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Chemical Fertilizers and Pesticides in Indian Agriculture: Effect on Human Health and Environment

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ABSTRACT: Green revolution has shown the way to the world, how to improve production in the agriculture products to achieved the food demand for the booming of world's population. But along with the increase in the production of the food, the utilization of agrochemicals has also been increased very rapidly, and after few decades of start of green revolution, it had been increased up to the level, where it become one of the major environmental threat, which we have to address at an urgent basis. The uncontrolled use of these synthesised agrochemicals disturbing ecological dynamics, and creating several health related issues not only in the human being but in other living beings also. India is the biggest producer and consumer of agrochemicals in the world. This review is going to address the issues and impact of the production and consumption of these highly toxic and banned agrochemicals in India and how it is interfering with the health related problems.

Keywords: Chemical fertilizers, Banned pesticides, Plant growth regulators, Pollution, Human health.

INTRODUCTION

In India, Green revolution was started in 1960 due to the eminence efforts of the agricultural scientist namely Monkombu Sambasivan Swaminathan and others. It involves the yielding varieties of the grains along with chemical fertilizers, pesticides and heavy irrigation to increase the crop yields (Parayil, 1992; Sebby, 2010). The use of chemical fertilizer as well as pesticides have been increased rapidly after 1960s and green revolution slowly and stately become the greed revolution (Chakravarti, 1973; Chand and Birthal, 1997; Abhilash and Singh, 2009). A report of parliamentary standing committee on Agriculture (11, August 2016) in India stated that use of chemical fertilizers increased from one million tonnes to 25.6 million tonnes from 1960 to 2014-15. There are number of reports in Indian scenario where farmers are using excessive agrochemicals willingly or in the absence of proper awareness and training (Government of India, 2016a).

Excessive use of these chemicals has adverse effects at several levels. Primary on the production level, to fulfil the farmers demand, there is excessive production of these chemicals due to which investment at the level of input as fuels and raw chemical etc. has been increased several folds. Those chemical which cannot be produced in India or Indian industries or not able to meet the farmers demand are imported from the other countries. Government investing a huge amount of money to meet the demand of agrochemicals (Government of India, 2016a; 2018). On secondary level these chemicals are responsible for contamination and air, soil and water pollution (He *et al*., 2005; Loukil *et al.*, 2015; Bishnoi, 2018). Industries involved in the production of these agrochemicals are producing a huge amount of industrial effluent which contains a large amount of toxic chemicals and heavy metals. They are disturbing and disrupting the whole ecosystem, contaminating the ground water and causing several severe diseases such as cancer, asthma, diabetes, cognitive effects etc. (*He et al*., 2005; Sarwar, 2015, Government of India, 2016a). Moreover, the enhanced and unselective use of chemical pesticides and fertilizers has led to soil fertility depletion, microbial population and reduction in crop production (Valiki *et al.*, 2015; Arora, 2016).

Agrochemicals used in India Broadly, the agrochemicals are classified under 3 categories; chemical fertilizers, pesticides and plant growth regulators.

Chemical fertilizers

Consumption of Chemical Fertilizers in India

India is the 2nd in the world, after China, in the consumption of the chemical fertilizers (IFA, 2017). Chemical fertilizers are used basically for 3 macronutrients as nitrogen, phosphorus and potassium. They are collectively called as NPK. There are various types and grade of fertilizers for these macronutrients, which are produced or used in India (Government of India, 2017). Although the first fertilizer industry in India was established in 1906 Ranipet, Tamil Nadu but its production and consumption stated grooming after green revolution (FAO, 2005; Tandon and Tiwari,

2007). According to the fertiliser association of India, the production of fertilizes and consumption of NPK fertilizers were 201.6 and 65.6 tonnes in 1951-52, is now enhanced up to 41427.8 and 25949.9 tonnes in 2016-17, respectively (Fig. 1 and 2).

The enhancement in the production and consumption of fertilizers in the year 2016-17 is about 395 and 205 times more than that it was in 1951-52(FAI, 2015).

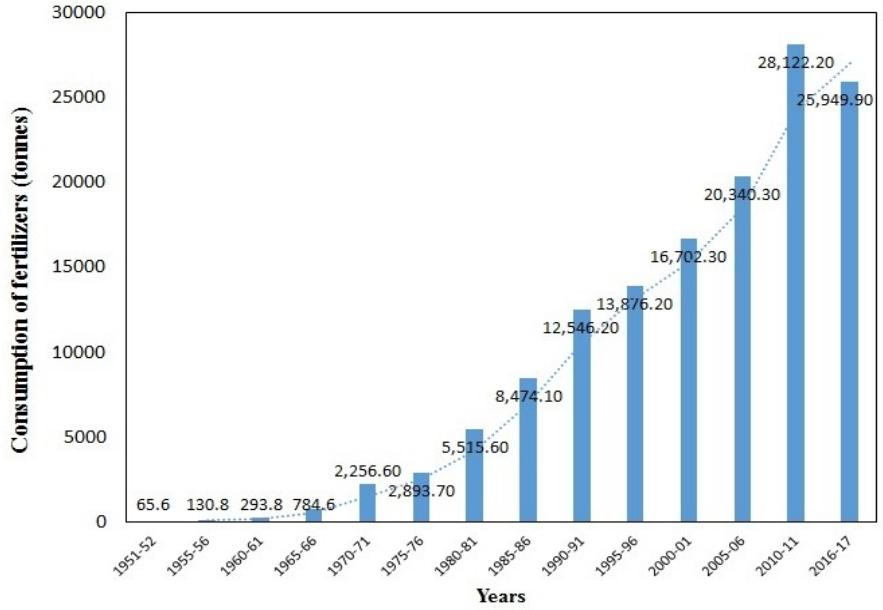

Fig. 1. Consumption of NPK fertilizers in India during 1951-52 to 2016-17 (Source: Fertiliser Association of India).

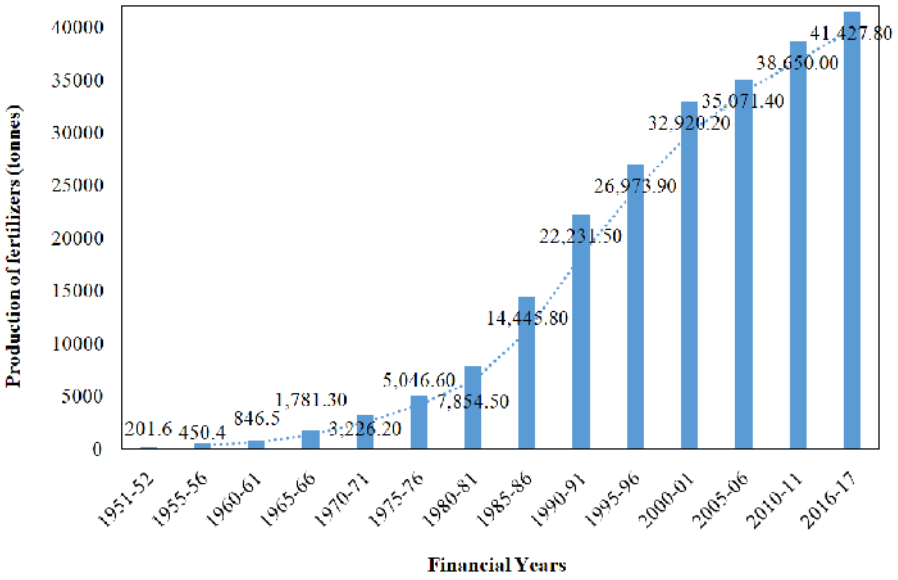

Fig. 2. Production of fertilizers in India during 1951-52 to 2016-17 (Source: Fertiliser Association of India).

Due to the lack of the commercially viable sources of potash, India fulfil its requirement of potassic fertilizers through imports. The proportion of indigenous produced fertilizers and the imported fertilizers in total used NPK fertilizers in India for past 5 years is shown in the Fig. 3 (Government of India, 2017).

Data regarding the exact use of chemical fertilizers in India is little controversial, according to the data given by Department of Agriculture & Cooperation and Department of Fertilizers, the total use of NPK fertilizers in 2014-15 was 25576 tonnes (Fig. 3). Whereas according to the report of parliamentary standing committee on agriculture (2015-16), presented in the Lok Sabha and Rajya Sabha on August 11, 2016, the use of urea only in 2014-15 was 30609.97 tonnes, use of NPK fertilizers was 41088.88 tonnes (Government of India, 2016a; 2017; Mazen *et al.*, 2018).

