Chapter: 6

Discussions and Conclusion
It is the well known fact that the auto component industry now a day is considered the rising industry with huge growth potential. This industry is also expected to drive the growth of the engineering sector in view of its strong downstream and upstream linkages with many other segments of the engineering sectors like raw materials, capital goods, intermediate products etc. Today, the auto-component industry has emerged as a highly competitive segment of the manufacturing sector. Indian auto component industry is wide and has been one of the fastest growing segments of auto industry allover the world.

Now a days India is emerging as one of the key auto components centre in Asia and is expected to play a significant role in the global automotive supply chain in the near future. Automobile industry is not only a leading source of economic but also a leading source of pollution. Environmental point of view air, water and soil are highly affected by automobile sectors. Environmental pollution is one of the most horrible ecological crises, which occurs usually due to the addition of waste products of anthropogenic activities of intelligent human being. If these waste products are not removed by the natural process, and the biospheres are accumulated and cause pollution to environment, particularly in case of water.

During the production in automobile sector, huge quantity of water is utilized for various purposes like washing, cleaning, electroplating, phosphate-coating, and painting etc., using water is highly contaminated by various impurities such as heavy metals like Zinc (Zn), Copper (Cu), Lead (Pb), Chromium (Cr), Calcium (Ca), etc., coolant, phosphate-coating and paint particles. During the survey it is found that the generated wastewater is treated only by the chemical
methods, and thereafter it is directly discharged in natural resource of water. Due to the scarcity of water, waste water should be treated by proper manner so as to reuse the water for washing, cleaning and plantation purposes.

In general, physico-chemical methods, such as chemical precipitation, chemical oxidation or reduction, electrochemical treatment, evaporative recovery, filtration, ion exchange, and membrane technologies are widely used to remove heavy metal ions from the effluent in the automobile industries. All these processes are used especially when the heavy metal ions are in solutions form containing in the order of 1-100 mg dissolved heavy metal ions/L (Voilesky, 1990a; Volesky, 1990b). The operating costs of these processes are expensive. After employing all these methods, trace amount of heavy metals still remains in the effluent of automobile industries. Therefore biological methods such as bioaccumulation for the removal of heavy metal ions will prove an attractive alternative technique for physico-chemical methods. The removal of heavy metals by bioaccumulation process was also studied by Kapoor and Viraraghavan et. al (1995).

The Waluj MIDC area in Aurangabad of Maharashtra state was selected for studying the effluent characteristics and treatment methodology of automobile industries. The location of the Waluj MIDC area is shown in the figure no. 2.2. To know the characteristics of the generated effluents of the automobile industries parameters such as colour, odour, temperature, TSS, TDS, oil and grease, pH, DO, COD, BOD, PO$_4$, OUR (Oxygen uptake rate), MLSS (Mix liquor suspended solids), MLVSS (Mix liquor volatile suspended solid), SVI (Sludge volume index), and heavy metals were studied. The effluent generated
from the automobile industry is mainly contaminated with aromatic chemicals (as Thinners and paints particles), oil and grease (used for lubrication), phosphate and various heavy metals like chromium, copper, zinc, and lead (used for plating) etc. Hence to mention the effluent quality as per the MPCB norms it is one of the greatest challenges for the automobile industries.

During the analysis, various parameter characteristics of the inlet effluent of automobile were recorded. pH about to be neutral, whereas other parameters were recorded average mean values of TSS (287.6 mg/l), TDS (2673.2 mg/l), COD (6899.16 mg/l), BOD (1403.75 mg/l), O & G (5.95 mg/l), PO$_4$ (29.61 mg/l), Cu (12.58 mg/l), Cr (8.71 mg/l), Zn (19.15 mg/l), Fe (71.95 mg/l), Pb (3.92 mg/l), and Ca (0.53 mg/l) are recorded respectively. Dissolve oxygen (DO) was totally absent in the inlet effluent of automobile industries, 12 months average data is shown in the table no.3.1. After the analysis of the inlet effluent of automobile industries the results shows that each parameter concentration is very high as compared to MPCB norms. Therefore, before biological treatment, chemical treatment is very essential.

