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Pesticides utilization in agricultural sector of Gujarat and its effect on environment: A conceptual review

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Abstract
With the advent of technology in agriculture, and utilization of chemicals for improving production has led to application of pesticides. Pesticides were introduced to control pests and protect produces from crops. Subsequently pesticides got accumulated in soil and slowly entered into the ecosystem. Bioaccumulation of pesticides is leading to adverse effects on environment and thereby to living organisms. India being an agriculture based country is using pesticides from last few decades to improve the agricultural production. In India, Gujarat holds a significant position in agriculture and utilizes pesticides for controlling pests and improving production. The present review paper is prepared based on the researches depicting the adverse effects of pesticides application on environment in general and possible strategies to minimizing its effects by bioremediation techniques.

Keywords: pesticides, agriculture, environmental hazards, bioremediation

Introduction

As world population is expected to grow to nearly 10 billion by 2050, food production become the prime most objective of all countries. Based on evidence, world population is increasing by an estimated 97 million per year (Saravi and Shokrzadeh, 2011) [38], a huge portion of agricultural land is being depleted each year by industries and urban encroachments, which creates food scarcity. The increasing worldwide need of food demands a higher agricultural productivity, which can only be achieved by an extensive use of pesticides, because annually average 45% of the world total food productivity was lost due to pest infestations (Abhilash and Singh, 2009) [1]. Pesticides have now become an integral part of our modern life and are used to protect agricultural land, stored grain, flower gardens as well as to eradicate the pests transmitting dangerous infectious diseases.

Agriculture in India

India is primarily an agriculture based country with more than 60-70% of its population dependent on agriculture and covers maximum portion of its economy (Sachdeva, 2007) [37]. Indian agriculture sector has an impressive long term record of taking the country out of serious food shortages despite rapid population increase. After green revolution in 1960, the scenario of Indian agriculture has changed drastically due to promotion of high yielding varieties of crops that marked the green revolution, has led to large scale use of agrochemicals as pesticides. During this period of revolution a lots of agrochemical industries were established, which not only helped to increase the production of food grains, but also provided job opportunities to large population. Meanwhile, a vast majority of the Indian population have engaged in agricultural works and therefore, exposed to huge amount of pesticides utilised in agriculture for improving productivity though pest management practices. The increased demand of agrochemicals in changing regional climatic condition has resulted in high consumption rate and application of pesticides (Shetty, 2008) [41]. The annual spent on pesticides are approximately $38 billion in the world (Pan-Germany, 2012) [33]. The pesticides are a diverse group of inorganic and organic chemicals employed in agriculture as herbicides, insecticides, nematicides, fungicides and soil fumigants.

Organophosphates represent the largest group of chemical insecticides used in plant protection throughout the world (Hertel, 1993; Shimazu, 2001 and Zhongli, 2001) [21, 42, 49]. In agriculture, these pesticides are applied worldwide to enhance crop yield and quality and to maximize economic returns by prevention of pest attack. The pesticides are widely used to control agricultural and household pests. The use of pesticides helps to reduce the crop losses, provide economic benefits to farmers, reduce soil erosion and help to ensure food safety and security for the nation. Pesticide use is high in the cultivated regions with better irrigation facilities and where commercial crops are planted (Shetty, 2004) [32], e.g., cotton is grown in 5% of cropped area but uses up whopping 45% of total pesticides.

Pesticides utilization in Indian Scenario

Pesticides are the chemical substances used to kill pests such as unwanted plants, fungus, insects etc. in agricultural as well as domestic field. As reported earlier that 45% of annual food production is depleted by pest infestations (Abhilash and Singh, 2009) [1], effective pest management seems one of the main strategies to increase crop productivity for rapidly growing population, that requires utilization of a wide variety of pesticides in agricultural fields to combat pests. During the mid-1940s, the production and use of synthetic organic pesticides rapidly increased. By 1991, there were approximately 23,400 pesticide products registered with the U.S. Environmental Protection Agency (EPA). In 1997, 1.2 billion pounds of pesticides were used. Approximately 4.6 million tons of chemical pesticides are annually sprayed into the environment worldwide, in which currently about 500 pesticides with mass applications are organochlorine pesticides, some herbicides and the pesticides containing mercury, arsenic and lead are highly poisonous to the environment.About 140 organophosphate compounds being used as pesticides and as plant growth regulators around the world (*Kang*, 2006) [4].