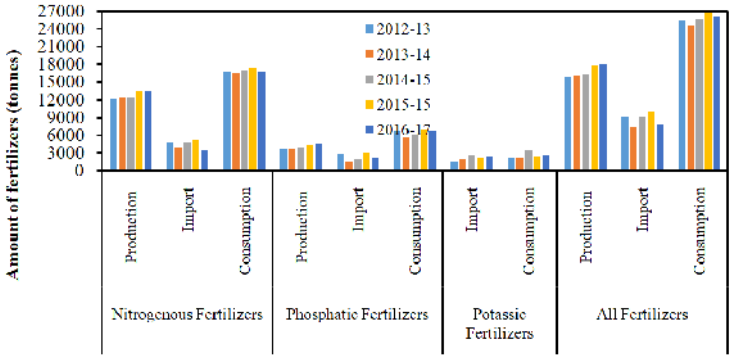

Fig. 3. Production, imports and consumption of fertilizers in India during 2012-13 to 2016-17.

Imbalance in use of Fertilizers: India is using huge amount of chemical fertilizers and there is a lot of imbalance in the use of fertilizers not only in terms of the total use but also in the consumption ratio of N, P and K. Around 292 districts are observed as 85% consumption of all fertilizers during 2014-15. The higher consumption ratio i.e. 6.7:2.4:1 was recorded against desirable ratio of 4:2:1. The condition is grimmer in major agricultural states such as Punjab and Haryana, where NPK use ratio is higher as 31.4:8:1 and 27.7: 6.1:1, respectively (Government of India, 2016a). The average consumption of chemical fertilizer per hectare of area is increasing continuously, as it increased form 2 kg/ha (1960-61) to 180.75 kg/ha (2011), but there is a lot of variation in state-wise consumption (Index Mundi, 2021; Tandon and Tiwari 2007; Government of India, 2016a). In the year 2014-15 states like Andhra Pradesh, Karnataka, Uttar Pradesh and Punjab have average consumption of 237.23, 231.43, 227.46, and 221.44 kg/ha, respectively, whereas states like Tamil Nadu, Goa, Odisha, West Bengal and Arunachal Pradesh have average consumption of only 40.55, 54.51, 38.39, 57.49 and 6.34 kg/ha, respectively (Government of India, 2016a).

Ban on Fertilizers: Unscientific use of chemical fertilizers may force the government to impose the ban on chemical fertilizers. One such report is from Kerala, where, the Kerala Agriculture University (KAU) recommended to restrict the use of all the high analysis mixture fertilizers, but the agriculture department of Kerala banned only the NPK 18:18:18, with effect from April 1, 2019 (The Times of India, 2019a). Other such report is from USA, where at least 11 states of USA ban the use or sale of phosphorus fertilizer (OLR Research Report, 2012).

Impact of Chemical Fertilizers: The by-products of the fertilizer industries and use of fertilizers itself effecting the human and animal health along with the environment in several ways. Some of them are summarised in Table 1.

Table 1: Some major symptoms, disease and ecological impacts caused by the fertilizers and its by-products.

Fertilizers and its by-products	Symptoms and disease	Environmental impacts
Urea	Skin diseases (Bremner 1990).	Decrease in soil pH, acidification and adverse effects on seed germination (Bremner 1990; Savci 2012).
Ammonium and nitrogen oxides	Respiratory illness, asthma, methaemoglobine, infant disease and premature death etc. (Savci 2012; Loukil *et al*., 2015; Bishnoi 2018).	Ozonedepletion, global warming and acid rain etc. (Motavalli *et al.*, 2008; Savci 2012).
Phosphorus	Hyperphosphatemia, renal failure, heart disease, arthritic syndromes, atherosclerosis, and osteoporosis (Sharpley and Menzel 1987).	Increase the concentration of cadmium in soil. Eutrophication in lakes and ponds (Sharpley and Menzel 1987, Bennett *et al*., 2001).
Potassium chloride	Gastric disease and stomach pains, dizziness, bloody diarrhea (Loukil *et al*., 2015).	Disrupt the balance of nutrients in soil (Sharpley and Menzel 1987).

Pollution of Water Resources: Groundwater is polluted with nitrates and recorded as above pollution of ground water in agriculturally rich states namely Andhra Pradesh, Gujarat, Haryana, Punjab and Maharashtra (Government of India, 2016a). There are several types of metals present above the permissible levels in the contaminated water due to production and use of chemical fertilizers, such as aluminium, lead, chromium, zinc, copper, cobalt, cadmium etc. and the continuous consumption of these waters may cause various types of dangerous diseases such as cancer, arthritic syndromes, diabetes, kidney disease, improper mental and physical growth, hypertension, haemoglobin deficiency, hair loss, skin diseases, low sperm counts and impotence in men, and reduce fertility in women etc. (Loukil *et al*., 2015; He *et al.*, 2005).

Soil Pollution: Excess use of fertilizers is responsible for the deterioration of soil fertility. Toxic substances accumulate within the vegetables and causing negative effects in humans and animals such as nitrogen fertilizers (decrease soil pH), potassium fertilizers (disrupt nutrients balance). High level of nitrogen consists of carcinogenic substances such as nitrosamines (spinach and lettuce showed harmful accumulation of NO_3 and NO_2) (Savci, 2012).

Air Pollution: Excess use of nitrogen fertilizers causes air pollution by nitrogen oxides (NO, N_2O, NO_2), which along with the other atmospheric gases contribute to the

greenhouses effect, ozone depletion and acid rain etc (Savci, 2012). The emissions of Nr (reactive nitrogen) released into the atmosphere from industry, cities, agriculture and contribute to the vast levels of particulate matter (PM 2.5), ground level O_3 and NOx in the air we breathe contribute to premature death and other serious health effects (Bishnoi, 2018).

Pesticides

Consumption of Chemical Pesticides in India: It is observed that approximately 5.6-billion-pound pesticide are used annually which causes poisoning in 25 million agricultural workers (World Ecology Report, 2019). India among the top 10 pesticide consuming countries in the world (World atlas, 2019). First pesticide produced in India in 1948 as organochlorine insecticide DDT, since then, it developed as major agrochemical industry and in 2013-14 India consumed a total of 60282 metric ton of pesticides (Bhardwaj and Sharma, 2013; Government of India, 2016b). Like the chemical fertilizers, the use of chemical pesticides in India start growing after the green revolution. It grows continuously up to 1990-91, after that with little fluctuations, it is more or less constant. In term of Kg per hectare, Panjab and Haryana are the top pesticide consumer in India (Kumar *et al.*, 2013; Devi *et al.*, 2017). Demand and consumptions of pesticides in India during 2010-11 to 16-17 are summarised in Fig. 4.

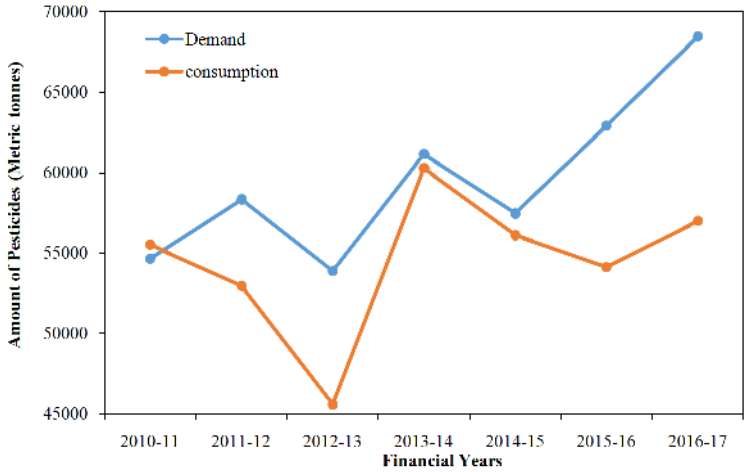

Fig. 4. Demand and consumption of pesticides in India during 2010-11 to 16-17 (Source: States/UTs Zonal Conferences on Inputs (Plant Protection))

Use of Banned and hazardous Pesticides in India: At present time, a total of 288 pesticides are registered for the use in the India (Government of India, 2016b). According to the pesticide action network (PAN), a total of 85 pesticides registered for use in India are banned in other parts of the world. In India 6 pesticides namely, dichlorvos and phorate and are bannedin 2020. Fig.5 shows an outlook of the banned pesticides according to the number of countries in which they are banned.

