2 Literature Survey

2. 1 Bioremediation of pesticides

Bioremediation techniques consistently use living microorganisms to remove pesticides. Microorganisms may be occurring naturally or cultivated in laboratory. These microbes can ingest and metabolize the contaminants in the surrounding area to render the local area virtually contaminant free. The substances ingested include organic compounds, heavy metals, and pesticides. Bioremediation harness the process to use and promote the microbial growth, quick reproduction of these microbes that can degrade specific pollutant effectively and mineralized them to low toxic metabolites.

Bacteria, fungi, or plants can be used to treat pesticides at a contaminated site. The microbes play important role to breakdown of toxicants to less toxic products. The microbial degradation of pesticides that can occurs when microbes use pesticides as nutrients. One gm of soil may contain in excess of hundred million of bacterial species (including 5,000–7,000 variety of strain) and numerous fungal strains (Anjum *et al*., 2012; Kalevitch and Kefeli, 2007). The native microorganisms are used for mineralization of polluted environment (Karpouzas and Singh, 2006; Kumar and Philip, 2006; Siddique *et al*., 2003). Microorganisms obtained from natural site have been used extensively for degradation of pesticides (Ramsay *et al*., 2000; Richardson *et al*., 2002). The strains of *Acinetobacter johnsonii*, *Lysinibacillus*, *Bacillus* sp., and *Pseudomonas* sp. have been isolated from polluted site and sludge generated from the farming and manufacturing land used for pesticides degradation as shown in **Table 3** (Sujatha *et al*., 1999; Yadav *et al*., 2014; Geed *et al*., 2017)

Pointing (2001) reported that the fungal species have capability to transform a range of toxicants into less toxic compounds. The microbes present in the soil vary within a range of humid soil. In this range, the fungi have a better efficiency of toxicant removal (Dave *et al*., 1994; Paszczynski and Crawford, 1995; Verma *et al*., 2007). Highly intractable toxicants such as Atrazine (triazine herbicide 2-chloro-4-ethylamine-6-isopropylamino-1,3,4-triazine) altered with the help of fungi *Phanerochaetechry sosporium* and *Pleurotuspulmonarius,* produce hydroxylated and *N*-dealkylated intermediates (Masaphy *et al*., 1996; Mougin *et al*., 1994; Reddy and Mathew, 2001; Van Aken *et al*., 1999). Fungi were grown mostly by branching; filamentous mode shows more efficient degradation of contaminants (Verdin *et al*., 2004). The fungi are filamentous microorganisms that offer various advantages more than bacterial strain such as diversity in the oxidation of toxicants (Pointing, 2001).

The batch biodegradation of atrazine was studied by various researchers at different concentrations (100-500 mg/L) and found removal efficiencies of 64-95% by different isolates (Qingyan *et al.*, 2008; Chirnside *et al.*, 2009;Stelting *et al.*, 2014; Das, 2015). Plangklang and Reungsang. (2011) have reported the field study of Carbofuran using *Burkholder iacepacia* PCL3 at a concentration of 1630 μg/kg and observed the removal efficiency of 60%. Chlorpyrifos was successfully degraded by various species (*Ochrobactrum sp, Paracoccus sp, Pseudomonas putida* and microbial consortia, etc.) in a batch study by varying concentration of 50-500 mg/L and found corresponding removal efficiency of 50-97%. The operating condition for chlorpyrifos biodegradation was maintained at a pH (3-7), temperature (25-30ºC) and RPM (120-150) (Xu *et al.*, 2008; Abraham and Silambarasan, 2016; Liu *et al.*, 2016; Singh *et al.*, 2016)

Sari *et al.*, (2012); Qu *et al.*, (2015) and Liu *et al.*, (2015) have reported that the removal of DDT by various reactors (pilot-scale, batch, and continuous reactor) and different microorganisms by varying operating conditions and found the removal efficiencies of 73-92.11% at concentration of 6.97-35.449 mg/kg. Diazion and Endosulfan were biodegradated in a batch reactor by different isolates obtained from various contaminated sites under the optimized conditions. The removal efficiencies were observed for diazion to be 80-92% (Drufovka *et al.*, 2008; Cycon *et al.*, 2009; Cycon *et al.*, 2013) and for endosulfanto be 70-89% respectively (Bhalerao and Puranik, 2007; Kong *et al.*, 2013; Thangadurai and Suresh, 2014; Gupta *et al.*, 2016).

