devi, 2012). The supernatant were analyzed for physico-chemical parameters like pH, EC, Total Suspended Solids, Total Dissolved Solids, Biological Oxygen Demand and Chemical Oxygen Demand. Physico chemical parameters of the effluent were analyzed before biotreatment (control) and after biotreatment by following the Standard procedure of APHA (1995).

After degrading the untreated polymer effluent using bacteria, E. coli for 96hrs the degraded water was reutilized for the growth of ornamental plant, Impatiens balsamina by following the procedure of Mehayaatba (2008). The seeds of Balsam , Impatiens balsamina was procured from a local nursery located in Chennai, Tamil Nadu, India for the germination and growth in 100% polymer effluent and biotreated water.

The seeds of ornamental plant, Impatiens balsamina were washed with mercuric chloride solution for 2 minutes and then thoroughly washed in distilled water. Earthen pot filled with farm yard manure was sown with 10 seeds, allowed to germinate by irrigating with equal volume of 100% untreated polymer effluent and biotreated water separately. One set was irrigated with tap water as control. Duplicates were maintained for the experiment. The vegetative features (i.e) shoot length, root length, number of leaves and number of roots of the above plant was recorded on 15th day of plant growth.

The data obtained from the experiments was analysed and expressed as mean, Standard Deviation and percentage change.
RESULTS AND DISCUSSION

Environmental pollution is caused by synthetic polymer, such as wastes of plastic and water-soluble synthetic polymers in wastewater. Two general mechanisms were usually considered for degradable plastics, namely photodegradation and biodegradation. Hence a preliminary investigation has been carried out to analyse the physicochemical parameters of untreated polymer effluent such as colour, odour, pH, EC, TSS, TDS, BOD and COD. Results of the analysis of Physico-chemical parameters of untreated polymer effluent was depicted in Table 1. Colour of the untreated polymer effluent was yellow in colour. Odour of untreated polymer effluent has pungent smell.

The pH of untreated polymer effluent was 8.8, thereby indicating the alkaline nature of the polymer effluent. Discharge of such effluent with alkaline pH into ponds, rivers etc for irrigation may be detrimental to aquatic biota such as ornamental plants. According to Singh et al. (1998), highly alkaline water if consumed would affect the mucous membrane and may cause metabolic alkalosis.

The electrical conductivity of the untreated polymer effluent was 16,240 µmhos/cm and the value of EC were higher than the permissible limits (400 µmhos/cm) of CPCB (1995). Untreated polymer effluent showed higher level of electrical conductivity which could reflect the presence of organic and inorganic substances and salts that would have increased the conductivity (Krishnapriya, 2010).

The composition of solids present in a natural body of water depends on the nature of the area and the presence of industries nearby. TSS level of untreated polymer effluent was 227 mg/l indicating that the TSS value was higher than the permissible limit (100 mg/l) prescribed by CPCB (1995). High amounts of suspended particles has detrimental effects on aquatic flora and fauna and reduce the diversity of life in aquatic system and promote depletion of oxygen and sliting in ponds during rainy season (Karthikeyan, 2009).

TDS of untreated polymer effluent was 10,068 mg/l and the value of TDS was higher than permissible limits (2100 mg/l) of CPCB (1995). High levels of TDS (10,068 mg/l) may be due to high salt content and also renders it unsuitable for irrigation hence further treatment or dilution would be required (Goel, 1997).

Determination of BOD is one of the important parameters used in water pollution to evaluate the impact of wastewaters on receiving water bodies. BOD of untreated polymer effluent was 84 mg/l and the value was higher than the permissible limit (30 mg/l) of CPCB (1995) due to the presence of considerable amount of organic matter.

Table 1: Physico chemical parameters of untreated polymer effluent.

| Parameters                  | CPCB (1995) | Oct’ 2017 |
|-----------------------------|-------------|-----------|
| Colour                      | Colourless  | Yellow    |
| Odour                       | Odourless   | Pungent   |
| pH                          | 5.5-9.0     | 8.8       |
| Electrical Conductivity (EC µmhos/cm) | 400     | 16,240    |
| Total Suspended Solids (TSS mg/l) | 100     | 227       |
| Total Dissolved Solids (TDS mg/l) | 2100    | 10,068    |
| Biochemical Oxygen Demand (BOD mg/l) | 30     | 84        |
| Chemical Oxygen Demand (COD mg/l) | 250     | 383       |

± Standard deviation

% - Percentage change

Table 2: Analysis of physico-chemical parameters of 100% untreated effluent before (control) and after degradation using E. coli (96 hours).

| Parameters                  | CPCB (1995) | Control(Untreated effluent) | Biotreated water Sample(E. coli) |
|-----------------------------|-------------|-----------------------------|----------------------------------|
| Colour                      | Colourless  | Yellow                      | Colourless                       |
| Odour                       | Odourless   | Pungent                     | Odourless                        |
| pH                          | 5.5-9.0     | 8.9±0.115                   | 7.8±0.0577(12.35%)               |
| Electrical conductivity (µmhos/cm) | 400     | 16,350±1.154                | 2,613.67±1.527(84.10%)          |
| Total Suspended Solids (mg/l) | 100     | 10,620±0.577                | 111.33±1.547(98.93%)            |
| Total Dissolved Solids (mg/l) | 2100    | 10,150±0.577                | 1620.67±1.154(84.03%)           |
| Biochemical Oxygen Demand (mg/l) | 30     | 200±0.577                   | 178.667±1.527(10.66%)          |
| Chemical Oxygen Demand (mg/l) | 250     | 610±0.577                   | 488.75±0.577(19.87%)           |

