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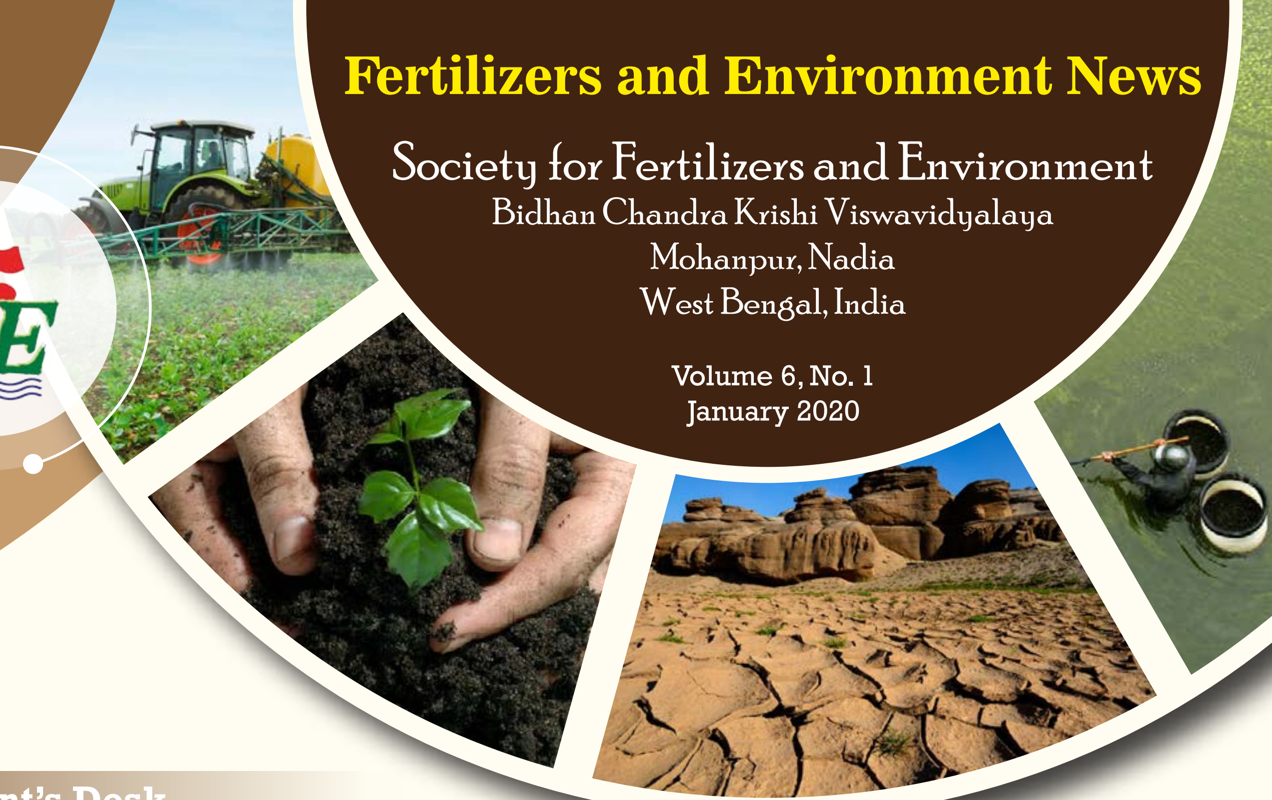

From President's Desk

Alternative strategies to agrochemical use for environmental sustainability

Agrochemical utilization in agriculture has substantially contributed to crop yields and protection from pests. However, agrochemical application has also noxious effects on human health, ecosystem and environment. It seems impractical to completely abandon the use of conventional fertilizers and pesticides in agriculture; non-conventional approaches may, however, significantly reduce their use and can contribute to saving ecological and environmental sustainability.

