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Pollution Load Index (PLI) of Field Irrigated With Wastewater of Mawaiya Drain in Naini Suburbs of Allahabad District

ARTI YADAV[1]* and PAWAN KUMAR YADAV[2]

[1]Department of Botany, University of Allahabad, Allahabad, Uttar Pradesh, India.
[2]Center for Env. Sc. and Tech., Banaras Hindu University, Varanasi, Uttar Pradesh, India.

Abstract

Wastewater irrigation is practiced in outskirts of several cities of India. Enhanced growth and productivity of crops possess threat of heavy metal accumulation while irrigated with wastewater. Assessment of heavy metal accumulation in soil flooded with wastewater of Mawaiya drain in Naini region of Allahabad district, using parameter of contamination factor and pollution load index (PLI). Samples of soil were taken from the fields irrigated with wastewater and analyzed for heavy metals by using Atomic Absorption Spectroscopy (AAS). The maximum accumulation of heavy metal was observed for iron in soil. Heavy metal contamination is soil was assessed by estimation of contamination factor which was observed for Cu (0.7858), Fe (296.1864), Zn (0.4304), Pb (1.1661) and Ni (1.8912). Pollution load index (PLI) used for assessment of soil contamination and observed that maximum contamination (PLI, 74.31) was in water stressed conditions of summer. Heavy metals concentration in wastewater and accumulation in soil found within WHO limits in present study which may increase if unmanaged wastewater flooding continued.

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Keywords

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Heavy metals,
Wastewater irrigated soil,
Contamination Factor,
Pollution Load Index (PLI).

Introduction

Water is unquestionably the most precious natural resource on earth. In global perspective, only 3% of the liquid resource is fresh water and other 97% water is oceanic which is saline in nature, although water covers nearly 71% of the Earth's surface. In Palestine under review of water resource, recycled wastewater as the primary water source for future irrigation demand[11]. Wastewater is often a match as irrigation resource where other water sources are inadequate for irrigation. Number of interesting historical illustrated for the wastewater flow in western United States. Approx 20 Mha under agriculture are estimated to irrigated using treated, partially treated, diluted and untreated wastewater[5]. Wastewater irrigation have implication on soil along with crop grown in form of accumulation of heavy metals and change in nature of substrate[6,8,12]. Soil contamination with heavy metal leading to bioaccumulation of in food chain; disrupt the function and balance

CONTACT Arti Yadav arti.yadav39@gmail.com Department of Botany, University of Allahabad, Allahabad, Uttar Pradesh, India.

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of ecosystem along with health problems across the globe. Apart from wastewater irrigation other activities such as solid waste disposal, sludge applications and metal mining are the major sources of soil contamination with heavy metals[7,13]. The drains carry runoff of fields along with wastewater in monsoon season making its contribution to river pollution. Wastewater of the drain is extensively used by local farmers leading to heavy metal accumulation in soil which may cross the safe limit in future[2]. It is proven fact in several regions of world that for poor urban farmers, wastewater irrigation is a substantial and primary source of irrigation which support urban food supply[4,15,16]. Economic value of wastewater used for irrigation represents a significant economical benefit to community substituting fresh water for irrigation[3,18]. Several countries such as Japan, Egypt, Mexico, Jordan, Kuwait, Portugal, India and in many developing countries, especially in the urban areas, wastewater is being used for agricultural purposes[3,10].

Materials and Methods

Sampling Area

Mawaiya drain is a major drain in Naini Industrial area of Allahabad district. Naini Township established in 1950s on the bank of river Ganga and Yamuna as industrial area of Allahabad city. Being an industrial area Naini provide space to reputed industries which discharge the waste water in the river Ganga. They discharge their effluents through Mawaiya Drain in Ganga near Mawaiya village, which is situated about 4 km downstream the Sangam. So, this Drain contains industrial & municipal wastes. Six different sites were selected for the regular monitoring of the physico-chemical parameters of the drain. The water quality survey was conducted at six sites in downstream of Mawaiya Drain, in all three seasons of the year from December 2011 to December 2013.