Liu *et al.* (2008) have performed the field experimental study on fipronil biodegradation by *Brassica pekinensis* species. Similarly, type of batch experiment was done by Tan *et al.*(2008); Mandal *et al.* (2013) and Mandal *et al.* (2014) under the optimum condition as shown in **Table 3**. Removal efficiencies was found to be 71 and 73% at a concentration of 1.50 and 20.5 mg/kg respectively. The biodegaradation of Lindane was studied by various bacterial species, the batch experimental results was observed and removal efficiency was noted to be 83.3-97% at a concentration range 1-100 mg/L (Saez *et al.*, 2015; Rigas *et al.*, 2005; Aresta *et al.*, 2015; Guillen-Jimenez *et al.*, 2012). Organophosphate pesticides such as Malathion and Methyl parathion were mineralized from the contaminated environment in a batch system using the various bacterial species. The experiments were performed under the optimum condition for malathion (25-250 mg/L) and methyl parathion (50-360 mg/L) and got removal 49.31-78 % (Adhikari *et al.*, 2010; Mohamed *et al.*, 2010; Singh *et al.*, 2012; Khan *et al.* 2016) and 41.66- 90 % respectively (Liu *et al.*, 2007; Zhao *et al.*, 2014; Rodrigues *et al.*, 2016).

Gundi and Reddy, (2006); Bhalerao and Puranik, (2009); Deng *et al.*, (2015) researchers investigated the performance of slurry and batch bioreactor under the optimum condition using the different potential species for the biodegradation of Monocrotophos pesticide. Monocrotophos removal was found to be 63-75% in a batch at a concentation of 50-500 mg/L and 96-98% in a slurry bioreactor at a concentration of 100 mg/kg respectively.

Table 3: Literature review on bioremediation of pesticides

Sl. No	Pesticide	Microorganism	Process	Experimental condition							References
				Batch study synthetic water Pesticide concentration (mg/L)	pH	Temperature (°C)	Stirring speed (RPM)	Duration (day)	Pesticide removal efficiency (%)	Lab scale study for pesticide degradation in soil	
1	Atrazine	*Arthrobacter sp.*	Batch (Flask incubation)	500	7	30	120	3	95	-	(Qingyan *et al.*, 2008)
		Pseudomonas sp.	Batch immobilized	100	7.4	25	150	70	64	-	(Stelting *et al.*, 2014)
		Pichia kudriavzevii	Batch immobilized	500	7	30	120	5	94.3	-	(Das, 2015)
		Microbial consortium	Site study	-	-	-	-	160	48	160 µg/kg soil	(Chirnside *et al.*, 2009)
2	Carbofuran	*Burkholder iacepacia*	Batch	-	6.9	Room temperature		35	-	5000µg/kg soil	(Plangklang and Reungsang, 2009)
		Burkholder iacepacia PCL3	Field study	-	6.7	29-32		60	-	1630µg/kg soil (Field study)	(Plangklang and Reungsang, 2011)
3	Chlorpyrifos	*Ochrobactrum sp*	Flask incubation	100-500	6.8-7	Room temperature	100	5	50	-	(Abraham and Silambarasan, 2016)
		Paracoccus sp.	Flask incubation	50	7	30	100	5	-	-	(Xu *et al.*, 2008)
		Pseudomonas putida	Flask incubation	10-100 µg/L	3	25	200	3	97	-	(Liu *et al.*, 2016)
		Microbial consortium	Flask incubation	-	7	30	150	10	82	50 mg/kg soil	(Singh *et al.*, 2016)
4	DDT	*Chryseobacterium sp.*	pilot-scale ex situ	50	6.5±0.5	Room temperature		45	80.3	6.97-35.37 mg/kg	(Qu *et al.*, 2015)
		Trametes versicolor	Batch	-	4.5			40	73	35.449 mg/kg	(Sari *et al.*, 2012)
		Microbial consortium	Slurry	-	7	Room temperature		20	78.93-92.11	33.23 mg/kg	(Liu *et al.*, 2015)