In India, use of pesticides began in 1948 when DDT{1,1,1-trichloro-2,2-bis (4-chlorophenyl) ethane} was imported for malaria control and BHC (Benzene hexachloride) for locust control, but production started with the establishment of a plant for the production of BHC at Rishra near Calcutta followed by two units for manufacturing DDT by Hindustan Insecticides Ltd. By 1958, India was producing over 5000 metric tonnes of pesticides and in nineties, there are approximately 145 pesticides registered for use, and production has increased to approximately 85,000 metric tonnes. At present, India is the leading producer of pesticides among Asian countries. The Indian Pesticide Industry with 82000 MT of production for the year 2005-2006 is ranked second in Asia (behind China) and ranks twelfth in the world for the use of pesticides with an annual production of 90,000 tons (Gupta, 2004, Boricha and Fulekar, 2009) [20, 6].

[206]. India uses approximately 3% of total pesticides used in world and it is increasing at the rate of 2-5% per annum. Out of total pesticide consumption in India, approximately 67% is consumed by agriculture and horticulture field and insecticides accounts 75% of the total. The insecticides include organochlorines (40%), organophosphosphates (30%), carbamates (15%), synthetic pyrethroids (10%) and others (5%). The remaining 25% of total pesticides used are fungicides (10%), herbicides (7%) and others (8%).As per official data presented by the Directorate of Plant Protection, Quarantine and Storage, Govt. of India, during the period of 2005-06 to 2009-10, sulphur, a fungicide is the maximum consumed pesticide in India with a total of 16424 metric tonnes (MT) followed by endosulfan, as summarised in Table 1.

Table 1: Example of most consumed pesticides in India (2005-06 to 2009-10)

S. No.	Pesticide (Technical Grade)	Quantity consumed (MT)
1	Sulphur (fungicide)	16424
2	Endosulfan (insecticide)	15537
3	Mancozeb (fungicide)	11067
4	Phorate (insecticide)	10763
5	Methyl Parathion (insecticide)	08408
6	Monocrotophos (insecticide)	08209
7	Cypermethrin (insecticide)	07309
8	Isoproturon (herbicide)	07163
9	Chlorpyrifos (insecticide)	07163
10	Malathion (insecticide)	07103
11	Carbendazim (fungicide)	06767
12	Butachlor (herbicide)	06750
13	Quinalphos (insecticide)	06329
14	Copper oxychloride	06055
15	Dichlorvos (insecticide)	05833

Source: Directorate of Plant Protection, Quarantine and Storage, Govt of India) (www.indiaforsafefood.in/farminginindia.html)

As agricultural development becomes the most important objective of Indian planning and policy, pesticides play an important role as a plant protecting agent for boosting food production. The Indian agriculture are dependent on use of pesticides and agrochemicals to increase the productivity. During the green revolution, more chemical fertilizers and pesticides were used to enhance the production of food grains needed to meet the needs of the ever expanding human population. Although use of chemicals to control pest dates back to 2500BC, but in the mid -1940s the production and use of synthetic organic pesticides increased rapidly and by 1991, approximately 23,400 pesticide products were registered with the U.S. Environmental Protection Agency (EPA). In India, cotton accounts maximum consumption of pesticide across agricultural crops with 45%, followed by rice (22%), vegetables (9%), plantation crops (7%), pulses (4%), wheat (4%) and others (9%) (Subramanyam, 2012). (Fig. 1) [45].