Sample Collection

The samples were collected in 5 L plastic container between 8 to 10 AM as several parameters of water which depends on temperature such as TDS, conductivity, DO, Chlorine etc. In northern plains of India average temperature of stream water between 8-10 AM is 25+1.5 ^{0}C. The containers were thoroughly washed and rinsed with concentrate HNO_3 followed by distilled water. The water samples were analyzed for heavy metal contents through digestion with concentrated HNO_3 at 80 ^{0}C. Filtrate of digested sample taken analyzed for heavy metal on an atomic absorption spectrophotometer (Perkin Elmer AAnalyst 300).

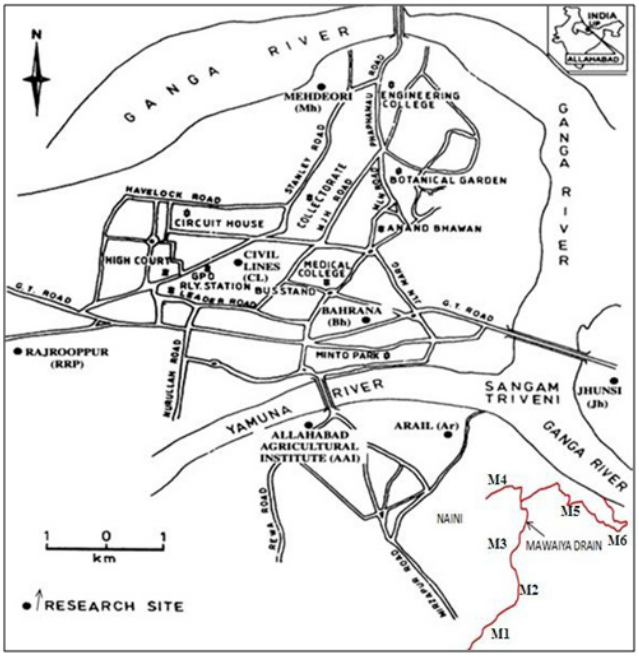

Fig. 1: Sampling sites and adjoining areas along the Mawaiya drain

Sample Analysis

Air dried soil samples powered and sieved through a 2-mm nylon mesh. The sieved samples (500 gm each) are then dried at 105 °C for 2 hour to remove moisture content. The dried sample was then digested through triacid mixture which comprises of HNO_3, H_2SO_4 and $HClO_4$ in 5:1:1 ratio at 80 °C until a transparent solution was obtained. The solution was filtered through Whatman No. 42 filter paper and filtrate was analyzed for heavy metal same as water same.

Statistical Analysis

Statistical analysis of the result obtained from AAS was done through Microsoft Excel (version 2007).

Heavy Metal Pollution Assessment for Soils

The Pollution Load Index (PLI) evaluates the degree to which the soil sediment associated which heavy metal which might impact the micro flora and fauna of soil.

Calculation Method of PLI

CF = C metal / C background value

PLI= $n\sqrt{}$ (CF1 x CF2 x CF3 x…x CFn)

CF: contamination factor; n: number of metals; C metal: metal concentration in polluted sediments & C Background value: background value of that metal.

Results and Discussions

Heavy metal concentrations in wastewater of Mawaiya drain are mentioned in table 1, which is source for heavy metal contamination in soil mentioned in table 2. With the help of background value of the heavy metals the contamination factor and pollution load index (PLI) was calculated (table 3) which reflects the pollution of metals in soil.

Winter season of the year 2011-12, contamination factor of metals in soil irrigated with Mawaiya drain year was Cu (0.7560), Fe (258.1695), Zn (0.4036), Pb (1.0813) and Ni (1.7235). The PLI for the season was (63.6679). In summer season contamination factor of Cu (0.7791), Fe (274.5763), Zn (0.4051), Pb (1.0866) and Ni (1.7294) respectively with PLI value (63.8029). In Monsoon season contamination factor of Cu (0.7231), Fe (236.8644), Zn (0.4038), Pb (1.0866) and Ni (1.7250) respectively and PLI was (56.9283). In winter season of year 2012-13 contamination factors of different metals in soil irrigated with Mawaiya drain was Cu (0.7360), Fe (268.0085), Zn (0.3846), Pb (1.0664) and Ni (1.5184). The PLI for the season was (55.4195). In summer season contamination factor of Cu (0.7858), Fe (296.1864), Zn (0.4304), Pb (1.1661) and Ni (1.8912) respectively with PLI value (74.3153). In Monsoon season contamination factor of Cu (0.7478), Fe (247.6695), Zn (0.3545), Pb (0.9994) and Ni (1.4450) respectively and PLI was (48.688). Seasonal variation of PLI was not as significant as lowest PLI was reported in monsoon only which was slight lower to the summer and winter season PLI respectively (fig.3).