In general practice, automobile industries use sodium hydroxide (NaOH) and BTS-809 polyelectrolyte (cation) for treating the effluent in order to remove the impurities from the effluent. This practice shows that it is not a satisfactory combination for the effluent treatment, because sodium compound increase the salinity and yellowish colour of the effluent. Treated effluent with sodium hydroxide can not be used for plantation and agriculture purpose due to the high salinity. Market cost of the sodium hydroxide is 25 Rs. per kg. Therefore during investigation again, it is tried with another alternative treatment with more effective
results i.e. Ca(OH)$_2$ and BTS-809 polyelectrolyte (cation). During work 50 mg/l of Ca(OH)$_2$ (conc. 5%) and 10 mg/l of BTS-809 polyelectrolyte (conc. 0.1%) is used for treatment of the effluent. The immediate separation is observed and it is shown in the fig. no. 6.2. The cost of the calcium hydroxide in the market is 5 Rs. per kg. Calcium compound is contributed to the total dissolved solids (TDS) level as compared to sodium hydroxide. The high TDS level changes the reduction of COD in the treatment plants. Therefore treated effluent with calcium hydroxide can be used for various purposes such as plantation, cleaning, washing, purposes etc.

Fig.no. 6.1, shows the dosing adjustment for chemical treatment

Fig.no. 6.2, shows the result of before and after chemical treatment.
Inlet effluent of the automobile industries is highly dark blackish, reddish, whitish in colour due to the presence of paint particles and other impurities like oil and grease, phosphate, and heavy metals like Cr, Cu, Zn, Pb, and Fe etc. During the course of chemical treatment pH of the effluent is increased to 9.5 up to 10.5 due to the addition of Ca(OH)$_2$ some chemical alteration took place. The hydroxide groups from the calcium is attached to other heavy metal like Zn, Cu, Cr, Pb, and Fe, and get converted into hydroxide compounds like Zinc hydroxide, Chromium hydroxide, copper hydroxide, lead hydroxide and iron hydroxide etc. within 1 (one) minutes the polyelectrolyte is added to the effluent.

Polyelectrolyte helps to adhere impurities such as paint particles, oil and grease, phosphate etc. and each hydroxide group such as zinc hydroxide, chromium hydroxide, copper hydroxide, lead hydroxide and iron hydroxide are attached, and get converted into the flocs. The flocs are easily separated out from the effluent by gravitational force, with the help of this force the flocs are settled at the bottom of the reaction tank, and finally get cleaned and become alkaline effluent. The alkaline effluent is neutralized by addition of dilute sulphuric acid i.e. in the ratio of 1:1. After neutralization, the effluent is used as a feeding effluent in the bioreactor for biological treatment. The 12 months data is exhibited in the table no. 4.3. The average means values of the 12 months data of each parameters like pH (7.46), TSS (119.1 mg/l), TDS (1457.50 mg/l), COD (1655.6 mg/l), BOD (629.5 mg/l), DO (0.37), O & G (0.86 mg/l), PO$_4$ (4.87), Cu (2.91), Cr (2.60 mg/l), Zn (2.69 mg/l), Fe (9.08 mg/l), Pb (0.67 mg/l), and Ca (0.34 mg/l) are recorded respectively. Due to the
chemical treatment approximately 65% impurities load is reduced from the inlet effluent. After this treatment still some concentration of metals are found in the effluent. Therefore, these effluents are again treated by biological way.

Chemical sludge is generated after chemical treatment. Quantity of the sludge and heavy metal concentration are analyzed from the chemical sludge, 12 months mean values average data are given in the table no. 3.2. The average mean values of the chemical sludge per months is 45.38 gm, pH of the sludge is 10.06, oil and grease (5.07 mg), PO₄ (27.23 mg), Cu (9.67 mg), Cr (6.11 mg), Zn (16.45 mg), Fe (62.84 mg), Pb (3.24 mg), and Ca (0.23 mg) are recorded respectively.

To study the efficiency of biological treatment of the feeding effluent of automobile industries two pilot plants were set up at lab scale which is shown in the fig.no. 4.6 and 4.7, one is the conventional bioreactor plant (fig.4.7) and another is the novel bioreactor (fig.4.6) with modified the design concept. In general, the automobile industries are practicing with conventional type of bioreactor for the biological treatment. Therefore, to increase the efficiency of biological treatment a novel bioreactor has been designed during the investigation period. The novel bioreactor is designed in such a manner, in which two types of baffles walls are used, one is of half circle and another is of square inside the reactor. The isometric and schematic engineering view diagram of the novel and conventional bioreactor are shown in the figure no. 4.1, 4.2, 4.3 and 4.4. The related opinion was also given by many workers for the treatment of waste water Brindle et al. (1996).

