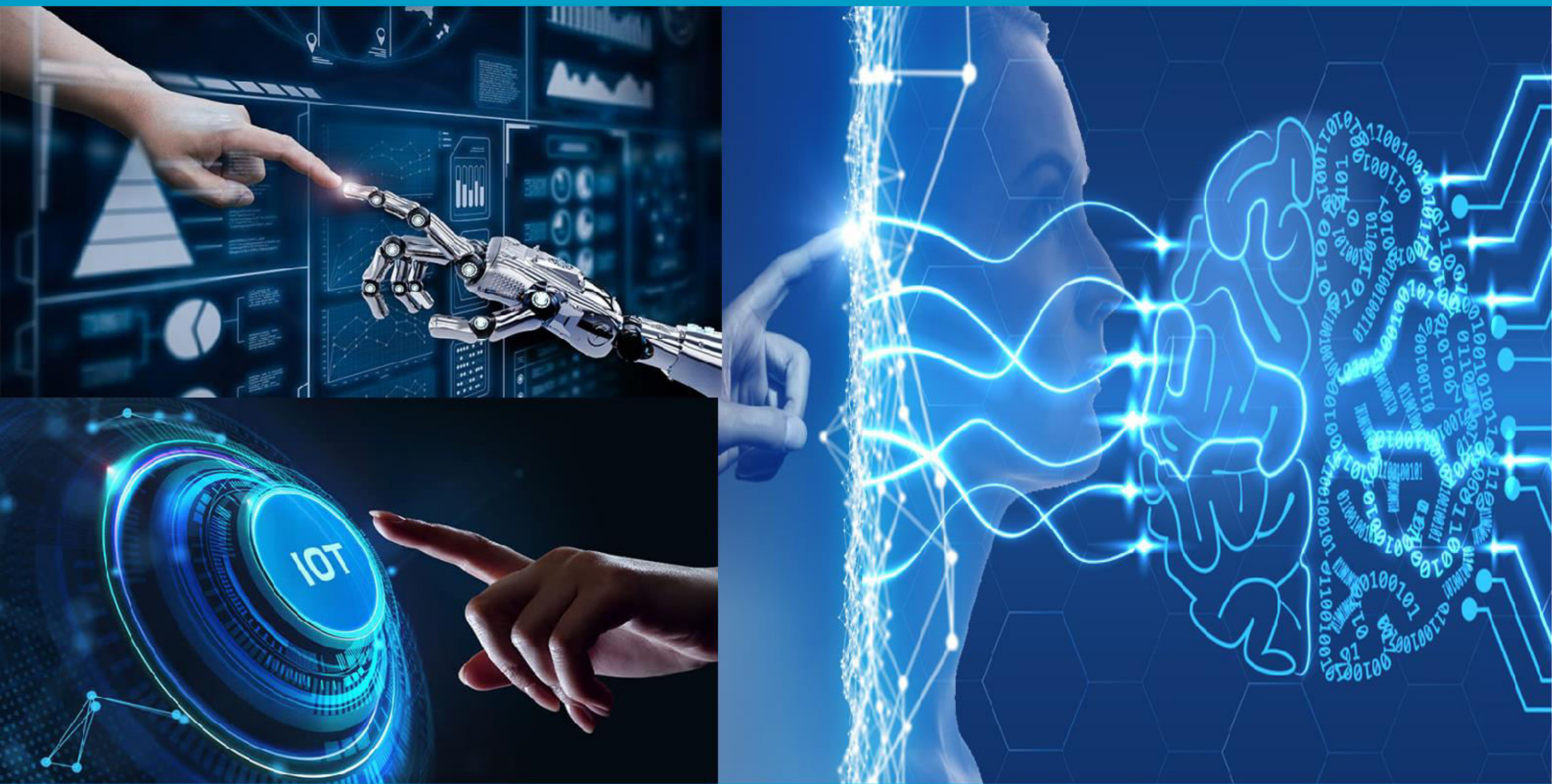
IJMRSETM

e-ISSN: 2395 - 7639



INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING, TECHNOLOGY AND MANAGEMENT

Volume 10, Issue 1, January 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.580