I have discussed in the previous issues of this Newsletter about the nature and extent of environmental damage mainly in the form of noxious gas emission due to fertilizer addition to agricultural fields. Besides, excessive use of fertilizers may also lead to the contamination of groundwater with nitrate, a chemical compound, that in large concentrations is poisonous to humans and animals. Further, the runoff (or leaching from the soil) of fertilizers into streams, lakes, and other surface waters (the aqua sphere) can increase the growth of algae resulting in eutrophication and formation of dead-end zones, which can have a significant adverse effect on the life-cycle of fish and other aquatic animals.

Alternative strategies

Alternative strategies to application of fertilizers and pesticides, in the form of biofertilizers and bio-pesticides along with integrated pest management (IPM), could be potential areas to mitigate noxious effects on the environment, farmers' awareness to the ill-effects of their conventional counterparts notwithstanding. The specific areas deserving higher thrust in the field of pesticides use and management are use of bio-pesticides, bioremediation of pesticide-contaminated soils/land, utilization of plant-associated microbes, and effect of transgenic crop cultivation.

Past trends in research: The impact of agricultural chemicals on the environment can be divided into three periods over the last three decades. In the early stage (1990–99), studies mainly focussed on the application of agricultural chemicals, pollutant emissions and their concentration in various environmental media. During the middle stage (2000–07), studies mainly focussed on the production mechanism, source apportionment, transmission channel and source/sink relationship of pollutants. In the later stage (2008–16), studies mainly focussed on discussing the influence of specific pollutants on various environmental media and comparing the changes under different conditions (*Lu Zhang et al., The impact of agricultural chemical inputs on environment: global evidence from informatics analysis and visualization, International Journal of*

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Low-Carbon Technologies, Volume 13, Issue 4, December 2018, Pages 338–352). The salient agricultural inputs used for the analysis (i.e. pesticides and fertilizers) in various studies have distinctive uses in agricultural activities and their effects on the environment may greatly vary by input. In addition, pesticides can further be divided based on their function (e.g. fumigants, insecticides, biopesticides, herbicides, etc.) and the impact of these on the environment may differ. The same is true for agricultural fertilizers which are often classified based on their efficiency, origin and phase**.**

Role of microbes & their applications: Based on the above background, I now wish to stress that microbial inoculants can be successfully used as biofertilizers and biopesticides by using diverse plant growth promoting traits. Microorganisms either improve plant growth by direct effects, such as BNF, hormone production, nutrients solubilization, or are indirectly involved in the protection of plants from biotic and abiotic stresses. Most of the studies conducted so far have focused on the use of microbial inoculants for agricultural productivity. As these microbes may also affect ecology and soil microbial community structure, leading to improved soil health, future research should be focused on quantifying the impact of microbial inoculants on ecosystem and soil health.

Studies on consortia inoculants should be the priority for degradation of complex agrochemicals, polyaromatic hydrocarbons, and azidoes. Moreover, root colonization efficiency of these microbes should also be further studied to increase their effectiveness as bioremediatory-specific plant-microbes' interactions in the decontamination of environmental pollutants requiring to be explored, as it has been suggested that microbes use unknown mechanisms to enhance metal uptake and accumulation in plants. Research is also needed to find out the pathways for the degradation of industrial effluents by microbial strains.

Scope for genetic engineering of microbes: The use of genetically engineered microbes has also been reported in literature. Comprehensive research is needed as little is known about these microbes *in situ*. Their behaviour in a natural environment and their impact on soil health and soil microbial community structure and functional genes should be studied extensively. Furthermore, the specific mechanisms and genes involved for bioremediation and detoxification of pollutants should also be explored. There is a need to investigate site-specific microbial communities under a wide range of environmental conditions. Another area of interest is the formulation of suitable inoculants and the testing of their environmental impact.