± Standard deviation

Table 3: Germination and Growth (Shoot length, Root length, No. of Roots and No. of Leaves) of Impatiens balsamina (Balsam) exposed to control (tap water), untreated and biotreated (E. coli) of polymer effluent.

| Duration | Parameters | Control | Untreated | Bio treated(E. coli) |
|----------|------------|---------|-----------|---------------------|
| 15th Day | Shoot length | 10±0.1 | 5.3±0.05 | 8±0.2               |
|          | Root length | 2.0±0.15 | 1.2±0.15 | 1.4±0.15            |
|          | No. of Roots | 6±0.2 | 3±0.20 | 5±0.15             |
|          | No. of Leaves | 4±0.11 | 1±0.15 | 3±0.25             |

± Standard deviation
COD test is the best method for organic matter estimation and rapid test for the determination of total oxygen demand by organic matter present in the sample. COD of untreated polymer effluent was 383 mg/l and the value was beyond the permissible limit (250 mg/l) of CPCB (1995). The present investigation revealed that high level of COD indicates that the effluent is unsuitable for the existence of aquatic organisms due to the reduction in DO content (Goel, 1997).

Thus the analysis of physicochemical parameters of untreated polymer effluent confirms that the wastewater released from the polymer industry has higher concentration of EC, BOD, COD, TSS, TDS, which surpassed the permissible limits prescribed by CPCB (1995) for discharge of industrial effluent into inland surface water as well as an land for irrigation.

Alkaline pH, high TSS, TDS, BOD and COD of the polymer effluent reveals that the polymer effluent is highly polluted and it has to be treated before disposal. Hence it is imperative to adopt technologies to reduce or degrade the polymer effluent using microbes.

Biodegradation technology is potentially useful for wastewater treatment. It is important to document enhanced biodegradation of the pollutant under controlled conditions, this cannot be accomplished in sites and thus must be accomplished in laboratory experiments before the technology is transferred to field.

According to Goudar and Subramanian (1996), laboratory experiments which provide real environmental conditions are most likely to produce relevant results with indigenous microbial population.

Based on the above suggestions, biodegradation of polymer effluent was planned and executed using microbes. *Escherichia coli* was selected for degradation of the effluent. The results of degradation of 100% untreated polymer effluent using *E. coli* was presented in Table 2.

Results of the biodegradation of untreated polymer effluent using *E. coli* revealed that the colour and odour of untreated polymer effluent was yellow with pungent odour which may be due to presence of large quantity of organic and inorganic pollutants (Singh *et al.*, 1998) or may also be due to microbial activities (Nagarajan and Shasikumar, 2002). But after biodegradation of the effluent for 96 hrs, the colour changed to almost colourless and odourless condition using *Escherichia coli*. This may be due to the action of bacteria, *E. coli*, which decomposed the toxic pollutants present in the effluent and changed the colour and odour of the effluent. This is supported by the work of Sukumaran (2008).

pH of untreated polymer effluent before degradation was 8.9±0.115 which were alkaline in nature but after degrading the sample using *E. coli* degraded alkaline pH to 7.8±0.0577 and percentage change was 12.35% there by indicating that the alkaline nature of pH has changed to the neutral state. EC of 100% untreated polymer effluent before treatment was 16,350 (µmhos/cm) ± 1.154 which were beyond the permissible limit (400 µmhos/cm) of CPCB (1995) but after degradation for 96 hrs using *E. coli* degraded EC to 2,613.67 µmhos/cm ± 1.527 and the percentage change of EC was 84.10%. This is in agreement with the reports of Noorjahan *et al.* (2004).

TSS of 100% untreated polymer effluent before treatment was 10,620 mg/l ± 0.577 which were beyond the permissible level (100 mg/l) of CPCB (1995) for effluent disposal, but after degradation, *E. coli* degraded TSS to 111.33 mg/l ± 1.547 and the percentage change was 98.93%. Since TSS and TDS are the major pollutants, the above biodegradation results are encouraging and scale up studies for continuous treatment of wastewater at pilot scale is required. The information generated would help to scale up the process and assess the economic feasibility of the technology.

TDS of 100% untreated polymer effluent before treatment was 10,150 mg/l ± 0.577 which were beyond the permissible limit (2100 mg/l) of CPCB (1995) but after degradation for 96 hrs, *E. coli* degraded TDS to 1,620.67 mg/l ± 1.1547 and the percentage change was 84.03%. TDS of polymer effluent was higher before biodegradation than the permissible limit of CPCB (1995) which may be due to presence of large amounts of salts in the effluent but after biodegradation of effluent for 96 hrs, maximum reduction of TDS 84.03% was recorded using *E. coli*. This is supported by the work of Noorjahan (2017).