+91 99405 72462 +91 63819 07438 ijmrsetm@gmail.com www.ijmrsetm.com

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

| ISSN: 2395-7639| www.ijmrsetm.com| Impact Factor: 7.580 | A Monthly Double-Blind Peer Reviewed Journal |

|| Volume 10, Issue 1, January 2023 ||

|DOI:10.15680/IJMRSETM.2023.1001021|

Impact of Untreated Sewage Water on Vegetable Chemical Contamination

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ABSTRACT: In this study an assessment is made of the negative impacts of untreated sewage water irrigation on soils, crops & vegetables sampled in India. For this purpose, samples of soil profiles (0–60 cm in depth) and crops were collected from two untreated sewage irrigated sites and a tube well-irrigated (control) site. Total concentrations of the five heavy metals (Ni, Pb, Cd, Zn and Cr) were determined. The Pollution Load Indexes (PLIs) and Contamination Factors (CFs) for soils and Hazard quotients (ΣHQ) for some vegetables were also calculated. The results showed the use of untreated sewage water has caused the following changes as compared to control site: (1) a 20–30% increase in organic matter content of soil; (2) increase in pH by 2–3 units; (3) significant concentration increase in Ex-Ca especially in top layers of soil resulting in high CEC; (4) build up of heavy metals (notably Pb and Ni) in topsoil above Maximum Permissible Limits (MPLs) indicating a moderate contamination (PLI > 1, CF > 2.5); (5) contamination of some vegetables (spinach and lettuce) with Cd due to its high phytoavailability in topsoil causing a HQ > 1; (6) excessive accumulation of Ni and Pb in wheat due to continual addition of heavy metals through long-term untreated sewage water application. The study concludes that strict protection measures, stringent guidelines and an integrated system for the treatment and recycling of sewage water are needed to minimize the negative impacts of untreated sewage irrigation in the study area.

KEYWORDS: untreated sewage water, irrigation, heavy metals, vegetables, contamination, chemical, recycling

INTRODUCTION

The volume of sewage water generated by domestic, industrial and commercial sources has increased along with the increasing population, urbanization, improved living conditions, and economic development. In the urban areas of many (developing) countries, urban and peri-urban agriculture depends, at least to a certain extent, on sewage water as a source of irrigation water. The quality of water and the conditions under which this water is used vary significantly. In poor countries, this water may, in extreme cases, take the form of diluted raw sewage, even if this practice is considered illegal[1] .However, the quality of the wastewater used and the nature of its use vary enormously, both between and within countries. Sewage water irrigation is also known to contribute significantly to the heavy metal content of soils . Plant species have a variety of capacities to remove and accumulate heavy metals; therefore, there are reports indicating that certain species may accumulate specific heavy metals, causing a serious risk to human health when plant-based foodstuffs are consumed .The disposal of sewage water and industrial waste is a significant problem. The sewage water and industrial waste are often drained to agricultural lands where they are used for growing crops[2], including vegetables. These sewage effluents are considered a rich source of organic matter and other nutrients, but they elevate the levels of heavy metals, such as Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd and Co, in the receiving soils .
There is an increasing risk of public exposure to heavy metals because of the consumption of food grown in sewage wastewater[3] .

The problem of heavy metals entering the food chain requires systematic assessments to make timely decisions to avoid severe health effects because of the invisible mode of heavy metal toxicity. Risk assessments have been performed using various risk assessment techniques, such as the hazard quotient (HQ),the Health Risk Index (HRI), the morbidity status (MS), the enrichment factor (EF), the degree of contamination (C_{deg}), the uptake/transfer factor (UF) , statistics, geostatistics and geographic information systems GIS .