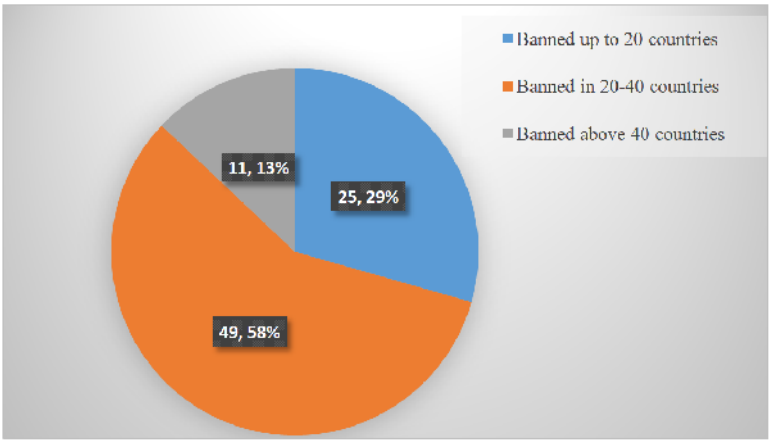

Fig. 5. Pesticides banned in other countries but are registered for use in India (Source: Pesticide Action Network).

There are about 20, 36 and 17, highly hazardous, moderately hazardous and slightly hazardous banned pesticides which are currently registered for used in India (WHO, 2010, Government of India, 2016b, PAN-International 2018, PMEP 2018). The toxic effect and consumption of banned pesticides is summarised in Table 2. Hazardous pesticides registered for the use in India, which are not banned for use in other parts of world, their toxicity and consumption in past 5 years (2011-12 to 15-16) is summarised in Table 3.

Table 3: Hazardous pesticides registered for the use in India (other than the banned one), their toxicity and consumption during last 5 years (2011-12 to 2015-16).

Sr. No.	Chemical Name	Trade and Other Names	Acute Toxicity (Chronic toxicity C: Carcinogenic; M: Mutagenic; T: Teratogenic)	Symptoms	Consumption during 2011-12 to 2015-16 (MT)	References
1.	Abamectin	Avermectin B1 and MK-936. Trade names include Affirm, Agri-Mek, Avid, Dynamec, Vertimec and Zephyr.	High	Moderate eye irritation and mild skin irritation		PMEP 2018
2.	Chlorantraniliprole		High	Eye and dermal Irritation	145	Government of India 2016b; PAN-international-2016; EPA 2008a
3.	Clothianidin		High	Eye Irritation	4	Government of India 2016b; PAN-international-2016; EPA 2003a
4.	Cypermethrin***	Ammo, Arrivo, Barricade, Basathrin, CCN52, Cymbush, Cymperator, Cynoff, Cypercopal, Cyperguard 25EC, Cyperhard Tech, Cyperkill, Cypermar, Demon, Flectron, Fligene CI, Folcord, Kafil, NRDC 149, Polytrin, PP383, Ripcord, Siperin, Stockade and Super	High	Irritation to the skin and eyes	8785	Government of India 2016b; PAN-international-2016; PMEP 2018; The Times of India 2018b
5.	Deltamethrin (Decamethrin)	Butoflin, Butoss, Butox, Cislin, Crackdown, Cresus, Decis, Decis-Prime, K-Othrin, and K-Otek	High	Ataxia, convulsions leading to muscle fibrillation and paralysis, dermatitis, edema, diarrhea, dyspnea, headache, hepatic microsomal enzyme induction, irritability, peripheral vascular collapse, rhinorrhoea, serum alkaline phosphatase elevation, tinnitus, tremors, vomiting and death due to respiratory failure.	221	Government of India 2016b; PAN-international-2016; PMEP 2018
6.	Dichloropropene	Telone II, Dow Telone	High	Skin and dermal irritation		PAN-international-2016; PMEP 1986; EPA 2000b
7.	Dodine	Dodine acetate, doguadine (France), and tsitrex (USSR). Trade names include AC 5223, Apadodine, Carpene, Curitan, Cyprex, Efuzin, Melprex, Sulgen, Syllit, Tebulan, Vandodine and Venturol.	High	Severe eye irritation	252.32	Government of India 2016b; PMEP 2018
8.	Epoxiconazole		High	Eye Irritation		PAN-international-2016; EPA 2006
9.	Ethion	Ethanox, Ethiol, Hylemox, Nialate, Rhodiacide, Rhodocide, RP-Thion, Tafethion, VegfruFosmite	High	Inflammation and redness in the eye and skin	308	Government of India 2016b; PMEP 2018
10.	Ethofenprox**		High	Skin and eye irritation	24.5	FAO 2007; Government of India 2016b; PAN-international-2016; Gktoday 2018
11.	Fenazaquin		High	No skin, eye, dermal irritation	3.42	Government of India 2016b; PAN-international-2016; EPA 2007b
12.	Flumioxazin		High	Eye and skin irritation		PAN-international-2016; FAO 2017b
13.	Glyphosate****	Roundup, Rodeo, and Pond master	High (C)	Irritation of skin, eye and respiratory tract	2674.5	Penn State Extension. 2017; Government of India 2016b; PMEP 2018; The Times of India 2018a; The Hindu 2018; 2019a
14.	Haloxyfop-R-methyl 10.55%.EC(FI)	Verdict, Gallant, Zellek, and Dowco 453 ME (haloxyfop methyl) or Dowco 453 EE (haloxyfopethoxyethyl)	High	Mild eye irritants		PAN-international-2016; PMEP 2018

15.	Hexythiazox	Savey	High	Respiratory tract, skin, and eye irritant	5.35	Government of India 2016b; PAN-international-2016; PMEP 1989; PPDB 2019b
16.	Imidacloprid***	Admire, Condifor, Gaucho, Premier, Premise, Provado, and Marathon	High (M, C)	Fatigue, twitching, cramps, and muscle weakness. Skin, eyes irritant		NPIC 2010; PAN-international-2016; PMEP 2018; The Times of India 2018b
17.	Imiprothrin		High	Dermal Sensitizer, Eye Irritation	5	Government of India 2016b; PAN-international-2016; EPA 1998
18.	Indoxacarb		High	Moderate eye irritant, dermal sensitizer	241	Government of India 2016b; PAN-international-2016; EPA 2000c
19.	Iprovalicarb		High		3	Government of India 2016b; PAN-international-2016
20.	Lufenuron		High	Skin sensitizing		PAN-international-2016; FAO 2008b
21.	Meptyldiinocop Or Dinocap	Arathane, Caprane, Capryl, Cekucap 25 WP, Crotonate, Crotothane, DCPC, Dikar (a mixture of dinocap and mancozeb), DNOPC, Ezenosan, Iscothane, Karathane, Mildane, Mildex.	High	Irritating to the skin, eyes, and mucous membranes lining the nose, throat and lungs	17.5	Government of India 2016b; PAN-international-2016; PMEP 2018
22.	Metaflumizone		High			PAN-international-2016
23.	Methabenzthiazuron		High			PAN-international-2016
24.	Metribuzin	Bay 94337, Bay DIC 1468, Lexone, Sencor, Sencoral and Sencorex	High	Irritation of the mucous membranes of the upper respiratory tract	664	Government of India 2016b; PAN-international-2016; PMEP 2018
25.	Metiram	Carbatene, NIA 9102, Polyram, Polyram-Combi, Zinc metiram	High (M)	Moderately irritating to the skin and respiratory mucous membranes	7	Government of India 2016b; PAN-international-2016; PMEP 2018
26.	Milbemectin		High	Eye irritation		PAN-international-2016; Toxnet
27.	Prallethrin		High	Eye irritant	2	Government of India 2016b; PAN-international-2016; WHO 2004
28.	Primiphos-methyl	Actellic	High	Causing nausea, dizziness, confusion, and at very high exposures respiratory paralysis and death.	21.30	Government of India 2016b; PAN-international-2016; PMEP 1985; EPA 2016
29.	Profenofos***		High	May be fatal if inhaled, skin and eyes irritant	658.1	Pub Chem 2021; Government of India 2016b; The Times of India 2018b
30.	Pyridaben		High	Eye irritation		PAN-international-2016; PMEP 2018
31.	Pyridalyl		High	Skin and eye irritant		PAN-international-2016; EPA 2008b
32.	Quizalofop-P-tefuryl		High	Skin sensitizer, eye irritant		PAN-international-2016; PPDB 2019c
33.	Spinetoram		High	Dermal sensitizer		PAN-international-2016; EPA 2009
34.	Spinosad		High	Skin or eyes irritation	363.5	Government of India 2016b; PAN-international-2016; NPIC 2014