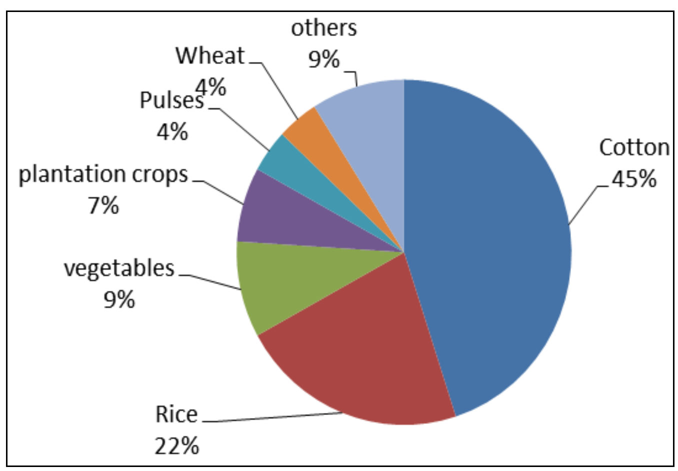
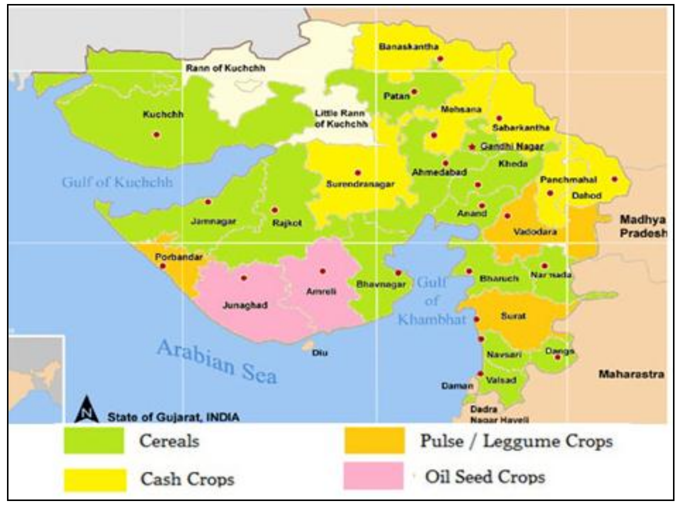