Wastewaters are contaminated with trace elements, such as lead (Pb), copper (Cu), zinc (Zn), boron (B), cobalt (Co), chromium (Cr), arsenic (As), molybdenum (Mo) and manganese (Mn), many of which are non-essential and, over time, are

| ISSN: 2395-7639| www.ijmrsetm.com| Impact Factor: 7.580 | A Monthly Double-Blind Peer Reviewed Journal |

|| Volume 10, Issue 1, January 2023 ||

|DOI:10.15680/IJMRSETM.2023.1001021|

toxic to plants, animals and human beings .The long-term application of treated and untreated wastewater has resulted in a significant buildup of heavy metals in the soil;as well as leachate to groundwater through dumpsites,and in vegetables and cereals and their subsequent transfer to the food chain, causing a potential health risk to consumers . Heavy metal concentrations in plants grown in wastewater-irrigated soils were significantly higher than in plants grown in the reference soil. Many scientists have concluded that the use of treated and untreated wastewater for irrigation increased the contamination with Cd, Pb and Ni in the edible portions of vegetables, causing a potential health risk in the long term. Scientists have found that the bioaccumulation of Pb and Cr in vegetables was above the critical concentrations for plant growth, while Pb and Cd were above the prescribed limit for animal diets.[4]

Although zinc is an essential element for plants, its elevated concentration is phytotoxic, directly affecting crop yield and soil fertility. Soil concentrations ranging from 70–400 mg/kg are classified as critical, above which toxicity is considered likely . In addition it is an essential element required by the human body in small amounts. The average daily zinc intake through the diet ranges from 5.2 to 16.2 milligrams. Food may contain levels of zinc ranging from approximately two parts of zinc per million (2 ppm) parts food (e.g., leafy vegetables) to 29 ppm (meats, fish and poultry). Cadmium and its compounds might travel through the soil, but its mobility depends on several factors, such as pH and the amount of organic matter, which will vary depending on the local environment.[5] Generally, cadmium binds strongly to organic matter, becoming immobile in the soil and is taken up by plant life, eventually entering the food chain.

Heavy metals are one of the important types of contaminants that can be found on the surface and in the tissues of fresh vegetables. The prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Vegetables, especially leafy vegetables grown in heavy metal-contaminated soils, accumulate higher amounts of metals than do those grown in uncontaminated soils because they absorb these metals through their leaves . Leafy vegetables, such as cauliflower, cabbage and spinach, grow quite well in the presence of sewage water , whereas other vegetables, such as radish, are sensitive to sewage water . Vegetables grown using sewage water contain many heavy metals, which cause serious health hazards to the community and animals.This concern is of special importance in locations where untreated sewage is applied for longer periods of time to grow vegetables in urban lands. Heavy metal bioaccumulation in the food chain can be especially dangerous to human health.[6] These metals enter the human body primarily through two routes, namely, inhalation and ingestion, with ingestion being the main route of exposure to these elements in the human population.

Okra (Abelmoschus esculentus (L) Moench) is an annual vegetable crop and belongs to the family Malvaceae. Okra is a good source of carbohydrates, protein, dietary fiber, calcium, magnesium, potassium and vitamins A and C . Okra contains glycans, substances responsible for the viscosity of aqueous suspensions and the stringy, gum-like consistency that is desired in good-quality soups. Glycans are also an excellent source of iodine, which is useful for the treatment of goiters. The powdered root of okra is consumed along with sugar as a treatment for leucorrhoea and backache. Okra acts as a tonic for both men and women and enables them to increase their vitality and vigor. The tender pods of okra are mainly used as a vegetable. The okra pods are also used as snacks and are sliced and sun dried for offseason use. Okra gum obtained from the seedpods of Hibiscus esculentus is an anionic polysaccharide, which can be used as a flocculant for the removal of solid waste from tannery effluent[7] .

The use of untreated sewage water for different purposes is one of the most important strategic alternatives for renewable water in many countries, especially those that suffer from a shortage of traditional water resources. The use of wastewater in agriculture provides water, N, P, and organic matter to the soils; however, there is concern about the accumulation of potentially toxic elements, such as Cd, Cu, Fe, Mn, Pb and Zn, from both domestic and industrial sources . Heavy metals can also accumulate in the soil at toxic levels, as do the salts during long-term applications of untreated and treated wastewaters. Soils irrigated by wastewater accumulate heavy metals, such as Cr, Zn, Pb, Cd and Ni, in the surface soil. When the capacity of the soil to retain heavy metals is reduced due to the repeated application of sewage water, heavy metals leach into the ground water or the soil solution, which are available for plant uptake. For the metals derived from anthropogenic sources, this factor can strongly influence their speciation and, hence, their bioavailability[8] .

The aim of this research is to evaluate the effect of untreated sewage water chemical contamination in field crops.