35.	Sulfoxaflor		High			PAN-international-2016
36.	Tetraconazole		High	Eye irritant, dermal sensitizer		PAN-international-2016; EPA 2005b
37.	Thiacloprid		High	Eye and dermal irritation	42.70	Government of India 2016b; PAN-international-2016; EPA 2003b
38.	Thiamethoxam**		High		149.72	FAO 2010; Government of India 2016b; PAN-international-2016; The Tribune 2019
39.	Thiophanate-Methyl	Topsin M, Fungo, Cercobin-M (48)	High	Skin sensitizer	269.75	Government of India 2016b; PAN-international-2016, PMEP 2018; EPA 2004b
40.	Allethrin	Allethrin: Alleviate, Pynamin. d-trans allethrin: D-Trans Conc. 90%, bioallethrin, MGK 264 and Esbiothrin	Moderate (M)	Iitching, burning, tingling, numbness, nausea, vomiting, diarrhea, hyper excitability, incoordination, tremors, convulsive twitching, convulsions, bloody tears, muscular paralysis etc.		PMEP 2018
41.	Bentazone	Basagran, Bendioxide, Bentazone, Bas 351-H, Leader, Pledge	Moderate	Vomiting, diarrhea, trembling, weakness, and irregular or difficult breathing		PMEP 2018
42.	Chlorpyriphos	Brodan, Detmol UA, Dowco 179, Dursban, Eradex, Lorsban, Piridane, Stipend	Moderate	Skin and eye irritation	4550	Government of India 2016b; PMEP 2018
43.	Copper Sulphate	BSC Copper Fungicide; CP Basic Sulfate; Tri- Basic Copper Sulfate. Pentahydrate form: bluestone, blue vitriol, Salzburg vitriol, Roman vitriol, and blue copperas, Bordeaux Mixture is a combination of hydrated lime and copper Sulfate	Moderate	Corrosive to the skin, eyes and respiratory tract. Metallic taste, nausea, vomiting, intestinal pain	2492	Penn State Extension; Government of India 2016b; PMEP 2018
44.	Fluvalinate	Klartan, Mavrik, Mavrik Aqua Flow, Spur and Yardex	Moderate	Irritation to the skin and eyes	2	Government of India 2016b; PMEP 2018
45.	Lambdacyhalothrin	Charge, Excalibur, Grenade, Hallmark, Icon, Karate, Matador, OMS 0321, PP321, Saber, Samurai and Sentinel	Moderate	Corrosive effects to skin and eyes		PMEP 2018
46.	Triadimefon	Amiral, Bay MEB 6447, and Bayleton	Moderate	Reduction in body weight, a decrease in enzyme activity	11.2	Government of India 2016b; PMEP 2018
47.	Ametryne	Evik, Ametryne, Ametrex, Gesapax (1), G34162, Trinatox-D (a combination with 2,4-D), Crisazina-Crisatrina Kombi (a combination with atrazine)(2), Doruplant, Mebatryne, and Amephyt	Slight	Nausea, vomiting, diarrhea, muscle weakness, and salivation		PMEP 2018
48.	Carboxin	Cadan, Padan, Sanvex, Thiobel, and Vegetox	Slight (M)	Vomiting and headache		PMEP 2018
49.	Clomazone	Command, Commence, Gamit, Magister and Merit	Slight			PMEP 2018
50.	Diflubenzuron**	Dimilin	Slight		3	Government of India 2016b; PMEP 2018; Gktoday 2018
51.	Dimethomorphe	Dimethomorphe, Acrobat, Forum, CME 151, and WL-127294	Slight		1	Government of India 2016b; PMEP 2018
52.	D-trans Allethrin	Allethrin: Alleviate, Pynamin. d-trans allethrin: D-Trans Conc. 90%, bioallethrin, MGK 264 and Esbiothrin.	Slight to Moderate	Itching, burning, tingling, numbness, a feeling of warmth	110.6	Government of India 2016b; PMEP 2018
53.	Triallate	Avadex BW, CP 23426, Diptal, Far-Go, Buckle, TDTC Technical and Carbamothoic acid	Slight			PMEP 2018
54.	Metolachlor	Bicep, CGA-24705, Dual, Pennant, and Pimagram	Slight	Cramps, anaemia, shortness of breath, dark urine, convulsions, diarrhea, jaundice, weakness, nausea, sweating, and dizziness. Irritation of skin and eye		Penn State Extension 2017; PMEP 2018
55.	Oxycarboxin	Cadan, Padan, Sanvex, Thiobel, and Vegetox. It is very often used in combination with other fungicides such as	Slight	Vomiting and headache	4	Government of India 2016b; PMEP 2018

		thiram or captan				
56.	Quizalofop ethyl	Assure II, Pilot Super, Targa D+ and Targa Super	Slight	Slightly irritating to the eyes	88	Government of India 2016b; PMEP 2018
57.	Buprofezin**		Low to moderate	Slightly irritating to the eye	60	FAO 2008a; Government of India 2016b; The Tribune 2019
58.	2,4-Dichlorophenoxy Acetic Acid	2,4-D, Barrage	Low	Irritation to skin, mucous membrane, vomiting, headache, diarrhea, confusion, bizarre or aggressive behaviour, muscle weakness in occupationally exposed individuals	3784	PennState Extension 2017; NPIC 2009b; Government of India 2016b
59.	Cymoxanil	Curzate, Sygan, and Syphal	Low	Irritation of the skin and eyes	6	Government of India 2016b; PMEP 2018
60.	Metsulfuron Methyl	Ally, Allie, Gropper, and Escort	Low	Mild skin irritation	468.95	Government of India 2016b; PMEP 2018
61.	Sulphur	Cosan, Crisazufre, Hexasul, Sulflox, Tiolene, and Thiolux	Low	Irritation of skin and the mucous membranes	7443	Government of India 2016b; PMEP 2018
62.						
63.	Tricyclazole**		Low	Harmful by inhalation	247.62	Kawai 1989; Government of India 2016b; The Tribune 2019
64.	Thiophanate methyl**		Low	Mild skin and eye irritant, skin sensitizer	269.75	Toxnet; Government of India 2016b; FAO 2017a; Gktoday 2018; The Tribune 2019
65.	Kasugamycin**		Very low	Mild eye irritant	120	EPA 2005a; Government of India 2016b; Gktoday 2018; PMEP 2018
66.	Chlorfenopyr**		Inhalation toxic	Inhalation irritation		EPA 2001; Gktoday 2018
67.	Ethephon	Arvest, Bromeflor, Etheverse, Flordimex, Flordimex T-Extra, Cerone, Etherel, ChipcoFlorel Pro and Prep				PMEP 2018
68.	Azoxystrobin	Abound, Amistar, Bankit, Heritage, and Quadris		Acute dermal, inhalation and eye irritation	21	Government of India 2016b; PMEP 2018
69.						
70.	Imazethapyr	Contour, Hammer, Overtop, Passport, Pivot, Pursuit, Pursuit Plus, and Resolve				PMEP 2018
71.	Propamocarb hydrochloride technical 66% w/w min (Aqueous concentrate)	Banol, Prevex, Previcur, Tattoo C, Tattoo M, Dynone, Filex, and Proplant		Eye and skin irritation		PMEP 2018
72.	Pyrethrin (pyrethrum)	Buhach, Chrysanthemum Cinerariaefolium, Ofirmotox, Insect Powder, Dalmation Insect Flowers, Firmotox, Parexan and NA 9184		Asthmatic breathing, sneezing, nasal stuffiness, headache, nausea, incoordination, tremors, convulsions, facial flushing and swelling, and burning and itching sensations		PMEP 2018
Total					**35549.78 MT**	

**Banned in Punjab
*** Banned in Maharashtra
****Banned in Kerala, Maharashtra and Punjab

Non-Genuine/Illegal Pesticides in India: A huge amount of pesticides used in India are non-genuine/illegal, which are very determinately affecting the agriculture sector of India. Pesticides (non-genuine/illegal) trade is on the rise even in relatively developed rural markets. Illegal import of technical grade chemicals without Central Insecticide Board and Registration Committee (CIB&RC) registration has led to the creation of a local pesticide market as shown in Fig. 6.

Counterfeiting the products of market leading companies, a new practice has also emerged whereby counterfeiters are selling pesticides in the name of 'organic products' to avoid the stringent registration process. as shown in Fig. 7.

Fig. 6. Non-genuine/illegal brands selling chemical pesticides with name "look-alike" to the branded genuine product. (Source: Federation of Indian Chambers of Commerce & Industry).

Fig. 7. Non-genuine/illegal brands selling chemical pesticides in the name of bio-pesticides. (Source: Federation of Indian Chambers of Commerce & Industry).