BOD and COD of untreated effluent before biodegradation was much higher than CPCB (1995) permissible limit (30 mg/l). BOD of 100% untreated polymer effluent before treatment was 200 mg/l ± 0.577 which were beyond the permissible limit (30 mg/l) of CPCB (1995) for disposal but after degradation, *E. coli* degraded BOD to 178.667 mg/l ± 1.527 and the percentage change was 10.66%.

COD of 100% untreated polymer effluent before treatment was 610 mg/l ± 0.577 which were beyond the permissible limit (250 mg/l) of CPCB (1995), but after degradation, *E. coli* degraded COD to 488.75 mg/l ± 0.577 and the percentage change was 19.87%. On biodegradation for 96 hrs, the results does not show much reduction of BOD and COD level using *E. coli*. This is in agreement with the work of Harinee *et al.* (2018).

Thus from the results of the above study, it can be inferred that maximum degradation of physicochemical parameters such as EC, TSS and TDS were recorded using *E. coli* in biotreated sample compared to untreated sample.
Thus from the foregoing discussion, it is very clear that microbes play an important role in the biodegradation of organic and inorganic matter. During biodegradation, the key element is the micro-organisms. They have enzymes that allow them to use environmental contaminants as food and hence make them ideal for biodegradation. Besides their characteristics like rapid growth, metabolism and a remarkable ability to adjust to a variety of environments make them very useful in biodegradation. How successful are the micro-organisms in degrading the environmental contaminants depends on the type of microbes, contaminant and on the nature of the contaminated site (Noorjahan, 2017). From the present study, E. coli, showed efficient degrading capabilities by degrading the contaminants as they use it for their growth and reproduction. Organic compounds are a source of carbon which forms one of the basic building blocks of new cell contaminants. In addition to the carbon source, they require nitrogen and phosphorus as primary nutrients and traces of inorganic salts through a series of complex enzymatically catalysed reactions, the toxic organic contaminant is converted to innocuous chemical compound, obtain energy by catalysing energy producing chemical reactions and this energy is used in the production of new cells finally resulting in carbon-dioxide and water (Goudar and Subramanian, 1996).

Waste treatment is the most vital aspect in any wastewater management programme. The results of this study have shown that the biological treatment almost satisfied the irrigation water guideline.

Thus degradation by microbes seems to be the most promising technique for 100% untreated polymer effluent as evidenced in the present investigation. It is well known that water of good quality and free of pollutants are primary requirements for agricultural practice. After degradation, the treated water could be used for crop cultivation, irrigation and aquaculture purpose.

Hence after degradation of 100% untreated polymer effluent, the treated water was used for germination and growth of Impatiens balsamina for a period of 15 days using 100% untreated and biotreated (E. coli) polymer sample. The results of the effect of 100% untreated and biotreated (E. coli) polymer water on germination and growth of ornamental plant, Balsam - Impatiens balsamina (15 days) was shown in Table - 3. The results of the study revealed that in control (Tape water) plant, the growth of shoot length was 10±0.1, root length was 2.0±0.15, number of roots was 6±0.2 and number of leaves was 4±0.11 were recorded. In 100% untreated polymer effluent, the growth of the shoot length was 5.3±0.05, root length was 1.2±0.15, number of roots was 3±0.20 and number of leaves was 1±0.15 were recorded. Whereas in biotreated water (E. coli), the growth of shoot length of the plant was 8±0.2, root length was 1.4±0.15, number of roots was 5±0.15 and number of leaves was 3±0.25.

The presence of toxic substances in waste water has decreased the growth of Impatiens balsamina exposed to 100% untreated sample (Mehaytaab, 2008). Whereas increased rate of germination and growth of ornamental plant, Impatiens balsamina in 100% biotreated (E. coli) is due to the maximum removal of toxic substances (Noorjahan et al., 2004). Thus the results of the study revealed that in control (Tape water) plant, the growth of shoot length was 10±0.1, root length was 2.0±0.15, number of roots was 6±0.2 and number of leaves was 4±0.11 were recorded. In 100% untreated polymer effluent, the growth of the shoot length was 5.3±0.05, root length was 1.2±0.15, number of roots was 3±0.20 and number of leaves was 1±0.15 were recorded. Whereas in biotreated water (E. coli), the growth of shoot length of the plant was 8±0.2, root length was 1.4±0.15, number of roots was 5±0.15 and number of leaves was 3±0.25.

Hence from the results of the overall study the bacteria, E. coli degraded the toxic substances by showing maximum reduction from 10.66-98.93%. This biotreated water can be reutilized for the growth of ornamental plant as evidenced in the present study.

CONCLUSION

Hence from the overall results of the above study it can be concluded that bacteria E. coli played a key role in the degradation of untreated polymer effluent and the treated water can be utilized for growth of ornamental plant as evidenced in the present work. It can be recommended that the E. coli can be used for treatment of any industrial waste water. Since they have several advantages such as low energy consumption, low operation cost, fast growth rate and simple growth requirements. More over the treated water can be recycled for washing the industries, cooling towers etc. and also reused for agricultural and aquacultural purposes.

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