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II.DISCUSSION

The study area was Jaipur where crops and vegetables are irrigated by untreated sewage water. Sewage contained on an average 1.20 $mg·Kg^{-1}$ Cd, over 8 times the permissible level by the EU standards (0.2 $mg·Kg^{-1}$); Cu concentrations were 29.07 $mg·Kg^{-1}$, which is little higher than EU Standard (20 $mg·Kg^{-1}$); concentrations of Pb were 6.77 $mg·Kg^{-1}$, over 22 times the permissible levels allowed by both EU standards and UK guidelines (0.3 $mg·Kg^{-1}$); Zn concentrations were 221 $mg·Kg^{-1}$, over 4 times the guideline value (50 $mg·Kg^{-1}$). All the plants contained concentrations of heavy metals[9] above the permissible levels. Furthermore the concentrations observed in this study were higher than those reported by other workers who have examined vegetation from other contaminated sites. The plants grown on the soil polluted with sewage-effluents were found to record higher uptake of heavy metals when compared to plants grown on normal soils [16]. The Fe concentration in sewage is high as soil in Agra is alluvial and has capacity to absorb iron. Cd and Pb content is also high in sewage. Zn, Cu and Cd were highly significant ($p < 0.01$) (Table 1). The treated site (Dhandupura) has comparatively lower amount of Cd as compared to other sites. In pre and post harvested soil Fe, Zn, Pb, Cu and Cd are highly significant ($p < 0.01$) (Tables 2 and 3). Cu is negatively correlated to Cd concentration in all the vegetables and vice versa (Table 4).
The Fe content in sewage, pre and post harvested soil post < pre < sewage, Zn content post < pre < sewage, Pb content sewage < post < pre, Cu content sewage < pre < post, Cd content sewage < post < pre.

The Fe content in vegetables tomato < okra < brinjal

Table 1. Showing ANOVA for comparison of heavy metals of different sites of sewage in Jaipur.

Fe	Between sites	0.915	6	0.152	2.104	0.078	*
	Error	2.537	35	0.072			
	Total	3.451	41				
Zn	Between sites	2347.682	6	391.280	15.640	0.000	**
	Error	875.643	35	25.018			
	Total	3223.326	41				
Pb	Between sites	355.420	6	59.237	4.178	0.003	**
	Error	496.231	35	14.178			
	Total	851.651	41				
Cu	Between sites	924.134	6	154.022	9.106	0.000	**
	Error	591.994	35	16.914			
	Total	1516.128	41				
Cd	Between sites	1.099	6	0.183	1.576	0.183	NS
	Within error	4.067	35	0.116			
	Total	5.165	41				

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Table 2. Showing ANOVA for comparison of heavy metals of different site in pre harvested soil, Jaipur

	Between sites	2.381	6	0.397	5.016	0.001	**
Fe	Error	2.769	35	0.079			
	Total	5.150	41				
	Between sites	1665.300	6	277.550	7.471	0.000	**
Zn	Error	1300.320	35	37.152			
	Total	2965.621	41				
	Between sites	2010.395	6	335.066	20.570	0.000	**
Pb	Error	570.124	35	16.289			
	Total	2580.519	41				
	Between sites	3279.855	6	546.642	26.801	0.000	**
Cu	Error	713.883	35	20.397			
	Total	3993.737	41				
	Between sites	7.305	6	1.217	5.185	0.001	**
Cd	Error	8.219	35	0.235			
	Total	15.524	41				

Table 3. Showing ANOVA for comparison of heavy metals of different site in post harvested soil, Jaipur

	Between groups	1.949	6	0.325	4.674	0.001**
Fe	Within groups	2.432	35	0.069		
	Total	4.381	41			
	Between groups	860.047	6	143.341	7.283	0.000**
Zn	Within groups	688.826	35	19.681		
	Total	1548.873	41			
	Between groups	1336.214	6	222.702	11.949	0.000**
Pb	Within groups	652.336	35	18.638		
	Total	1988.550	41			
	Between groups	4572.126	6	762.021	69.481	0.000**
Cu	Within groups	383.858	35	10.967		
	Total	4955.983	41			
	Between groups	5.851	6	0.975	5.695	0.000**
Cd	Within groups	5.993	35	0.171		
	Total	11.843	41			

and cucumber < reddish < spinach and beetroot, Zn content as brinjal and copper < okra < tomato < reddish < spinach < beetroot < Pb content as tomato < okra < brinjal and cucumber < reddish < beetroot < spinach. Cu as okra < tomato < cucumber < brinjal < reddish < spinach < beetroot Cd as okra < brinjal and cucumber < tomato < reddish < beetroot <

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spinach. The mean values and range of heavy metals in sewage pre and post harvested soil and vegetables are shown in Tables 5-7.