Fig 1: Pesticide consumption by different crops in India

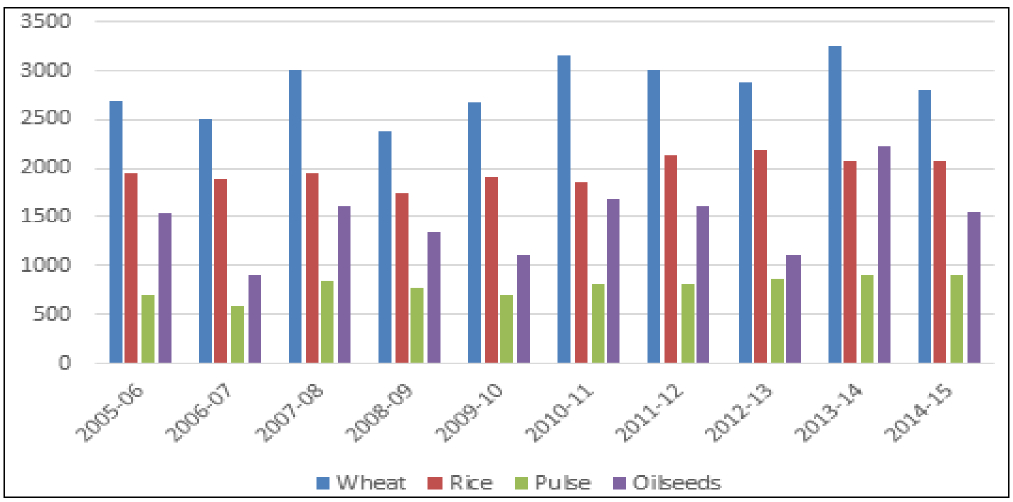
Agriculture in Gujarat

Gujarat is the one of the fastest growing states of India. Gujarat constitutes nearly 6.2 % of total geographical area and 4.99 % of total population of India. It has made rapid strides in economic growth, particularly in manufacturing and service sectors. Yet the role of the agriculture sector remains crucial because it is the main source of employment for majority of population. Agriculture, which is the main stay of the people in Gujarat, forms a major part of the state economy and provides Gujarat with the required food grains, as well as it also contributes a major share for the adjoining areas. As per Census 2011, about 3.47 crores people of the state live in rural areas forming about 57.4 % of its total population (GoI, 2011) [17]. About 70.5 % of total workers in the state are rural based and agriculture is the primary occupation. About 51.8 % of total workers are cultivators and agricultural labourers. Despite of many hindrances, one of the vital part of Gujarat agriculture is that the cropping pattern, which is predominant with cash crops. The major cash crops in the state are cotton, groundnut, tobacco, sugar cane, cumin, rice, pulses and vegetable including green chillies. Gujarat is the single largest cotton producing state with 36% of the total national production. According to Agricultural Statistics at a Glance 2015, Ministry of Agriculture, the major food grains production in Gujarat has been fairly volatile during the past decade, 200 06 to 2014-15 (Fig.3).



Source: http://glpc.co.in

Fig 2: District wise agriculture production in Gujarat



Source: Agricultural Statistics at a Glance 2015, Ministry of Agriculture; PRS

Fig 3: Major food grains production in Gujarat during 2005-06 to 2014-15

Pesticides use in Gujarat

Gujarat has adopted a novel pattern of progress with the strategic development in the key sectors like energy, industry and agriculture for which it has achieved ambitious double digit growth rate since 10th Five Year Plan period. In the state of Gujarat, where the commercial cropping is predominant, the use of pesticides are common to protect them from pests. They are used to application of pesticides for the protection of crops from pests for higher production. As per data available from Department of Agriculture, Government of Gujarat, the estimated consumption of technical grade pesticides was approximately 3643 metric tonnes during 2001-2002. According to the Directorate of Plant Protection, Quarantine and Storage, Government of India (2010); Gujarat consuming 13430 metric tonnes of pesticides, stands 6th in maximum pesticides consuming state during 2005 to 2010 (Table 2).

Table 2: The maximum pesticide-consuming states in India (during 2005–2010)

Sl. No.	State	Pesticides consumption (MT)
1.	Uttar Pradesh	39948
2.	Punjab	29235
3.	Haryana	21908
4.	Maharashtra	16480
5.	Rajasthan	15239
6.	Gujarat	13430
7.	Tamil Nadu	12851
	All India	210,600

Source: Directorate of Plant Protection, Quarantine and Storage, Govt. of India. (www.indiaforsafefood.in/farminginindia.html)

Environmental Hazards due to pesticides application

Although consumption of pesticides in India is comparatively very low with respect to many other countries, but there has been a widespread contamination of food commodities with pesticide residues, basically due to non-judicious usage. Unfortunately, India is included among those countries, where production and use of some chlorinated pesticides such as DDT and lindane is still going on (Abhilash and Singh, 2009; Vijgen 2011) [1, 48].

Despite of many benefits of pesticides, it can be hazardous to both humans and the environment. Improper use and misuse of pesticides in agriculture has increased the risk of environmental contamination due to the dispersion into non-target sites. A number of chemicals are environmentally stable and prone to bioaccumulation, and cause toxicity (Fenik, 2011) [14]. Because some pesticides can persist in the environment, they can remain there for years. Environmental contamination or occupational use can expose the general population to pesticides residues, including physical and biological degradation products present in the air, water, soil and food (Mostafalou and Abdollahi, 2013) [29]. Uncontrolled practice of pesticide application in agricultural field attributes greatly to the environmental and health hazard. Intensive use of chemicals in agriculture has contributed to build up of many hazardous compounds in air, soil and water, which cause environmental pollution (Patnaik, 1997) [35]. Improper handling and unsafe spraying of the agrochemicals cause high risk of health hazards (Bag, 2000; Gupta, 2004) [3, 20]. Pesticide usage has direct impact on human beings and the environment. According to the Environmental Protection Agency (EPA), 60 % of herbicides, 90 % of fungicides and 30 % of insecticides are known to be carcinogenic.