The position of the impeller stirrer is differently in both the bioreactors for comparative study. The novel bioreactor has two
impellers, one at the bottom and another at the top of the stirrer, whereas conventional bioreactor has only one impeller at the top of the stirrer which is exhibited in the fig.no.4.5. Due to these differences in the bioreactor system, changes in the effluents are recorded in both bioreactors. The 12 months data are presented in the table no. 4.4 and 4.5.

The 12 months average mean values data of the novel bioreactor as pH (7.43), SVI % (57.41), TDS (1268.83 mg/l), COD (320.58 mg/l), MLSS (4768.2 mg/l), MLVSS (2412.75), DO (3.14 mg/l), OUR (0.81 mg/l), PO₄ (1.18 mg/l), Cu (0.80 mg/l), Cr (0.24 mg/l), Zn (0.24 mg/l), Fe (2.28 mg/l), Pb (0.19 mg/l), and Ca (0.08 mg/l) were recorded respectively, whereas parameters of conventional bioreactor like pH (7.43), SVI % (47.91), TDS (1312.75 mg/l), COD (833.66 mg/l), MLSS (4062.75 mg/l), MLVSS (2204.83 mg/l), DO (1.56 mg/l), OUR (0.43 mg/l), PO₄ (1.83 mg/l), Cu (0.91 mg/l), Cr (0.73 mg/l), Zn (0.48 mg/l), Fe (2.94 mg/l), Pb (0.29 mg/l), and Ca (0.13 mg/l) were recorded respectively. The similar findings were also reported by many workers from the metal contaminated water Anderson, J.G. et. al.(1987), Dvorak, D.H. et.al.(1992), Allard, A.S et. al. (1997), and Ansola et.al. (2003).

Some parameter like SVI (sludge volume index), MLSS (mix liquor of suspended solids), MLVSS (mix liquor volatile suspended solids), DO, and OUR (oxygen uptake rate) are studied in order to recognize the microbial growth rate in both the bioreactor. In novel bioreactor SVI is recorded 57.41 %, MLSS 4768.25 mg/l, MLVSS 2412.75 mg/l, DO 3.14 mg/l, and OUR 0.81 mg/l respectively whereas conventional bioreactor SVI is recorded 47.91 %, MLSS 4062.75 mg/l, MLVSS 2204.83 mg/l, DO 1.56 mg/l, and OUR 0.43 mg/l are recorded.
respectively. This difference indicates that bacterial growth rate in the novel bioreactor is more than the conventional bioreactor.

After the study, finally concluded that two impellers and baffles are assisting to increase the DO rate in the effluent, when the dissolved oxygen rate is increased in the effluent simultaneously the bacterial growth rate is also increased in the reactor. Proper mixing of the effluent and bacterial biomass is very essential during the biological treatment. The bottom impeller of the stirrer helps to mix the bacterial biomass in the effluent uniformly in the novel bioreactor. The baffles and the bottom impeller are absent in the conventional bioreactor. Therefore the bottom effluent and the biomass remain unchanged, and hence the anaerobic condition is revealed. Therefore the rate of bacterial growth decreases. When the parameters like SVI, MLSS, MLVSS, DO and OUR are at increasing side then the concentration of COD, BOD, PO₄ and heavy metals show towards decreasing. All these changes were shown in the table no. 4.4 and 4.5. Some experts have also reported same finding in the mineral hydrometallurg and from oil refinery streams Crundwell, F.K. (2003), and Babich, I.V. et. al. (2003).

The treated effluent sample from both the bioreactor were collected and analyzed. The outlet effluent quality of the novel bioreactor is analyzed and their parameter results as pH (7.30), TSS (31.83 mg/l), TDS (1236.0 mg/l), COD (68.25 mg/l), BOD (27.16 mg/l), DO (2.92 mg/l), O & G is BDL (Below detection limit), PO₄ (0.25 mg/l), Cu (0.14 mg/l), Cr (0.17 mg/l), Zn (0.19 mg/l), Fe (0.31 mg/l), Pb (0.02 mg/l), and Ca (0.01 mg/l) are recorded respectively, at the same time the outlet effluent of the conventional bioreactor is also analyzed and the results are pH (7.36), TSS (46.75 mg/l), TDS (1286.41 mg/l), COD
(618.58 mg/l), BOD (98.66 mg/l), DO (1.36 mg/l), O & G is BDL (Below detection limit), PO₄ (1.74 mg/l), Cu (1.0 mg/l), Cr (1.06 mg/l), Zn (1.01 mg/l), Fe (3.33 mg/l), Pb (0.23 mg/l), and Ca (0.12 mg/l) are recorded respectively. The 12 months average values of the both bioreactor data is illustrated in the table no.4.6 and 4.7.