Table 4. Correlation between different components of vegetable in different sites, Jaipur

Component	(r)	Fe	Zn	Pb	Cu	Cd
Fe	Pearson corr.	1	0.414**	0.207	0.396**	0.308*
	Sig.		0.003	0.154	0.005	0.032
Zn	Pearson corr.	0.414**	1	0.192	0.092	0.363*
	Sig.	0.003		0.187	0.531	0.010
Pb	Pearson corr.	0.207	0.192	1	0.078	0.368**
	Sig.	0.154	0.187		0.597	0.009
Cu	Pearson corr.	0.396**	0.092	0.078	1	−0.009
	Sig.	0.005	0.531	0.597		0.954
Cd	Pearson corr.	0.308*	0.363*	0.368**	−0.009	1

Table 5. Showing heavy metal conc. ($mg \cdot Kg^{-1}$) in sewage water of different sites, Jaipur

Sewage water (Heavy metals)	1	2	3	4	5	6	7	Overall average
Iron (%)	0.98 - 1.9 (1.21)	0.97 - 1.17 (1.05)	0.87 - 1.43 (1.11)	0.93 - 1.12 (1.03)	1.23 - 1.76 (1.43)	1.09 - 1.89 (1.4)	0.9 - 1.99 (1.2)	0.87 - 1.99 (1.20)
Zinc ($mg \cdot Kg^{-1}$)	45.34 - 60.11 (53.49)	56.56 - 71.78 (63.27)	49.9 - 57.76 (53.82)	65.87 - 78.98 (71.82)	56.78 - 76.76 (70.4)	54.76 - 61.67 (57.93)	65.71 - 73.56 (70.64)	45.34 - 78.98 (63.05)
Lead ($mg \cdot Kg^{-1}$)	21.0 - 32.66 (29.12)	30.43 - 40.78 (35.06)	30.13 - 37.87 (32.95)	32.65 - 40.43 (36.78)	23.76 - 39.76 (30.91)	28.54 - 36.01 (32.27)	23.73 - 29.32 (27.92)	21.0 - 40.78 (32.14)
Copper ($mg \cdot Kg^{-1}$)	29.09 - 32.87 (30.98)	25.9 - 35.76 (30.15)	17.34 - 29.02 (24.45)	28.76 - 40.64 (35.72)	19.09 - 29.54 (22.07)	30.13 - 39.23 (34.1)	21.54 - 30.1 (26.02)	17.34 - 40.64 (29.07)
Cadmium ($mg \cdot Kg^{-1}$)	0.84 - 1.78 (1.13)	0.67 - 1.75 (1.02)	0.54 - 1.2 (0.94)	0.98 - 1.9 (1.34)	1.1 - 2.01 (1.49)	0.98 - 1.52 (1.2)	0.67 - 1.92 (1.15)	0.54 - 2.01 (1.18)

Table 6. Showing heavy metal conc. ($mg \cdot Kg^{-1}$) in pre harvested soil of different sites, Jaipur