An emerging area - cyanobacteria: Another known yet emerging area I wish to draw attention to, in the field of biology of plants, targeting higher productivity without environmental degradation that shows how cyanobacteria use solar energy to drive the chemistry of life, how the molecular machines that capture solar energy are assembled and maintained, how cyanobacteria respond to environmental changes at the systems level, and finally how to engineer new strains of cyanobacteria that are capable of channelling solar energy into biochemical production.

On an ending note, I would like to say that only the tip of the iceberg has been identified, while the vast majority of beneficial species and their potential are yet to be unravelled.

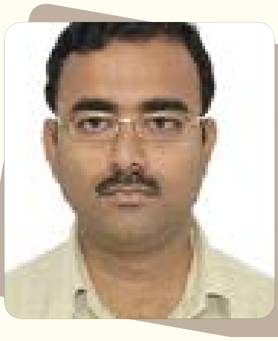
H. S. Sen

President

HONOURS AND AWARDS

Dr. Bijay Singh former Professor of Punjab Agricultural University, Ludhiana and Life Member of SFE received the Platinum Jubilee Commemoration Award of the Indian Society of Soil Science for his lifetime contributions in the fields of "nitrogen (N) balance in soil-plant systems for enhancing N use efficiency in rice-wheat cropping system; fertilizer N related environmental pollution; site-specific N management using leaf colour chart, chlorophyll meter and optical sensors; and integrated nutrient management" at the 84th Annual Convention of the Society on November 15, 2019 at Varanasi.

Dr. Ratikanta Ghosh, Professor (Emeritus) GIET University, Gunupur, Odisha; Guest Professor, Gurukul Edutech; former Professor in Agronomy, Bidhan Chandra Krishi Viswavidyalaya and Life Member of SFE received the Gold Medal Award 2019 of the Indian Society of Weed Science, Jabalpur; the Certificate of Merit 2020 from GIET University, Gunupur and is honoured as the Fellow of Indian Society of Oil Seed Research, Hyderabad for the year 2020 for his lifetime contributions in the field of Agronomy.



Dr. Pratap Bhattacharyya, Principal Scientist, ICAR-NRRI, Cuttack and Life Member of SFE is honoured by the Indian Association of Soil and Water Conservationists (IASWC), Dehradun in recognition of his outstanding contributions in the field of Soil and Water Conservation by awarding him the IASWC Fellow for the year 2019.

Dr. Tapan Jyoti Purakayastha, Principal Scientist, Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi and Life Member of SFE is honoured by the National Academy of Agricultural Sciences and West Bengal Academy of Science and Technology by their Fellowships 2019 for his outstanding contributions in quantifying the potential of maize-wheat cropping to sequester C in semi-arid subtropics and identifying the critical indicators of soils quality assessment for sustainability of rice-rice cropping systems.

Dr. Satadeep Singha Roy, WBAS (Admin.) and Member of SFE was conferred Young Agriculturist Award for his contribution in the field of Agricultural Chemistry and Soil Science by Agro Environmental Development Society (AEDS), Rampur, Uttar Pradesh and Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India

Article

Long term impact of use of sewage effluent on changes in soil properties, uptake of heavy metals and other nutrients by crops and their environmental implications

An estimated 38,354 million liters of sewage with an equivalent amount of sludge per day is presently generated in India (Kaur *et al.,* 2012). In another estimate, about 15,644 million liters per day of sewage effluent is generated from the 35 Indian metropolitan cities with population of greater than one million (CPCB, 2013). In India, estimates revealed that ~73,000 of land hectares are irrigated with sewage effluents during early nineties and presently the area under sewage effluents irrigation is on the rise (Dotaniya *et al.,* 2018). The conservative estimates on the basis of 70% of the sewage available from large cities show that these effluents have the potential for irrigating (7.5 cm) about 21 thousand hectares of land on daily basis or alternately about 7.8 million hectares on annual basis (Minhas and Samra, 2004).