Table 1: Heavy metal concentration in wastewater of Mawaiya drain

			Wastewater Quality from December 2011-December 2012				Wastewater Quality from December 2012-December 2013			
	Parameter	Unit	Winter Season	Summer Season	Monsoon Season	Mean±SD	Winter	Summer Season	Monsoon Season	Mean±SD Season
1	Copper	mg/L	0.016	0.019	0.018	0.018±0.002	0.017	0.020	0.019	0.019±0.002
2	Iron	mg/L	0.254	0.257	0.249	0.253±0.004	0.274	0.297	0.269	0.280±0.015
3	Manganese	mg/L	0.034	0.037	0.029	0.034±0.004	0.044	0.047	0.039	0.044±0.004
4	Zinc	mg/L	0.054	0.057	0.049	0.053±0.004	0.056	0.058	0.052	0.055±0.003
5	Lead	mg/L	0.040	0.043	0.035	0.039±0.004	0.050	0.053	0.045	0.049±0.004
6	Nickel	mg/L	0.031	0.038	0.035	0.035±0.004	0.041	0.048	0.045	0.045±0.004

Table 2: Heavy metal level in soil irrigated with Mawaiya drain

			Soil sample collection from December 2011- December 2012				Soil sample collection from December 2012- December 2013			
	Parameter	Unit	Winter Season	Summer Season	Monsoon Season	Mean±SD	Winter Season	Summer Season	Monsoon Season	Mean±SD
1	Copper	mg/Kg	8.96	7.4	7.2	7.853±0.964	9.96	7.45	7.27	8.227±1.504
2	Iron	mg/Kg	22.82	22.96	22.48	22.753±0.247	9.96	7.45	7.27	24.42±1.344
3	Manganese	mg/Kg	0.034	0.038	0.031	0.034±0.004	0.044	0.048	0.041	0.044±0.004
4	Zinc	mg/Kg	2.82	2.9	2.64	2.787±0.133	2.92	2.91	2.74	2.857±0.101
5	Lead	mg/Kg	0.48	0.56	0.037	0.359±0.282	0.31	0.35	0.038	0.233±0.170
6	Nickel	mg/Kg	0.032	0.036	0.028	0.032±0.004	0.042	0.046	0.048	0.045±0.003

Table 3: Pollution Load Index of soil irrigated with Mawaiya drain

Duration		Contamination Factor					PLI
		Cu	Fe	Zn	Pb	Ni	
2011-2012	Winter season	0.7560	285.1695	0.4036	1.0813	1.7235	63.6679
	Summer season	0.7791	274.5763	0.4051	1.0866	1.7294	63.8029
	Monsoon season	0.7231	236.8644	0.4038	1.0866	1.7250	56.9283
2012-2013	Winter season	0.7360	268.0085	0.3846	1.0664	1.5184	55.4195
	Summer season	0.7858	296.1864	0.4304	1.1661	1.8912	74.3153
	Monsoon season	0.7478	247.6695	0.3545	0.9994	1.4450	48.6880