Heavy metals in soil	1	2	3	4	5	6	7	Overall range
Iron (%)	0.9 - 2.01 (1.41)	0.99 - 1.9 (1.42)	0.54 - 0.73 (0.68)	0.87 - 1.61 (1.23)	0.98 - 1.61 (1.24)	0.9 - 1.19 (1.07)	0.89 - 1.26 (1.05)	0.54 - 2.01 (1.15)
Zinc ($mg \cdot Kg^{-1}$)	45.76 - 55.09 (49.69)	48.03 - 58.98 (53.71)	47.61 - 54.9 (50.32)	47.69 - 76.43 (62.29)	42.6 - 63.6 (55.23)	47.9 - 54.16 (50.11)	62.19 - 70.69 (67.27)	42.6 - 76.43 (55.51)
Lead ($mg \cdot Kg^{-1}$)	34.9 - 46.98 (41.19)	35.76 - 43.98 (39.41)	21.66 - 36.94 (28.7)	24.36 - 31.93 (28.45)	21.65 - 36.0 (27.1)	17.21 - 24.64 (20.93)	20.17 - 29.79 (24.85)	17.21 - 46.98 (30.09)
Copper ($mg \cdot Kg^{-1}$)	29.04 - 40.32 (35.42)	29.76 - 48.2 (40.62)	16.69 - 18.96 (17.78)	16.72 - 21.93 (19.44)	12.34 - 18.98 (15.32)	22.96 - 36.19 (30.19)	16.94 - 32.8 (24.55)	12.34 - 48.2 (26.18)
Cadmium ($mg \cdot Kg^{-1}$)	0.92 - 2.98 (1.33)	0.8 - 1.65 (1.09)	0.07 - 0.32 (0.22)	0.29 - 1.61 (0.79)	0.36 - 2.41 (1.59)	0.22 - 1.01 (0.7)	0.56 - 1.07 (0.76)	0.07 - 2.98 (0.92)

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Table 7. Showing heavy metal conc. (mg·Kg^{-1}) in post harvested soil of different sites, Jaipur

Heavy metals in soil	1	2	3	4	5	6	7	Overall range
Iron (%)	0.89 - 1.09 (0.97)	0.91 - 1.82 (1.11)	0.49 - 0.64 (0.58)	0.47 - 1.72 (1.11)	0.8 - 1.02 (0.94)	0.89 - 1.17 (1.0)	0.19 - 0.94 (0.56)	0.19 - 1.82
Zinc (mg·Kg^{-1})	48.1 - 58.91 (52.48)	40.81 - 52.02 (47.37)	45.15 - 48.71 (47.53)	49.61 - 66.17 (58.64)	42.68 - 59.61 (50.74)	49.69 - 54.61 (51.95)	57.16 - 61.92 (59.36)	40.81 - 66.17
Lead (mg·Kg^{-1})	30.12 - 42.05 (37.18)	29.01 - 34.04 (31.68)	21.61 - 36.11 (28.57)	25.61 - 30.99 (28.22)	12.16 - 32.19 (24.78)	18.96 - 22.9 (20.59)	18.1 - 27.1 (20.09)	12.16 - 42.05
Copper (mg·Kg^{-1})	29.45 - 38.11 (33.28)	32.96 - 41.72 (36.77)	17.27 - 16.69 (18.22)	18.86 - 22.41 (20.36)	10.86 - 17.31 (13.02)	31.69 - 49.62 (43.98)	19.79 - 26.59 (22.28)	10.86 - 49.62
Cadmium (mg·Kg^{-1})	0.92 - 1.67 (1.12)	0.87 - 1.18 (0.97)	0.89 - 1.27 (1.05)	0.21 - 1.66 (0.65)	0.28 - 2.9 (1.6)	0.98 - 1.12 (1.06)	0.27 - 0.37 (0.31)	0.21 - 2.9

Table 8. Showing heavy metal conc. (mg·Kg^{s}) in vegetables of different sites, Jaipur