Studies have documented that direct disposal of effluents to land and water bodies for maximising productivity has potential to contaminate air, surface, groundwater as well as soils and crops grown on these soils. Thus, it is important to find out appropriate management techniques to produce more from per unit of sewage effluent use and enhance the farm income without deteriorating soil-plant-animal-human health. In this article, an attempt is made to discuss, based on the available literature, the beneficial and harmful effects of use of sewage effluents.

Nutritive value of sewage effluents

Efforts are on to promote the sewage effluent use in agriculture worldwide as means of cheap disposal (Rattan *et al*., 2005). Huge amount of organic carbon and essential plant nutrients delivered towards cultivating fields reduced the need for fertilizer application during crop production (Biswas and Ghosh, 2018). Sewage effluents have been considered as low price fertilizer because of its high nitrogen (N), phosphorus (P) and potassium (K) content. Although of wide variation in nutrient concentrations, sewage effluents contain on an average 48.3, 7.6, 72.4 and 34.6 mg L^{-1} of N, P, K and sulphur (S), respectively, besides micronutrient contents of 0.34, 10.8, 0.2 and 0.36 mg L^{-1} of zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn), respectively. Thus, five irrigations of 7.5 cm each with sewage effluents could add about 181, 29, 270 and 130 kg ha^{-1} of N, P, K and S, respectively, which is adequate to meet the nutrient requirement of the crops. Computations made on the basis of an average content of N, P and K in sewage effluents and ~70% utilization in agriculture sector show that sewage effluents can annually contribute 380, 60, 520 and 1.4 thousand tonnes of N, P, K and Zn, respectively in addition to other micronutrients and heavy metals. The total value of these nutrients would be around 1.78 million US$ annually.

Effect of long term sewage irrigation on soil physicochemical properties

Soil pH

There are different views associated with effects of long term application of sewage effluents on soil pH. Many studies confirm an increase in soil pH with application of sewage effluents to soil. Such effect may be attributed to the high content of basic cations like Na^+, Ca^{2+} and Mg^{2+} in the sewage effluents, which after accumulation in surface soil layer for a long period of time, leads to increase in soil pH. On the contrary, there are studies also which suggest the decrease in surface soil pH with sewage effluents irrigation to soils.

Electrical conductivity (EC) and related parameters

Remarkably higher accumulation of soluble salts in the deeper soil layers (20-40 and 40-60 cm) than surface (0-20 cm) soil layer has been ascribed due to the leaching effect with irrigation water. Increased EC of surface soil with sewage effluents application in comparison to groundwater irrigated soils has also been reported in few other studies conducted depending on agro-climatic conditions.

Soil organic carbon

Soil organic carbon (SOC) has been the exclusive indicator of soil quality as it acts as a store of plant available nutrients. Long term use of sewage effluents for irrigation to crops results in significant increase in soil SOC than the soils irrigated with groundwater. In subtropical Indian soils an increase in SOC content in soils over groundwater irrigation by 38-79% due to 20-years of irrigation with sewage effluents has been reported. Therefore, long term use of sewage effluents can be a good means of carbon sequestration in soil and can thus be referred as a soil quality sustaining practice. Data on these parameters is shown in Table 1.

Table 1. Physicochemical properties of surface (0-15 cm) soils irrigated with waste water and ground water

Source	Reference	pH (1:2)	EC (1:2) (dS m^{-1})	OC (%)	$CaCO_3$ (%)	Clay (%)	CEC [cmol (p^+) kg^{-1}]
Sewage effluents	Fakayode (2005)	7.1-8.3	0.42	0.95	1.5	11.3	11.16
Groundwater		7.7-8.5	0.33	0.77	3.5	7.3	6.35
Sewage effluents	Amiri *et al.* (2008)	7.95	0.89	0.83	-	-	-
Groundwater		7.68	0.69	0.37	-	-	-
Sewage effluents	El-Hady (2007)	8.2-8.4	3.15-3.53	1.4-2.2	18.8-19.8	3.8-5.0	-
Groundwater		7.9	2.5	0.14	14.0	16.0	-
Sewage effluents	Brar *et al.* (2002)	6.6	0.64	0.41	-	-	-
Groundwater		6.9	0.28	0.32	-	-	-
Sewage effluents	El-Arby and Elbordiny (2006)	8.36	0.92	-	2.08	1.0	12.8
Groundwater		7.87	1.12	-	2.11	1.0	12.6
Sewage effluents	Osaigbovo *et al.* (2006)	7.15	-	1.28	-	9.0	42.1
Groundwater		5.98	-	1.00	-	9.0	4.25