The bio-sludge is generated after biological treatment. The quantity of the bio-sludge and heavy metal concentration are analyzed from the sludge, 12 months mean average values data of both the bioreactors are given in the table no. 4.8 and 4.9. The average mean value of the novel bioreactor biomass sludge per months is 0.133 gm, PO₄ (3.43 gm), Cu (1.96 gm), Cr (2.18 gm), Zn (2.23 gm), Fe (6.50 gm), Pb (0.46 gm), and Ca (0.25 gm) are recorded respectively, whereas conventional bioreactor biomass per months is 0.059 gm, PO₄ (1.30 gm), Cu (0.97 gm), Cr (0.81 gm), Zn (1.19 gm), Fe (2.82 gm), Pb (0.14 gm), and Ca (0.11 gm) difference in results are recorded respectively. Some of the authors are in opinion that there is continuous reduction in excess sludge production from the activated sludge process (Liu, Y. et.al. 2001), R. Gerards et. al. (2004), Curds, C. R. et. al. (1970), Curds, C. R. et. al. (1969).

The percent reduction in TDS, COD, PO₄, Cu, Cr, Zn, Fe, Pb, and Ca are calculated by following formula, but only COD example is presented here -

| Feeding effluent Average COD of per month | Bioreactor Average COD of per month | Outlet Average COD of per month | Next Month of Bioreactor Average COD of per month |
The percent reductions of the conventional and novel bioreactor are shown in the table no.6.1 and 6.2 of the respective months. Percentage mean values of the conventional bioreactor parameters are TDS (10.93%), COD (63.05%), PO$_4$ (65.10%), Cu (64.89%), Cr (61.06%), Zn (63.41%), Fe (64.43%), Pb (64.86%), and Ca (66.26%) are recorded respectively, similarly percentage mean values of the novel bioreactor parameters are also TDS (14.51%), COD (96.12%), PO$_4$ (96.03%), Cu (94.45%), Cr (93.83%), Zn (93.72%), Fe (95.72%), Pb (94.95%), and Ca (94.15%) are recorded respectively. After the investigation, both the bioreactor effluents it is finally concluded that the treatment efficiency of the novel bioreactor is between 29.56-33.07 %, which is more than the conventional bioreactor. Seviour et. al. (2003), and Kong, Y. et. al. (2007) also reported that the reduction of phosphorus from the activated sludge system.

Today various industries are well acquainted with diffuse bioreactor, because its efficiency is six times more than the surface (conventional) bioreactor. Even though it is feasible, but industries have been keeping away from the diffuse bioreactor, because of its high initial cost and maintenance cost. During the survey it is observed that all automobile and electro-plating industries are engaged with surface bioreactor (conventional bioreactor). To improve the efficiency of outlet effluent, a novel bioreactor has been designed during the work. After the comparative study, it is finally concluded that the novel bioreactor efficiency is 2 (two) times more than the conventional bioreactor. Hence it is recommended that the novel bioreactors can play a vital role in treating the effluent of automobile industries. Then novel bioreactor will
maintain the middle stage between the surfaces and the diffuse reactor. It is simple for installation and maintenance, and it is also economically reliable for operation. It too helps in oxygen transfer and for mixing thoroughly.

The microbe of the activated sludge helps to adsorb various heavy metals from the effluent. Therefore, during the work, some selective species of the bacteria as *P. aeruginosa*, *P. fluorescens*, *Alcaligens faecalis*, *Enterobacter aerogen*, *Bacillus subtilis*, *Aeromona hydrophila*, *Agrobacterium tumefaciens*, *Escherichia coli*, and *Zoogloea ramigera*, fungi as *Aspergillus niger* and plankton as *Sendedesmus*, *Ankistrodesmus*, *Paramecium*, *Arthrodesmus*, and *Diatoms as Navicula* were identified from the activated sludge of both bioreactors of automobile industries. The list of the isolated bacteria is given in the chapter 5th. In order to confirm the identified microbe’s, the samples were sent to the recognized laboratory for the confirmation.