5	Diazinon	*Pseudomonas sp.*	Batch	50	7.2	30		14	80–92%	100 mg/kg soil	(Cycon *et al.*, 2009)
		Serratiamarcescens	Batch study	50	7.2	30		14	80	-	(Cycon *et al.*, 2013)
		Microbial consortium	Batch	10	7	28	150	4	35	-	(Drufovka *et al.*, 2008)
6	Endosulfan	*Alcaligenesfaecalis*	Flask incubation	100	7	40	-	5	89	-	(Kong *et al.*, 2013)
		Pseudomonas sp.	Flask incubation	-	7	37	200		86	203.465	(Gupta *et al.*, 2016)
		Aspergillus niger	Flask incubation	400	6.8	28±2	120	12	72	-	(Bhalerao and Puranik, 2007)
		Microbial consortium	Flask incubation	100	7	Room temperature	-	4	70	-	(Thangadurai and Suresh, 2014)
7	Fipronil	*Bacillus firmus*	Flask incubation	-	7	25	-	56	71	1.50-20.5 mg/kg	(Mandal *et al.*, 2014)
		Bacillus thuringiensis	Flask incubation	-	7	28	-	42	73	1.5mg/kg	(Mandal *et al.*, 2013)
		Brassica pekinensis	Field study	-	7±0.5	25±10	-	-	-	-	(Liu *et al.*, 2008)
		Microbial consortium	Flask incubation	-	5.85-8.35	30±1	-	19	-	2 μg/g soil	(Tan *et al.*, 2008)
8	Lindane	*Streptomyces consortium*	Batch immobilization	50	-	30	200	28	94	-	(Saez *et al.*, 2015)
		Pleurotusostreatus	Batch	4.46 mg/L	7	28	90	12	-	-	(Rigas *et al.*, 2005)
		Hymeniacidonperlevis	Batch	1 mg/L	-	Room temperature		8	97%	-	(Aresta *et al.*, 2015)
		Fusarium verticillioides	Batch	100	6.8	30±2	120	12	83.3	-	(Guillen-Jimenez *et al.*, 2012)
9	Malathion	*Bacillus sp.S14*	Flask incubation	25	7±0.2	30±1	120	10	64.5	-	(Adhikari *et al.*, 2010)
		Bacillus thuringiensis	Flask incubation	250	-	-	-	7	50	-	(Mohamed *et al.*, 2010)
		Bacillus cereus	Flask incubation	100	7±0.2	30	160	12	49.31	-	(Singh *et al.*, 2012)
		Bacillus licheniformis	Flask incubation	25	7.5	32	250	10	78	-	(Khan *et al.2016*)

10	Methyl parathion	*Pseudomonas sp.*	Batch study	50-100	7	28	180	-	75.95	-	(Zhao *et al.*, 2014)
		Penicilliumcitrinum	Batch study	120	8	27	130	15	90	-	(Rodrigues *et al.*, 2016)
		Fusarium proliferatum	Batch study	360	8	30	130	15	90	-	(Rodrigues *et al.*, 2016)
		Acinetobacter radioresistens	Batch study	130	5.0-8.0	30	200	4	41.66	-	(Liu *et al.*, 2007)
11	Monocroto-phos	*Aspergillus oryzae*	Flask incubation	100-500	6.8	30±2	120	8	75	-	(Bhalerao and Puranik, 2009)
		Stenotrophomonas sp.	Flask incubation	50	-	40	-	10	63	-	(Deng *et al.*, 2015)
		Microbial consortium	Batch slurry	-	6.5±0.5	28 ± 4	-	20	96–98%	100 mg/kg	(Gundi and Reddy, 2006)