Heavy metals in veg.	Fe (%) (mg·Kg^{-1})	Zn (mg·Kg^{-1})	Pb (mg·Kg^{-1})	Cu (mg·Kg^{-1})	Cd (mg·Kg^{-1})
Spinach	0.92 - 1.98 (1.38)	54.12 - 71.89 (63.91)	25.76 - 36.98 (31.42)	18.35 - 39.56 (24.72)	0.14 - 1.98 (1.09)
Brinjal	(0.61 - 1.09) (0.91)	49.09 - 60.12 (53.92)	20.12 - 32.56 (27.76)	15.23 - 31.35 (20.89)	0.12 - 0.97 (0.47)
Cucumber	0.61 - 1.09 (0.87)	50.12 - 60.12 (54.84)	20.12 - 32.56 (26.27)	15.23 - 29.56 (20.38)	0.12 - 0.97 (0.5)
Reddish	0.9 - 1.9 (1.12)	53.12 - 70.12 (60.84)	23.06 - 34.26 (28.99)	18.45 - 38.67 (24.35)	0.19 - 1.52 (0.87)
Beetroot	0.99 - 1.98 (1.4)	54.89 - 71.98 (63.03)	23.98 - 36.23 (30.93)	19.01 - 40.13 (24.95)	0.17 - 1.9 (1.3)
Tomato	0.69 - 0.97 (0.86)	49.78 - 69.03 (59.25)	19.23 - 30.12 (24.51)	16.23 - 29.12 (21.31)	0.12 - 0.98 (0.61)
Okra	0.26 - 0.98 (0.72)	48.67 - 62.87 (48.67)	18.34 - 31.23 (23.34)	16.45 - 25.3 (19.64)	0.19 - 0.89 (0.68)

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III.RESULTS

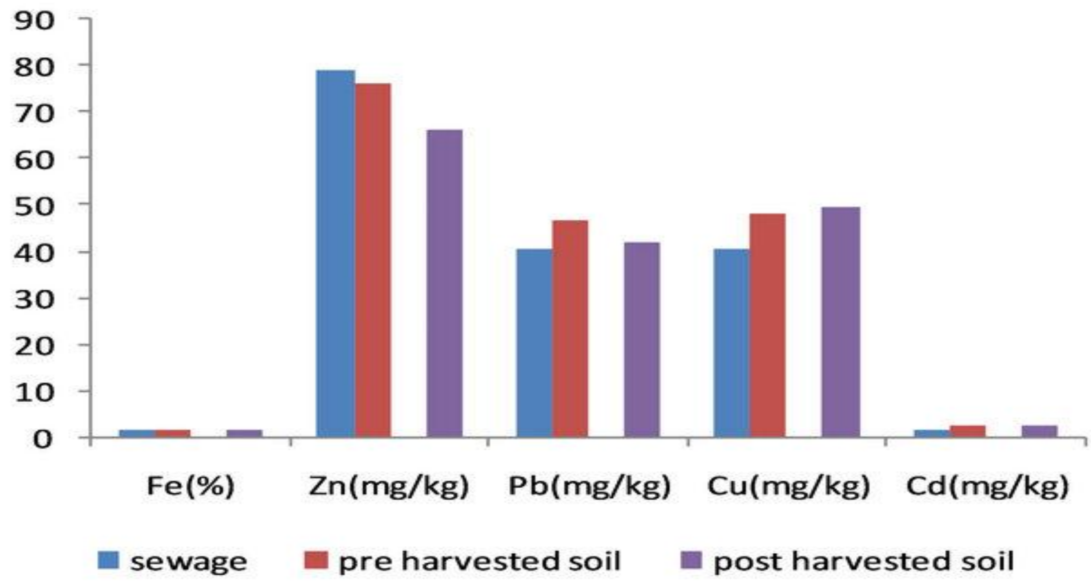

Figure 1. Showing comparison of conc. of heavy metals in sewage, pre and post harvested soil, Jaipur