Effects on Human /Animal Health

It is reported that more than 2500 pesticides are currently in use in the world (Singh, 2006) [43]. Recent evidence indicates that pesticides may damage the immune system and can mimic hormones and may thus disrupt the endocrine system in both humans and animals, causing a variety of disorders. According to the United Nation, approximately 1 to 5 million cases of pesticides poisoning occur every year, resulting in several thousand fatalities among agriculture workers (Northoff and Williams, 2004). Survey performed on the basis of pesticides application in the agricultural field by farmers in Punjab showed various health problems including cancer, kidney failure, still birth; infertility, etc. (Abhilash and Singh, 2009) [1].

Continuous and excessive use of pesticides can not only cause death but also induce various diseases. Among the total cancer patients 10 % are resulted from pesticide poisoning (Gu and Tian, 2005) [19]. The incidence of breast cancer was linearly correlated with the frequency of pesticide uses (Chen 2004) [8], and organochlorinated pesticide, DDT and its derivative such as DDE are likely responsible for breast cancer. In developing countries where users are often illiterate, ill-trained, and lacking appropriate protective devices, the risks are magnified. As per report available from Poison Information Centre in National Institute of Occupational Health, Ahmedabad, organophosphorus pesticides were responsible for the maximum number of poisonings (73%) among all agricultural chemicals (Dewan and Sayed, 1998) [12]. In a study of 190 patients of acute organophosphorus pesticide poisoning muscrinic manifestations were recorded (Bhatnagar, 2001) [5]. In certain developing countries, it has been observed that organophosphate pesticides are responsible for death in more than 70% cases and intentional poisonings make up a large proportion of the poisonings by pesticides of high toxicity (Gupta, 2004) [20].

Pesticide toxicity depends on various factors such as the route of exposure, concentration and time of exposure. The toxicity of pesticides from exposure to contaminated food is mostly unknown but the growing evidence of neurological damage, endocrine disruption, cancer, and birth defects are considered as major consequences of exposure (Miller and Sharpe, 1998; IARC, 2001; ATSDR, 2005) [27, 23, 2]. In addition, some organophosphate compounds may cause induced delayed neuropathy (Cho, 2001) and immunotoxicity towards human beings and wild-life (Galloway and Handy, 2003) [16]. The toxicity of organophosphatesis primarily associated with inhibition of acetyl cholinesterase, a vital enzyme involved in neurotransmission as acetylcholine substitutes (Bakry, 2006). [4]. which can interferes with muscular responses and leads to death (Shimazu, 2001) [42] in human and other exposed organism (Cho, 2001; Bravo, 2002). [24, 10, 4]. There are other clinical effects such as neck muscle weakness and diarrhoea in humans (Grimsley, 1998; Serdar and Gibson, 1985) [18, 39]. Also observed.

Organophosphorus pesticides poisoning is a worldwide health problem with around 3 million poisonings and 200,000 deaths annually (Karalliedde and Senanayake, 1999, Sogorb, 2004) [25, 44]. In general, Pyrethroids are less toxic than organochlorine, organophosphate and carbamate pesticides with some exception of esfenvalerate, deltamethrin, bifenthrin, tefluthrin, flucythrinate, cyhalothrin and fenpropathrin which show the highest acute oral toxicity. As studies carried out as acuteness and sub-acuteness of pesticides, pyrethroids has shown neurotoxic effect at higher doses and liver hypertrophy which are reversible if death does not occur. Some of the pyrethroids are mildly to severely irritating to the skin and eyes, whereas some cause facial skin sensitization. Improper use of pesticides can result in various health problems like pesticides poisoning in farmers and farm workers such as neurological and skin disorders, cardiopulmonary, miscarriages, foetal deformities and lowering the sperm counts in applicators (Bag, 2000) [3]. According to a report of WHO and UNEP, worldwide there are more than 26 million human pesticide poisonings with about 220,000 deaths per year (Richter, 2002) [36].