In a data of Federation of Indian Chambers of Commerce and Industry (FICCI) in collaboration with Tata Strategic Management Group (TSMG) showed that manufacturing of non-genuine/illegal pesticides was around Rs 3,200 crore in 2013. The growth in the counterfeit pesticides market is summarised in Table 4.

Table 4: Non-genuine/ illegal pesticides market size in India.

Financial Year	Counterfeit pesticides market size in India (Rs.)	Reported by
2008-09	1,200 Crore	Agrochemicals Policy Group (APG)
2009-10	1,400 Crore	Agrochemicals Policy Group and FICCI report on Indian Agrochemical industry
2013	3,200 Crore	FICCI and Tata Strategic Management Group

Moreover, the amount of these pesticides is not determined on various parameters like environmental degradation, non-target organisms, soil fertility, residues etc. They have no effect on the pests and hence, decreased production is obtained by the farmer and it also poses a threat to the health of the farmer (FICCI, 2015; Krishijagran, 2017).

Use of Pesticides Banned and Unapproved in India

The other major issue in the field of agriculture is used of pesticides already banned in India. For example, carbofuron was banned by the government of India on July 1, 2001, but it is still in use as Punjab government banned the use of Carbofuron on July 24, 2019 (Government of India, 2016b, The Tribune, 2019). The use of the unapproved pesticides on crops is another major issue in India (The Hindu-Business Line, 2018).

Improper use of pesticides: The amount of pesticide actually either directly exposed to or consumed by the targeted pests is a very small percentage of the applied amount. Although large amounts of insecticides are used on some crops, it is estimated that less than 0.1% of pesticide used for pest control affect the target pest. This means that over 99.9% of applied pesticides end up in the environment where they can adversely affect beneficial biota, like natural enemies, and contaminate the soil, water and atmosphere of our ecosystem. There are many reasons behind the disappearance of pesticide targets, but the most important are the techniques used in spraying and training individuals on the proper use of pesticides (Pimentel, 1995).

Impact of pesticides: Pesticides have contaminated almost every part of the environment. They cause serious health hazards to living systems due to their rapid fat solubility and bioaccumulation in non-target organisms (Agrawal *et al.,* 2010).

Water Pollution: Pesticides can enter water through surface runoff or through leaching. Suspended sediments of these pesticides can change water quality and affect many life forms. They are being toxic to aquatic organisms, and cause various diseases humans and other animals (Stevenson *et al.*, 1997).

Air Pollution: Frequent exposure to pesticides can be very dangerous to humans and other living organisms because they are designed to be toxic. Many life threatening risks are associated with exposure to the air contaminated with harmful chemical pesticides. There are various routes of exposure of the pesticides to animals and humans such as: dermal exposure, oral exposure, respiratory exposure and eye exposure. Pesticides can cause several severe human diseases such as cancer, asthma, diabetes, parkinson's disease, leukemia, cognitive effects, and infertility etc. (Sarwar, 2015).

Soil Pollution: Heavy soil treatment with pesticides can reduce populations of beneficial soil microorganisms. They can also affect many biological processes that are conducted by microorganisms to the benefit of plants such as the common landscape herbicides Triclopyre inhibits soil bacteria that convert ammonia to nitrites. They can block nitrogen fixation, inhibit the growth of mycorrhizal fungi, reduce the general biodiversity in the soil. Pesticides can directly affect non-target vegetation and are also responsible for soil erosion (Pell *et al*., 1998).

Plant growth regulator: Plant growth regulators are the 3rd class of chemical which are used in agriculture for growth promotion and better yield. There are several plant growth regulators used in India. Toxic effect and consumption of plant growth regulators are summarised in Table 5. Five plant growth regulators *viz.* chlorpropham, coumetetralyl, hydrogen cyanamide, paclobutrazole, and validamycin, which are used in India but banned in other countries.

Table 5: The symptoms and toxic effect of plant growth regulators and their consumption in India during last 5 years (2011-12 to 2015-16).

Sr. No.	Plant Growth Regulator	Acute Toxicity	Symptoms	Consumption during 2011-12 to 2015-16 (MT)	References
1.	Coumatetralyl*	High	Dermal and eye irritation	2	Toxnet; Government of India 2016b; PAN-international-2016; Murphy 2018
2.	Hydrogen Cyanamide*	High	Severe irritation and ulceration of the eyes, skin, and respiratory tract	4	Toxnet; Government of India 2016b
3.	Sodium Cyanide	High	Exposure to sodium cyanide can be rapidly fatal. It has systemic effects, particularly affecting those organ systems most sensitive to low oxygen levels: the central nervous system, the cardiovascular system, and the pulmonary system	1	CDC- NIOSH 2011; CSBP 2016; Government of India 2016b
4	Chlormequat chloride	Moderate	Dermatitis, irritates slightly the eyes.	28	Toxnet; Bardale *et al.* 2012; Government of India 2016b;FAO 2017a
5	Chlorpropham*	Moderate	Irritation of the eyes and skin		Government of India 2012; PAN-International 2018; PMEP 2018
6	Planofix (NAA)	Moderate	Corrosive, irritant, respiratory irritant, eye, skin	3	Government of India 2016b; Pfaltz & Bauer 2018
7	Paclobutrazole*	Moderate to low	Mildly irritating to skin and eyes	11	New York state department of environmental conservation 2000; Government of India 2016b; PMEP 2018
8	Forchlorfenuron	Low	Eye irritant		EPA 2004a; Government of India 2012
9	Gibberellic acid	Low	Irritation occurs in eyes and skins	195	Toxnet; EPA 1995; Abou-zeid and Abd-Ellah 2015; Government of India 2016b
10	Meleic hydrazide	Low	Irritating to eyes, nose, throat, and skin		Toxnet; EPA 1994
11	Mepiquat chloride	Low	Dermal irritant		Toxnet; EPA 1997; Government of India 2012
12	Triacontanol	Low	Eye, skin irritation, respiratory tract irritant	177	Bibra 1997; Cayman 2015; Government of India 2016b; PPDB 2018b
13	Alpha Napthyl Acetic Acid		Skin, mucous membrane, and severe eye irritant.	169	Toxnet; Government of India 2016b
14	Validamycin*	Non-toxic	Eye, dermal irritation.	136	Toxnet; Extoxnet 1996; Government of India 2016b
15	Ethephon	non-toxic	May be irritating to exposed skin and eyes, or if inhaled		Toxnet; Government of India 2012
Total				**726 MT**	

*Plant growth regulators restricted for use in countries other than India.

Some major tragedies caused by toxic pesticides in India

Bhopal gas tragedy: It is one of the world worst accident which was took place to the Union Carbide Corporation's chemical plant in Bhopal. Methyl isocyanate is an intermediate compound used in the production of carbamate pesticide. About 45 tonnes of methyl-isocyanate gas leaked in the Bhopal gas tragedy on 3 December 1984 at around 1:00 pm. Around 3800 people died instantly in the plant (slum area). The predictable death toll was 10,000, with close to 20,000 premature deaths. (Pesticide action network Asia Pacific 2017).

Kasargod end osulfan tragedy

Kerala's (Kasaragod) state-owned Plantation Corporation conducted trials on aerial spraying of endosulfan in its 45,000-hectare in 1977-78. Routine aerial spraying 2 to 3 times per year began in 1981 and caused disability in the villagers and domestic animals of Padre, Enmacaje. The Kerala Sastra Sahitya Parishad (1994) reported that the disability rate among people was 73% higher than the overall disability rate in the whole state (Adithya 2009; Pesticide action network Asia Pacific 2017).

The Yavatmal scandal

In 2017, hundreds of cotton farmers were poisoned and more than 40 people died in a matter of weeks in the central Indian district of Yavatmal, Maharashtra. A cocktail of highly dangerous pesticides, including the insecticide known as Polo. Syngenta exports this insecticide from Switzerland, where it has been banned for a long time (The Yavatmal scandal 2018; First post 2018).