Source: Khurana and Singh (2012)

Calcium carbonate

Increase in calcium carbonate ($CaCO_3$) content of surface soil receiving sewage effluents for irrigation in comparison to soils receiving groundwater, has been reported. However opposite trend has also been observed.

Soil macronutrients

Reports from different studies on soil fertility parameters indicated a spectacular change in all measured parameters due to irrigation with sewage effluents. Improvement in soil fertility under sewage effluents over a period of time has been well documented. After 10-years of municipal sewage effluents application, significant increase in soil available N, P and K content in surface (0-20 cm) soil has been reported. The long term use of sewage water in a wheat-soybean cropping system can save chemical fertilizers (60 kg N, 13 kg P and 25 kg K ha^{-1} yr^{-1}) and recover plant nutrients (18 kg N, 7 kg P and 49 kg K ha^{-1} yr^{-1}) through straw biomass due to recycling in addition to enhancement of soil fertility (Saha *et al*., 2017). The micronutrients supplied through the sewage effluents also meet the crop requirement and improve crop yield and quality of produce (Meena *et al*., 2016).

Heavy metals

Spectacular increase in total heavy metal content of surface soil layer with sewage effluents application has been documented. A long term study on the use of sewage effluents of Calcutta (India) reported 2.43, 46.5, 3.81, 0.86, 93.0, 15.9, 3.88, 2.44 and 6.61-fold increase in total Fe, Zn, Cu, Mn, Cd, Pb, Co, Ni and Cr concentration, respectively, in soils in comparison to soils receiving groundwater for irrigating the crops (Gupta and Mitra, 2002). The accumulation of heavy metals in the surface soil layers may be the result of sorption reactions of negatively charged soil colloids for the cationic heavy metals.

Heavy metals, being extremely immobile and persistent in environment and of non-biodegradable in nature, tend to accumulate mainly in the surface soil layer and their contents decrease down the profile. The concentrations of these metals are very low in sewage effluents, but the long term use of the sewage water for irrigation may build-up significant amount of these metals in soil (Saha *et al*., 2017).

Effect of waste water irrigation on yield and quality

Crop yield

Waste waters contain valuable plant nutrients and thus its reuse in agriculture serve as an important source of nutrients and irrigation water for crops. Better crop growth particularly of leafy vegetables like cauliflower, cabbage, spinach, etc. grown on fields receiving sewage effluents have been achieved, in contrast to radish, which is more sensitive to sewage effluents. The results of many studies on the use of sewage effluents for long period of time have shown significant increase in crop yields than groundwater irrigated fields. Significantly higher onion yield and maximum fertilizer use efficiency from plots fertilized with 40kg N, 20kg P_2O_5 and 20kg K_2O ha^{-1} dose conjointly with distillery effluents (25-times diluted) over groundwater irrigated plots has been reported. A significant augmentation in dry matter yield of berseem in pots irrigated with sewage effluents than groundwater irrigated pots suggests the essential nutrient supplementation from sewage effluents. The field experiments conducted on the use of sewage effluents for irrigation to maize, sunflower, groundnut and soybean registered 19.3, 29.9, 5.9 and 4.8% higher grain yield, respectively over fields irrigated with groundwater. The yield increase from 6.9 to 13.9% in different sugarcane varieties grown with sewage effluents over groundwater irrigation has been recorded. Another long term experiment has shown that sewage effluents irrigation has led to highest grain yield of wheat, rice and cotton by 23, 46 and 50%, respectively, over groundwater irrigation.