Utgikar et.al in (2000), Ganguli, A. et. al. (2002), Curtin, M.E. et. al. (1983), Bozkurt, M.K. et. al. (2008), Crabtree, K.W. et. al. (1966), Crabtree, K.W. et. al. (1967), Andrade, L. et. al. (2003), Voeshy et.al. (1995), and Alas.Abbas et. al. (2006) all these workers were also identified some species of microbes like *P. fluorescens*, *Alcaligens faecalis*, *Enterobacter aerogen*, *Bacillus subtilis*, *Aeromona hydrophila*, *Agrobacterium tumefaciens*, *Escherichia coli*, *Zoogloea ramigera and fungi as Aspergillus niger* is isolated from the acid mine drainage and as well as from heavy metal effluents.

It is found that after the biological treatment most the heavy metal were reduced in the outlet effluent from the automobile industries. The initial feeding concentration of heavy metals like Cu
(2.91mg/l), Cr (2.60mg/l), Zn (2.69mg/l), Fe (9.08mg/l), Pb (0.67mg/l), and Ca (0.34mg/l) and at outlet effluents results of novel bioreactor are Cu (0.14mg/l), Cr (0.17mg/l), Zn (0.19mg/l), Fe (0.31mg/l), Pb (0.02mg/l), and Ca (0.01mg/l) are recorded respectively. It seems that remaining concentration of heavy metal is accumulated in microbes and in the algal biomass. These average results are illustrated in the table no. 4.3 and 4.7. Many workers have also reported that these same species are highly useful in the reduction of heavy metal concentration by bioremediation method from the waste water Nilanjan a Das et. al. (2008), Deleo, P.C. et. al. (1994), Gonzalez, A.R. et. al. (2005), Melean, J. et. al. (2001) and Suranjana et.al (2009).

Most prominently from algal species like scenedesmus, ankistrodesmus, and navicula species are found from bioreactor sludge. Interesting results were recorded during analysis of bio-sludge. It seems that these identified algal along with some microbes are helping in the removal phosphorus and also useful in the progressive reduction in COD analysis. The average mean value of PO$_4$ (96.03 %), and COD (96.12%) are recorded respectively. Hammouda O. et. al. (2002), Bojarajan, A. et. al. (2007), Chang, I.S. et. al (2004) are also reported same from microalgae aquaculture waste water treatment. The algal species which are identified during work shown interesting relation in the bio-accumulation of oil special ankistrodesmus species in the inlet feeding effluents (0.86mg/l) after process it is below detection limit with the supporting references of Ben-Amotz et. al. (1985), Castanier, L.M. et. al (2003) from the waste water.

All species of the bacteria, fungi, plankton, and diatoms are playing vital role in the treatment of the effluent of automobile
industries. As we are familiar with the use of micro-organisms in day today life, but these microbes can not survive for a long time without any matrix supports. Therefore, during the experimental work we have selected two matrixes as a biocarrier i.e. alumina silicate for powder formulation and another is sodium alginate for immobilization. Out of identified bacterial species it is noted that *P. aeruginosa* was found abundant in the effluent of automobile industries. Therefore *P. aeruginosa* was selected for the detail study by immobilization and powder formulation techniques.

The capsulation is one of the most popular method for immobilizing enzymes, this technique have been reported by Mathiasson 1983. Techniques permitting the large scale production of biocatalyst beads by forced flow of the gelling material through nozzles are being developed (Hulst et al. & 1985, Brouers M. et. al. 1989). The first report involving the study on immobilized algal was published by (Park et al. 1966), where they used chemically fixed chlorella cells. Nirupama Mallick (2002), and Gadd, G.M. (2002) has prepared immobilized algal capsule for waste water treatment. All these references are referred during the preparation of immobilization capsulate (beads).

Bartelt et al. (1990) worked on preparation of powder formulation of Bacillus thuringiensis, and Jones et al. (1998) has developed the powder formulation technology of microbial bio-pesticide and their application, with the support of all these references powder formulations is prepared for *P. aeruginosa* during the experimental work.