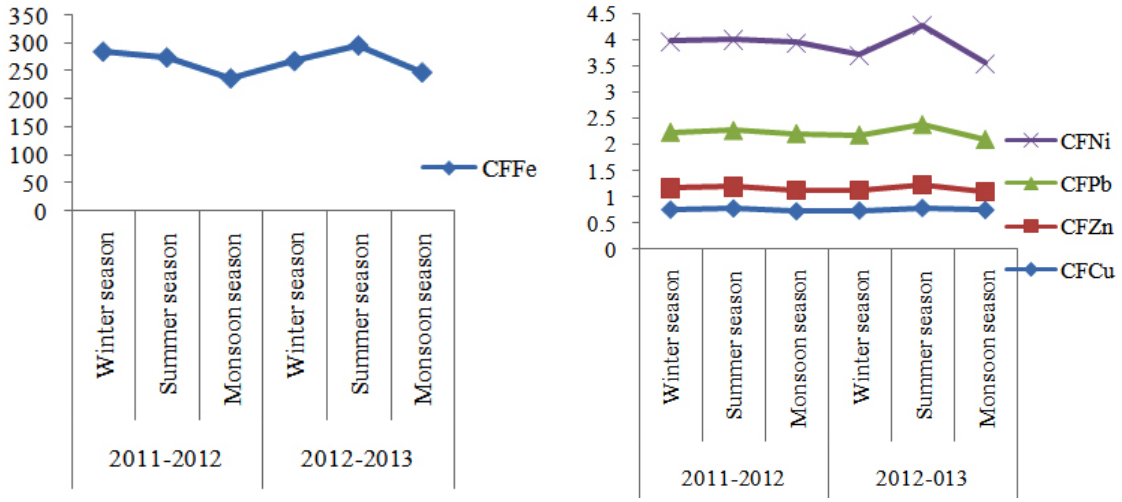

Fig. 2: Contamination factors of Mawaiya drain heavy metals in study area

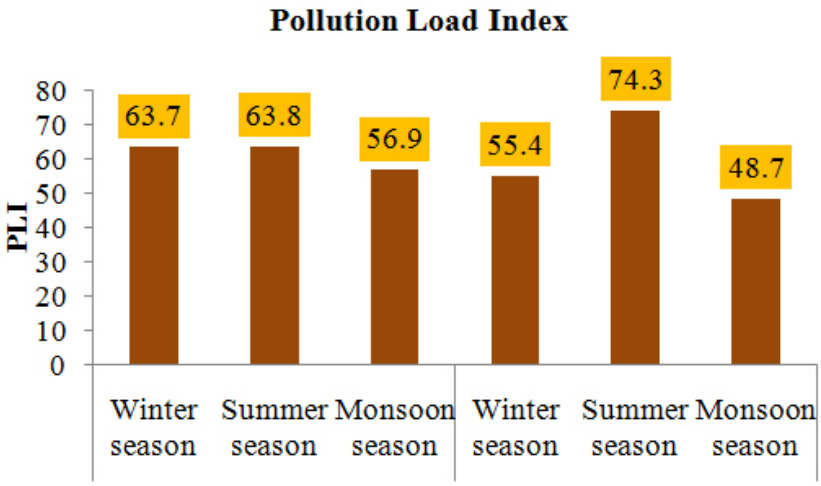

Fig. 3: Pollution load index of soil irrigated with Mawaiya drain from 2011-2013

Accumulation of iron in soil increase with time whereas other metals found to be constant in their respective presence in soil irrigated with Mawaiya drain during the study period. The intensity of adverse effects of several heavy metals depends upon the form and percentage distribution in soil. The soil parameters such as soil texture, organic matter content, pH, redox potential will affect the mobility of metal and it translocation in plan grown[14]. Most of the trace metals are found in crystalline state and are immobile. Oxides of iron and manganese are generally coated on organic matted present in soil and fine particles of clay along with other colloidal material which are generally active provide mobility platform to trace metal. Several human interventions in environment geochemical cycle of trace metals, resulting in soil and water contamination which finally enters in food chain[9].

Conclusion

Pollution Load index of soil is useful to assess the pollution level in soil and it was found that Mawaiya drain irrigated soil contamination with heavy metal within safe limits as per WHO[17]. Incremental change in population and industrial development, quantity of wastewater would increase in the region. It may cause increase in heavy metal concentration in wastewater of the drain and soil irrigated. The soil contamination is increasing in progressive time intervals and peaks in summers. Wash off of fields with rains in monsoon period, the pollution load in soil decreases in monsoon and winter. The heavy metals enter in food chain through crop raised on the irrigated soil wastewater[7,18]. Introduction of heavy metals in food chain will finally affect the ecology of the region. It is recommended to test heavy metals in soil at regular intervals where wastewater irrigation is practiced and regulatory bodies to control the industrial wastewater discharge in such drains.

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