Some death/accident records due to the direct contact/use of pesticides

- In Kerala 1958 first report of poisoning due to pesticides where over 100 people died after consuming wheat flour contaminated with parathion (Aktar *et al.,* 2009).
- During 90s, in Bhopal one survey was revealed that 58% of drinking water samples (hand pumps and wells) contaminated with Organo Chlorine pesticides (Aktar *et al*., 2009).
- Farmer commits suicide every 30 minutes, most of them by swallowing pesticides (The Yavatmal scandal, 2018).
- During 1997 to 2002, 8040 patients were hospitalized with insecticide poisoning, and 1819 of these died. The highest number of patients in a year was 1643 with 326 deaths (CFR 20%) in 2001, the lowest was 1035 deaths in 2002 with 230 deaths (CFR 22%). Highest CFR occurred in 1999, with 24% of patients dying (Srinivas Rao *et al.*, 2005).
- There were over 3500 suicides in Yavatmal district from early 2001 to mid-2016. As on July 14, 2018, the latest figures between March and May in Maharashtra - 639 suicides (The Yavatmal scandal 2018).
- According to the 6 studies carried out in 11 states of India by Pesticide Action Network Asia Pacific (PANAP) during 2015-18, 70% of the farmers and farm-workers have suffered ill-effects due to pesticide exposure (The Hindu-Business Line 2018).
- According to the figures given by agriculture ministry in the Lok Sabha on 5 March 2018, in Maharashtra due to the pesticide poisoning as many as 272 deaths in the last four years (The Times of India 2018c).
- Between August 2018 and September 2018, 3 farmers died in Maharashtra due to the exposures of toxic pesticides (India Spend 2018).
- According to district health office records, accidental exposure to insecticides during spraying has taken 135 farmers from Yavatmal to hospitals between July 2018 and September 2018 (India Spend 2018).
- Two people died and three others were hospitalized on January 18, 2019 in Thiruvalla, Kerala in an incident suspected to have been related to pesticide poising (The Times of India 2019b).
- In 31 August 2019, 13 workers were killed and 64 others injured due to the explosions of nitrogen gas cylinders at a pesticide factory in North Maharashtra's Dhule district (The Hindu 2019b).

CONCLUSION AND FUTURE SCOPE

Like the other developing countries, the economy of India heavily depends on agriculture. The green revolution achieved in India has been possible only because of the inputs to agriculture provided mainly by the energy sector, fertilizers, pesticides, and effective land and water resource management. But the continuous, uncontrolled, unscientific and exaggerated use of agrochemicals is adversely affecting our life, environment and biosphere at every level. They are not only responsible for water, air, soil pollutions but also disturbing the nutrients balance and pH, due to which a huge proportion of macro and microflora and fauna are under threat. They are also responsible for sever human health hazards and even death of person coming in directly or indirectly contact of these agrochemicals. Developing countries like India, which has an immense pressure of rapidly increasing human population, governments are primarily looking for industrial benefits and crop yield. But for the sustainable development, these issues are must be solved at primary basis. It seems totally impossible that governments are going to make policy for the abrupt decline in the use of agrochemicals but it is the demand of time that some effective polices must be implemented which insure the following points:

- Increase in the organic forming and use of bio-pesticides.
- Soil testing is necessary prior to the use of fertilizers and the fertilizers must be used in minimum required quantity and in the appropriate ratio.
- High analysis mixture fertilizers and hazardous pesticides must be banned.
- Use of the pesticides which are easily degradable with less half life time.
- Unnecessary and excess use of pesticides must be controlled.
- Pesticides are used only on approved crops.
- Proper training, skill development and awareness programs for persons using and handling of pesticides. Participation of policy-makers, researchers, extensionists, farmers and consumers, and the sharing

of responsibilities in evaluation, improvement and implementation of the programme.

- Revision of dosage rates used and development of techniques which can enhance the proportion of pesticides coming in direct contact with pest at minimum environment and human health hazard.
- Continuous revision of economic thresholds according to area, crop growth, crop economics and natural and environmental conditions affecting the pest.
- Use of more selective pesticides, as available, based on intensive population monitoring.
- Proper monitoring and awareness programs for the use of pesticides on only approved crops.
- Total control of non-genuine/illegal pesticides.
- Environmental and socio-economic studies on fertilizers and pesticides application.

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REFERENCES

Abhilash, P., C., & Singh, N. (2009). Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials, 165*(1-3), 1-12.

Abou-zeid, N., R., & Abd-Ellah, H., F. (2015). Neurotoxic Effects of Gibberellic Acid (GA3) and its Withdrawal in Adult Male Albino Rats: A Light and Electron Microscopic Study. *Global Journal of Pharmacology, 9*(3), 222-233.

Adithya, P., (2009). India's endosulfan disaster: A review of the Health impacts and status of remediation. Retrieved from http://www.indiaenvironmentportal.org.in/files/IndiaEndosulfan.pdf

Agrawal, A., Pandey, R., S., & Sharma, B. (2010). Water pollution with special reference to pesticide contamination in India. *Journal of Water Resource and Protection, 2*, 432-448.

Aktar, W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary toxicology*, *2*(1), 1-12.

Arora, S., Arora, S., Sahni, D., Sehgal, M., Srivastava, D., S., & Singh, A. (2019). Pesticides use and its effect on soil bacterial and fungal populations, microbial biomass carbon and enzymatic activity. *Current science*, *116*(4), 25.

Bardale, R., Sonar, V., & Waghmare, S., (2012). Fatal poisoning with plant growth regulator: Chlormequat. *J Punjab Acad Forensic Med Toxicol, 12*(2), 102-3.

Bayer crop science: Oxadiargyl (2013). Retrieved from https://www.westandcentralafrica.cropscience.bayer.com/en/~/media/Bayer%20CropScience/Region-West-And-Central-Africa Internet/products/msds/MSDS%20Topstar%20400%20SC%20Ang.ashx?force=1

Bennett, E., M., Carpenter, S., R., & Caraco, N., F., (2001). *human impact on erodible phosphorus and eutrophication: A global perspective. Bioscience*, *51*(3), 227.

Bhardwaj, T., & Sharma, J., P. (2013). Impact of pesticides application in agricultural industry: An Indian scenario. *International Journal of Agriculture and Food Science Technology*, *4*(8), 817-822.

Bibra (1997). Toxicity Profile For 1-Triacontanol . Retrieved from https://www.bibra-information.co.uk/downloads/toxicity-profile-for-triacontanol-1997/

Bishnoi, U. (2018). Agriculture and the dark side of chemical fertilizers. *Environmental Analysis & Ecology*, *3*(1), 198-201.

Bremner, J., M. (1990). Problems in the use of urea as a nitrogen fertilizer. *Soil Use and Management*, *6*(2), 70-71.

Business Standard (2018). CSE hails Punjab for ban on 20 pesticides. Retrieved from https://www.business-standard.com/article/news-ians/cse-hails-punjab-for-ban-on-20-pesticides-118013101207_1.html

CAYMAN (2015). Safaty Data Sheet: n-Triacontanol Retrieved from https://www.caymanchem.com/msdss/88840m.pdf

CDC-The National Institute for Occupational Safety and Health (NIOSH): Sodium Cyanide. (2011). Retrieved from https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750036.html

CFCL-Chambal fertilisers and chemical limited (2012). Micronutrients. Retrived from http://chambalfertilisers.com/index19df.html?option=com_content&view=article&id=65&Itemid=169

Chakravarti, A., K., (1973). Green revolution in India. *Annals of the Association of American Geographers*, 63(3), 319-330.

Chand, R., & Birthal, P., S. (1997). Pesticide use in Indian agriculture in relation of growth area and production and technological change. *Indian Journal of Agricultural Economics*, *52*(3), 1.

Coromandel (2009). fortified fertilisers. Retrived from https://coromandel.biz/prod_fortifiedfertilizers.html

CSBP-Safety Data Sheet: Sodium Cyanide (2016). Retrieved from https://www.csbp.com.au/docs/default-source/msds-products/ammonia-ammonium-nitrate-products/msds-sodium-cyanide-solution.pdf?sfvrsn=35c56c0d_18

Devi, P., I., Thomas, J., & Raju, R. K. (2017). Pesticide consumption in India: a spatiotemporal analysis. *Agricultural Economics Research Review*, *29*(347-2017-2047), 163-172.

Doğan, E., Güzel, A., Çiftçi, T., Aycan, İ., Çelik, F., Çetin, B., & Kavak, G., Ö., (2014). Zinc phosphide poisoning. *Case reports in critical care*.