Crop species exercise differentially in accumulating metals in their tissue (Datta *et al*., 2000) and efficiency of different crops in absorption of metals is judged either by plant metal uptake or by transfer factor of metals from soil to plants. Generally, soil to plant transfer factor of metals is computed based on total metal contents of soils. Roy *et al*. (2019) found that there was significant increase in the biomass yield of palak (spinach) when a combination of sewage sludge and chemical fertiliser was applied compared to application of either only sludge or the recommended dose of fertilizer. These phenomena could be attributed to the fact that the total nutrient requirement of palak could not be met through sludge alone. These findings also confirm that sewage sludge acts as a slow release fertilizer when applied along with inorganic fertilizers.

Heavy metal content in plants

Plant species differed widely with respect to their bio-accumulation of heavy metals and micronutrients (Table 2). Heavy metal and micronutrients content in the economic plant parts have been found to be higher. Palak has been found to accumulate higher amount of Pb, Cr and Cd compared to berseem. Root crops such as potato, carrot, turnip, and radish generally accumulate lower concentrations of pollutant elements than leafy vegetables such as palak, methi (*Trigonella cornuculata*), menthe (*Trigonella foenumgraecum*) and mint (*Mentha piprita*).

Higher concentrations of Zn and Cu, slight increase in Ni content and lower concentration of Mn in rice grains harvested from sewage effluent irrigated fields have been registered than those from groundwater irrigated fields. However, the metal concentrations in tissue of some cereals, millet and vegetables crops grown in peri-urban areas of Delhi were well below the generalized critical levels of phytotoxicity.

Studies on the relationships among soil heavy metal content and heavy metal uptake by plants and concentration of heavy metals in plants showed direct significant relationship with heavy metal concentration in the waste effluents.

Epilogue

It may be concluded that proper management of sewage effluent irrigation and periodic monitoring of soil, sewage effluents and crop quality are required to ensure successful, safe and long term use of sewage effluents for irrigation. Further, it is desirable that highly contaminated sewage effluent from industries has to undergo suitable treatments before its use as source of nutrients and irrigation.

Table 2. Heavy metal concentration (mg kg^{-1}) in crop plants with long term (21 years) sewage waste water irrigation in comparison to control

Crop	Heavy metal	Heavy metal content (mg kg^{-1})		
		Sewage waste water irrigation	Control (Tube well water irrigation)	% increase over control
Wheat	Zn	65.3	47.5	1.37
	Cu	9.39	7.45	1.26
	Fe	404	336	1.20
	Mn	15.3	13.6	1.13
	Ni	20.0	19.7	1.02
Sorghum	Zn	54.2	73.4	0.74
	Cu	16.9	115.5	0.15
	Fe	526	485	1.08
	Mn	40.6	44.8	0.91
	Ni	14.8	11.6	1.28
Maize	Zn	78.8	67.6	1.17
	Cu	14.9	13.3	1.12
	Fe	531	99.0	5.36
	Mn	26.0	15.3	1.70
	Ni	16.5	5.20	3.17
Oats	Zn	59.0	44.3	1.33
	Cu	8.71	6.35	1.37
	Fe	458	400	1.15
	Mn	23.8	29.2	0.82
	Ni	18.3	37.3	0.49
Gobhi sarson	Zn	66.9	38.7	1.73
	Cu	23.1	14.1	1.64
	Fe	454	401	1.13
	Mn	69.0	104	0.66
	Ni	12.0	3.73	3.22
Spinach	Zn	77.1	38.4	2.01
	Cu	20.6	16.1	1.28
	Fe	711	734	0.97
	Mn	39.3	87.8	0.45
	Ni	18.4	13.2	1.39

Source: Rattan *et al*. (2005)

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