In India, the first report of pesticides poisoning was come from Kerala in 1958, where over 100 persons died due to consumption of parathion contaminated wheat flour (Karunakaran, 1958) [26]. During 1970s, a number of villages were severely affected by endosulfan, a dangerous insecticide in Kasargod, Kerala, due to over spraying by state-owned Plantation Corporation of Kerala to check tea-mosquito attacks. The farmers of that villages noted serious health problems to their cattle population due to water contamination. The signs of serious ailments were also seen in case of women and children (Tholkappian and Rajendran, 2011) [47]. Subsequently several cases of pesticide-poisoning including the Bhopal disaster have been reported. In an extensive review of 573 cases of acute pyrethroid poisoning between 1983 and 1988 in China, most occurred from occupational or accidental exposure. The person suffered different health problems like dyspnea, nausea, headache and irritability due to accidental pyrethroids poisoning caused by introduction of insecticide into air conditioning ducts (Chen 1991) [9]. Chronic sequelae to pyrethroids exposure include cerebro-organic disorders, sensomotor-polyneuropathy in the lower extremities and vegetative nervous disorders, like paroxysmal tachycardia, increased heat sensitivity and reduced exercise tolerance related to circulatory dysfunction (Muller-Mohnssen, 1999) [30].

Effects on Environment

According to a report from the EPA of the United States, many of rural wells in the nation contain at least one of 127 pesticides. A research panel of Indiana University analysed barks from 90 sites from the equator to high latitude cold regions, and detected DDT, aldrin and lindane residues. The residues of DDT have been detected in the Greenland ice sheet and the bodies of Antarctic penguins which were resulted from atmospheric circulation, ocean currents and biological enrichment of pesticides. The excess use of pesticides leads to an accumulation of a huge amount of pesticide residues in the environment, therefore causing a substantial environmental health hazard due to uptake and accumulation of these toxic compounds in the food chain and drinking water (Mohammed, 2009) [28].

Bioremediation for alleviation of pesticides pollution

Bioremediation is a process in which microorganisms or their enzymatic products are employed to destroy or reduce the concentrations of hazardous wastes from contaminated sites without further disruption to the local environment. Bioremediation technologies utilize relatively low cost techniques, which generally have a high public acceptance and can often be carried out on site. It involves the utilization of naturally occurring microorganisms to degrade or detoxify persistent pollutants hazardous to human health as well as the environment. The rate of degradation depends on the type of pesticides, soil type, climate, the species of microbes present and the size of their population. The microorganisms used in bioremediation may be indigenous to the polluted area or they may be isolated from elsewhere and brought to the polluted sites. Pollutants are transformed by living organisms through various reactions such as biotransformation, biomineralization, bioaccumulation, biodegradation, bioremediation and co-metabolism (Shakoori, 2000, Park, 2003, Finley, 2010) [40, 34, 15], that take place as a part of their metabolic processes.

Nowadays wide array of molecular biology techniques are used to identify and analyse various aspects of microorganism such as gene and protein function, their interactions, metabolic and regulatory pathways. These techniques are facility quick analysis at molecular level to understand the cellular metabolism of microorganism (Desai, 2010) [11]. The genetic engineering, transcriptomics, proteomics and interactomics are now routinely been used in bioremediation process to study exact mechanism involved. The pesticide degrading microorganisms have ability to promote plant growth and yield due to production of phytohormones, ammonia, siderophore. The biological nitrogen fixation and phosphate solubilization have the antagonistic activity against phytopathogenic microorganism. These pesticide degrading microorganisms improve the soil health and fertility and thus, enhance the sustainable agriculture.

Conclusion

In current scenario, higher dose of pesticides are in use in agriculture sector in unmanaged manner for higher production of grain yield. But only 2-3% of the total pesticides used reached to the target point, rest remains in the environment and pollute the water, soil and air, and cause many human diseases. Bioremediation that involves the capabilities of microorganisms in the removal of pesticides would be the most promising, relatively efficient and cost effective technology.

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