As per the lab scale study, the stabilization of the microbes by powder formulation and immobilization technique is conducted. A detail
procedure of powder formulation and immobilization it is discussed in the chapter no. 5th. It is observed that the self-life of the microbes in powder formulation is shown more stable than that of immobilization technique. It seems that the immobilization technique has only 7 months stabilization period which is exhibited graphically form in fig. no. 5.17 and in tabular form no. 5.12 for self-life of microbes (P.aeruginosa), whereas the same specimen shown 1 year stabilization period by powder formulation is also exhibited graphically form in the fig. no. 5.12 and in tabular form no.5.10. These differences are recorded during the work. P.aeruginosa species was found more predominant in the effluent of automobile industry. Therefore this species is selected for the stabilization for commercial purpose.

The trial test is executed during the work. In order to check the effectiveness of *P.aeruginosa* in powder formulation and in immobilization beads are used to treat the raw effluent of automobile industries. Three beakers of 1 litre capacity of raw effluent were taken for the experimental work. 2000 mg of each powder formulation, immobilization beads, and mix-culture of bio-culture were added in three different beakers and kept for 7 hrs. The mean average values were recorded after treatment. These are shown in the table no.6.3.
<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Parameters</th>
<th>Raw Effluent (mg/l)</th>
<th>After using mix bioculture (mg/l)</th>
<th>After using immobilization beads (mg/l)</th>
<th>After powder formulation (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>7.53</td>
<td>7.53</td>
<td>7.53</td>
<td>7.53</td>
</tr>
<tr>
<td>2</td>
<td>COD</td>
<td>5240</td>
<td>1041</td>
<td>1120</td>
<td>1750</td>
</tr>
<tr>
<td>3</td>
<td>Cr</td>
<td>7.04</td>
<td>0.70</td>
<td>0.84</td>
<td>1.40</td>
</tr>
<tr>
<td>4</td>
<td>Fe</td>
<td>54.21</td>
<td>16.21</td>
<td>16.59</td>
<td>22.47</td>
</tr>
<tr>
<td>5</td>
<td>Pb</td>
<td>3.12</td>
<td>0.53</td>
<td>0.70</td>
<td>1.19</td>
</tr>
<tr>
<td>6</td>
<td>Ca</td>
<td>0.52</td>
<td>0.10</td>
<td>0.21</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table no.6.3. shows the mean average values of the raw effluent after treated by the mix culture, immobilization beads and powder formulation. The percent reductions of parameters were also recorded after treating the raw effluents which is shown in the table no.6.4.

<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Parameters</th>
<th>Raw Effluent (mg/l)</th>
<th>% reduction in bioculture</th>
<th>% reduction in immobilization beads</th>
<th>% reduction in powder formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>7.53</td>
<td>7.53</td>
<td>7.53</td>
<td>7.53</td>
</tr>
<tr>
<td>2</td>
<td>COD</td>
<td>5240</td>
<td>19.86</td>
<td>21.37</td>
<td>33.39</td>
</tr>
<tr>
<td>3</td>
<td>Cr</td>
<td>7.04</td>
<td>9.94</td>
<td>11.93</td>
<td>19.86</td>
</tr>
<tr>
<td>4</td>
<td>Fe</td>
<td>54.21</td>
<td>29.90</td>
<td>30.60</td>
<td>14.44</td>
</tr>
<tr>
<td>5</td>
<td>Pb</td>
<td>3.12</td>
<td>16.98</td>
<td>22.43</td>
<td>38.14</td>
</tr>
<tr>
<td>6</td>
<td>Ca</td>
<td>0.52</td>
<td>19.23</td>
<td>40.38</td>
<td>67.30</td>
</tr>
</tbody>
</table>

(Table no.6.4)
The above investigation clearly indicates that when the microbes are in bioreactor along with other micro-organism take less part in the degradation, but after the isolation of microbes and providing with essential nutrients by immobilization and powder formulation techniques. The same microbe’s i.e. P. aeruginosa shows the more efficiency in the degradation of COD, Cr, Fe, Pb, Ca respectively the percent reduction in power formulation is shown higher with compare to mix culture, and in immobilization. The percent reductions are 33.39%, 19.86%, 14.44%, 38.14%, 67.30% respectively. These techniques will prove success in the commercial market. It also helps to tackle the pollution problem in automobile industries.

The results which is shown in the table no. 6.4 is only due to one species i.e. P. aeruginosa, but using other species as an alone or with other species combination i.e. bacteria with fungi or algal with fungi or bacteria with algal will be the area of interest in future studies, in order to tackle pollution load of automobile industries by the biotechnological approaches.