EPA- R.E.D. Facts: Chlorpropham. (1996). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-018301_1-Oct-96.pdf

EPA- R.E.D. Facts: Maleic Hydrazide (1994). Retrieved from https://archive.epa.gov/pesticides/reregistration/web/pdf/0381fact.pdf

EPA- R.E.D. FACTS: Mepiquat Chloride 1997. Retrieved from https://archive.epa.gov/pesticides/reregistration/web/pdf/2375fact.pdf

EPA: Gibberellic Acid: Reregistration Eligibility Decision (RED) Fact Sheet (1995). Retrieved from https://archive.epa.gov/pesticides/reregistration/web/pdf/4110fact.pdf

EPA: Primiphos-Methyl IRED Facts (2016). Retrieved from https://archive.epa.gov/pesticides/reregistration/web/html/pirimiphosmethyl_ired_fs.html

EPA: Spinetoram (2009). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_G-4674_01-Oct-09.pdf

EPA: Tetraconazole (2005b). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-120603_01-Apr-05.pdf

EPA: Thiacloprid (2003b). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-014019_26-Sep-03.pdf
EPA: Thiophanate-Methyl (2004b). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-102001_1-Nov-04.pdf
EPA-Pesticide Fact Sheet (1998). Imiprothrin Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-004006_01-Mar-98.pdf
EPA-Pesticide Fact Sheet (2000a). Pymetrozine. Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-101103_01-Aug-00.pdf
EPA-Pesticide Fact Sheet (2000c). Indoxacarb Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-067710_30-Oct-10.pdf
EPA-Pesticide Fact Sheet (2005a). Kasugamycin. Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-230001_01-Sep-05.pdf
EPA-Pesticide Fact Sheet (2008b). Pyridalyl Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-295149_24-Apr-08.pdf
EPA-Pesticide Fact Sheet: Chlorantraniliprole (2008a). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-090100_01-Apr-08.pdf
EPA-Pesticide Fact Sheet: Chlorfenopyr (2001). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-129093_01-Jan-01.pdf
EPA-Pesticide Fact Sheet: Clothianidin (2003a). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-044309_30-May-03.pdf
EPA-Pesticide Fact Sheet: Dichloropropene (2000b). Retrieved from https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0224tr.pdf
EPA-Pesticide Fact Sheet: Epoxiconazole (2006). Retrieved from http://enfo.agt.bme.hu/drupal/sites/default/files/epoxiconazole_0.pdf
EPA-Pesticide Fact Sheet: Fenazaquin (2007b). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-044501_01-Aug-07.pdf
EPA-Pesticide Fact Sheet: Fluopicolide. (2007a). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-027412_01-Mar-07.pdf
EPA-Pesticide Fact Sheet: Forchlorfenuron (2004a). Retrieved from https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-128819_01-Sep-04.pdf?hc_location=ufi
EXTOXNET-Extension Toxicology Network-Pesticide Information Profiles (1996). Validamycin. Retrieved from http://extoxnet.orst.edu/pips/validamy.htm
FAI- The fertiliser association of India (2015). Statistical database. Retrieved from https://www.faidelhi.org/statistics/statistical-database
FAO - Food and agriculture organization of the United Nations (2008b). Lufenuron. Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Specs/Lufenuron08.pdf
FAO- Food and Agriculture Organization (2007). *FAO specifications and evaluations for agricultural pesticides-Ethofenprox* Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Specs/Etofenprox07.pdf
FAO-Food and Agriculture Organization (2008a). *buprofezin* Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Report08/Buprofezin.pdf
FAO- Food and agriculture organization of the United Nations (2005). *Fertilizer use by crop in India*. Rome, Italy: Food and Agriculture Organization of the United Nations.
FAO- *Food and Agriculture Organization* of the United Nations. (2017a). Pesticide residues in food. Joint FAO/WHO Meeting on Pesticide Residues. Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Report2017/5.6_CHLORMEQUAT__015_.pdf
FAO- Food and agriculture organization of the United Nations. (2017b). Flumioxazin. Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Specs/Flumioxazin_2017_07_07.pdf
FAO-Food and Agriculture Organization: thiamethoxam (2010). Retrieved from http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Report10/Thiamethoxam.pdf
FAO. (2014). Phosphamidon. Retrieved from http://www.fao.org/3/w5715e/w5715e06.htm
FICCI (2015). study on sub-standard, spurious/counterfeit pesticides in India 2015-Report. Retrieved from http://ficci.in/spdocument/20641/Pestiside-Report.pdf
Firstpost (2018). Maharashtra pesticide deaths: Bombay HC raps state Govt. for delay in submitting SIT report on tragedy Retrieved from https://www.firstpost.com/india/maharashtra-pesticide-deaths-bombay-hc-raps-state-govt-for-delay-in-submitting-sit-report-on-tragedy-4297961.html
Food safety commission of japan: Tolfenpyrad (2004). Retrieved from: https://www.fsc.go.jp/english/evaluationreports/pesticide/evaluationreport_tolfenpyrad.pdf
Gktoday (2018). Punjab Government bans sale of 20 insecticides Retrieved from https://currentaffairs.gktoday.in/punjab-government-bans-sale-20-insecticides-02201852218.html.
Government of India (2012). *Ministry of Agriculture:* Plant Growth Regulators. Retrieved from http://agritech.tnau.ac.in/crop_protection/pdf/8_Approved_uses_registered_PGR.pdf
Government of India (2016a). Ministry of Agriculture. *Impact of chemical fertilizers and pesticides on agriculture and allied sectors in the country* (29th Report). Retrieved from http://www.indiaenvironmentportal.org.in/files/file/Agriculture_0.pdf
Government of India (2016b). - Directorate of plant protection, quarantine & storage. *Pesticides Monitoring & Documentation*. Retrieved from http://ppqs.gov.in/
Government of India (2017). *Ministry of chemicals and fertilizer: Indian fertilizer scenario*. Retrieved from http://fert.nic.in/page/fertilizers-scenario
Government of India (2018). Department of chemicals and petro-chemicals. *Demand of grants*. Retrieved from https://chemicals.nic.in/document-report/demand-grants
Gupta, A, K.,& Nair, S. S., (2012). *Chemical (Industrial) disaster management, training module*. New Delhi, India: National

Institute of Disaster Management. Retrieved from https://nidm.gov.in/PDF/modules/chemical.pdf

He, Z., L., Yang, X., E., & Stoffella, P., J., (2005). Trace elements in agroecosystems and impacts on the environment. *Journal of Trace Elements in Medicine and Biology*, *19*(2-3), 125-140.

IFA (2017). *Assessment of Fertilizer Use by Crop at the Global Level* Retrieved from https://www.ifastat.org/plant-nutrition

IFFCO (2016). Secondary and micronutrients. Retrieved from http://www.iffco.in/ourproducts/index/zinc-sulphate

India Spend (2018). Why Toxic Pesticides That Killed 3 Farmers In 2 Months Are Still In Use In Maharashtra retrieved from https://www.indiaspend.com/why-toxic-pesticides-that-killed-3-farmers-in-2-months-are-still-in-use-in-maharashtra/

Kawai, M., (1989). Summary of toxicity studies on tricyclazole. *Journal of Pesticide Science*, 14(3), 407-413.

Krishijagran (2017). Identify fake pesticides with authenticated solutions. Retrieved from https://krishijagran.com/featured/identify-fake-pesticides-with-authenticated-solutions/

Kumar, S., Sharma, A., K., Rawat, S., S., Jain, D., K., & Ghosh, S., (2013). Use of pesticides in agriculture and livestock animals and its impact on environment of India. *Asian Journal of Environmental Science*, *8*(1), 51-57.

Loukil, B., Mallem, L., & Boulakoud, M., S., (2015). Study of health risks of fertilizers on biochemical parameters in workers. *American-Eurasian Journal of Toxicological Sciences*, *7*(1), 22-25.

Mazen, M. B., Ramadan, T., Nafady, N. A., Zaghlol, A., & Hasan, S. H., (2018). Comparative study on the effect of chemical fertilizers, bio-fertilizers and arbuscular mycorrhizal fungi on maize growth. *Biological Forum-An International Journal*, *10*, 182-194.

Minnesota Department of Agriculture: Tolfenpyrad (2014). Retrieved from https://www.mda.state.mn.us/sites/default/files/inline-files/nur-tolfenpyrad.pdf

Motavalli, P., P., Goyne, K., W., &Udawatta, R., P., (2008). environmental impacts of enhanced-efficiency nitrogen fertilizers. *Crop Management*, 7(1), 1.

Murphy, M., J., (2018). Anticoagulant rodenticides. *In Veterinary toxicology*. *Academic Press*, 583-612.

New York State Department of Environmental Conservation: Restricted use classification for one pesticide product profile 2SG Tree Growth Regulator (2000). Retrieved from http://pmep.cce.cornell.edu/profiles/herb-growthreg/naa-rimsulfuron/paclobutrazol/paclobutrazol700.pdf

NPIC (2009a). National Pesticide Information Center: Fipronil. Retrieved from http://npic.orst.edu/factsheets/archive/fiptech.html

NPIC (2009b). National Pesticide Information Center: 2,4-D. Retrieved from http://npic.orst.edu/factsheets/24Dgen.html

NPIC (2010. National Pesticide Information Center: Imidacloprid. Retrieved from http://npic.orst.edu/factsheets/archive/imidaclop rid.html

NPIC (2014). Spinosad Retrieved from http://npic.orst.edu/factsheets/spinosadgen.html

OLR Research Report (2012). - *State Laws Banning Phosphorus Fertilizer Use* Retrieved from https://www.cga.ct.gov/2012/rpt/2012-R-0076.htm

PAN-International (2016). PAN international list of highly hazardous pesticides. Retrieved from http://www.pan-germany.org/download/PAN_HHP_List_161212_F.pdf

PAN-International (2018). Consolidated List of Banned Pesticides. Retrieved from http://www.panintl.com/

Parayil, G., (1992). The green revolution in India: A case study of technological change. *Technology and Culture*, *33*(4), 737-756.

Pell, M., Stenberg, B., &Torstensson (1998). Potential denitrification and nitrification tests for evaluation of pesticide effects in soil. *Ambio*, 27(1), 24-28.

Penn State Extension (2017). Potential Health Effects of Pesticide. Retrieved from https://extension.psu.edu/potential-health-effects-of-pesticides

Pesticide action network Asia Pacific (2017). Global governance of hazardous pesticides to protect children: Beyond 2020. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/SAICM-PANAP-Children-and-Pesticides.pdf

Pfaltz & Bauer (2018). Safety Data Sheet. Retrieved from https://www.pfaltzandbauer.com/SDSFile.ashx?ItemCode=N00170

Pimentel, D., (1995). Amounts of pesticides reaching target pests: environmental impacts and ethics. Journal of Agricultural and environmental *Ethics*, 8(1), 17-29.

PMEP (2018). Cornell university. Pesticide management education program Retrieved from http://pmep.cce.cornell.edu/

PPDB (2018a). Pesticide Properties Data Base:Oxadiargyl. Retrieved from https://sitem.herts.ac.uk/aeru/iupac/Reports/495.htm

PPDB (2018a). Pesticide Properties Data Base:Triacontanol. Retrieved from http://sitem.herts.ac.uk/aeru/ppdb/en/Reports/3064.htm

PPDB (2019a). Pesticide Properties Data Base: sulfosulfuron. Retrieved from https://sitem.herts.ac.uk/aeru/ppdb/en/Reports/603.htm

PPDB (2019b). Pesticide Properties Database: Hexythiazox Retrieved from https://sitem.herts.ac.uk/aeru/ppdb/en/Reports/385.htm

PPDB (2019c). Pesticide Properties Database: Quizalofop-P-tefuryl 2019. Retrieved from https://sitem.herts.ac.uk/aeru/ppdb/en/Reports/584.htm

PRS (2016). Impact of chemical fertilizers and pesticides on agriculture and allied sectors in the country. Retrieved from https://www.prsindia.org/report-summaries/impact-of-chemical-fertilizers-and-pesticides-on-agriculture-and-allied-sectors-in-the-country-4417

Pub Chem (2021). Profenofos Retrieved 5 May 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/Profenofos#section=Hazards-Identification

Sarwar, M., 2015. The dangers of pesticides associated with public health and preventing of the risks. *International Journal of Bioinformatics and Biomedical Engineering*, *1*(2), 130-136.

Savci, S., (2012). An agricultural pollutant: Chemical fertilizer. *International Journal of Environmental Science and Development*, 3(1), 73.

Sebby, K., (2010). *The green revolution of the 1960's and its impact on small farmers in India* (Published Bachelor's thesis). University of Nebraska-Lincoln, Lincoln, Nebraska. Retrieved from https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1027&context=envstudtheses

Sharpley, A., N., &Menzel, R., G., (1987). the impact of soil and fertilizer phosphorus on the environment. *Advances in Agronomy*, 41, 297-324.

Singh, A., Kumar, R., & Das, D., K. (2006). Pesticide Use and Sustainability of Agriculture: Emerging Issues and Policy Options. Research Report 2006/01. *ICAR-Indian Agricultural Research Institute, New Delhi* 141.

Srinivas, Rao., Venkateswarlu, C., H., Surender, V., Eddleston, T., M., & Buckley, N., A., (2005). Pesticide poisoning in south India: opportunities for prevention and improved medical management. *Tropical Medicine & International Health*, 10(6), 581-588.

Stevenson, D., Baumann, P., A., & Jackman, J. A., (1997). Pesticide properties that affect water quality. *Texas FARMER Collection.* Retrieved from https://oaktrust.library.tamu.edu/handle/1969.1/87780

Tandon, H., L., S., & Tiwari, K., N., (2007). Fertiliser use in Indian agriculture-An eventful half century. *Better Crops*, 3-4.

The Hindu (2018). Punjab government bans sale of herbicide Retrieved from https://www.thehindu.com/news/national/other-states/punjab-government-bans-sale-of-herbicide/article25314146.ece

The Hindu (2019). Weedicide Glyphosate banned Retrieved from https://www.thehindu.com/news/national/kerala/weedicide-glyphosate-banned/article26176536.ece

The Hindu (2019b). 13 killed in Maharashtra chemical factory explosion Retrieved from https://www.thehindu.com/news/national/other-states/13-killed-in-maharashtra-chemical-factory-explosion-amit-shah-speaks-to-cm/article29308404.ece

The Hindu-Business Line (2018). that pesticide 'dressing' for your salad is to die for! Retrieved from https://www.thehindubusinessline.com/economy/that-pesticide-dressing-for-your-salad-is-to-die-for/article25251770.ece

The Times of India (2018a). Cancerous' glyphosate sale curbed, cos licence intact Retrieved from https://timesofindia.indiatimes.com/city/nagpur/cancerous-glyphosate-sale-curbed-cos-licence-intact/articleshow/65445382.cms

The Times of India (2018b). Five pesticides banned to curb deaths due to inhalation Retrieved from https://timesofindia.indiatimes.com/city/pune/5-pesticides-banned-to-curb-deaths-due-to-inhalation/articleshow/65916780.cms

The Times of India (2018c). Pesticide poisoning claimed 272 lives of farmers in Maharash in 4 years. Retrieved from https://timesofindia.indiatimes.com/city/mumbai/pesticide-poisoning-claimed-272-lives-of-farmers-in-maharashtra-in-4-years/articleshow/63194105.cms

The Times of India (2019a). Ban on popular fertilizer slammed Retrieved from https://timesofindia.indiatimes.com/city/thiruvananthapuram/ban-on-popular-fertilizer-slammed/articleshow/68416999.cms

The Times of India (2019b). Two die of suspected pesticide poisoning Retrieved from https://timesofindia.indiatimes.com/city/kochi/two-die-of-suspected-pesticide poisoning/articleshow/67606368.cms?utm_source=facebook.com&utm_medium=social&utm_campaign=TOIDesktop&fbclid=IwAR07cjh1gYdFExaLb9s5jS_Y1OfQx-xRmfhQ-Ogfv6HfK6J0mYEL7xqPezg

The Tribune (2019). State bans nine pesticides Retrieved from https://www.tribuneindia.com/news/punjab/state-bans-nine-pesticides/807340.html

The Yavatmal scandal (2018). Public eye. Retrieved from https://toxicexports.publiceye.ch/

Trautmann, N., M., & Porter, K., S., (2012). Pesticides: Health effects in drinking water. Pesticide safety education program. Retrieved from http://psep.cce.cornell.edu/facts-slides-self/facts/pes-heef-grw85.aspx

Valiki, S. R. H., Ghanbari, S., Akbarzadeh, M., Alamdari, M. G., & Golmohammadzadeh, S., (2015). Effect of organic and chemical fertilizers on dry yield, essential oil and compounds on rosemary (*Rosemarinus officinalis* L.). *Biological Forum-An International Journal, 7*(1), 773.

WHO (2004). Specifications and evaluations for public health pesticides: Prallethrin Retrieved from https://www.who.int/whopes/quality/prallethrin_spec_eval_Nov_2004.pdf

WHO (2010). The WHO recommended classification of pesticides by hazard and guidelines to classification 2009. Retrieved from https://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf

World Ecology Report (2019). Retrieved from https://worldinfo.org/wp-content/uploads/2019/02/WER-Spring-2019-XXXI.pdf

Worldatlas (2019). Top Pesticide Using Countries Retrieved from https://www.worldatlas.com/articles/top-pesticide-consuming-countries-of-the-world.html

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