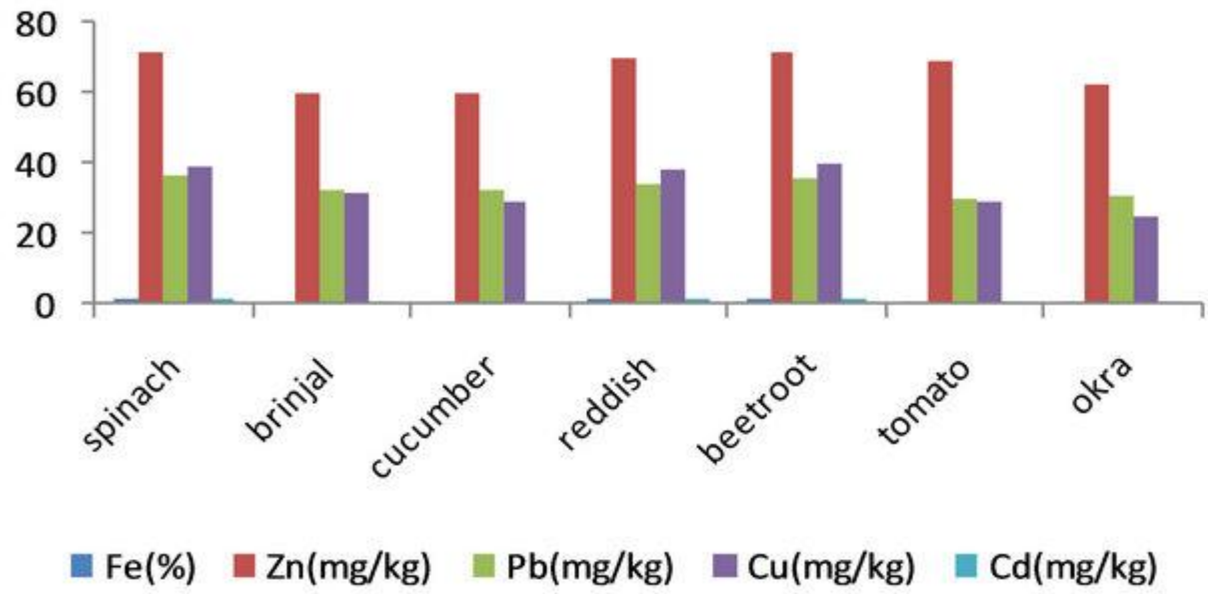

Figure 2. Showing comparison of conc. of heavy metals in various vegetables, Jaipur

Sewage treatment (or domestic wastewater treatment, municipal wastewater treatment) is a type of wastewater treatment which aims to remove contaminants from sewage to produce an effluent that is suitable for discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges.[2] Sewage contains wastewater from households and businesses and possibly pre-treated industrial wastewater. There are a high number of sewage treatment processes to choose from. These can range from decentralized

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systems (including on-site treatment systems) to large centralized systems involving a network of pipes and pump stations (called sewerage) which convey the sewage to a treatment plant. For cities that have a combined sewer, the sewers will also carry urban runoff (stormwater) to the sewage treatment plant. Sewage treatment often involves two main stages, called primary and secondary treatment, while advanced treatment also incorporates a tertiary treatment stage with polishing processes and nutrient removal. Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic biological processes.[10]

Sewage can be treated close to where the sewage is created, which may be called a "decentralized" system or even an "on-site" system (on-site sewage facility, septic tanks, etc.). Alternatively, sewage can be collected and transported by a network of pipes and pump stations to a municipal treatment plant. This is called a "centralized" system (see also sewerage and pipes and infrastructure).[11]

A large number of sewage treatment technologies have been developed, mostly using biological treatment processes (see list of wastewater treatment technologies). Very broadly, they can be grouped into high tech (high cost) versus low tech (low cost) options, although some technologies might fall into either category. Other grouping classifications are "intensive" or "mechanized" systems (more compact, and frequently employing high tech options) versus "extensive" or "natural" or "nature-based" systems (usually using natural treatment processes and occupying larger areas) systems.[12] This classification may be sometimes oversimplified, because a treatment plant may involve a combination of processes, and the interpretation of the concepts of high tech and low tech, intensive and extensive, mechanized and natural processes may vary from place to place.

Primary treatment

Primary treatment is the "removal of a portion of the suspended solids and organic matter from the sewage".It consists of allowing sewage to pass slowly through a basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface and are skimmed off. These basis are called "primary sedimentation tanks" or "primary clarifiers" and typically have a hydraulic retention time (HRT) of 1.5 to 2.5 hours. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank where it is pumped to sludge treatment facilities.[13]

Rectangular primary settling tanks at a sewage treatment plant

Sewage treatment plants that are connected to a combined sewer system sometimes have a bypass arrangement after the primary treatment unit. This means that during very heavy rainfall events, the secondary and tertiary treatment systems can be bypassed to protect them from hydraulic overloading, and the mixture of sewage and storm-water receives primary treatment only.[14]

Secondary treatment

The main processes involved in secondary sewage treatment are designed to remove as much of the solid material as possible. They use biological processes to digest and remove the remaining soluble material, especially the organic fraction. This can be done with either suspended-growth or biofilm processes. The microorganisms that feed on the organic matter

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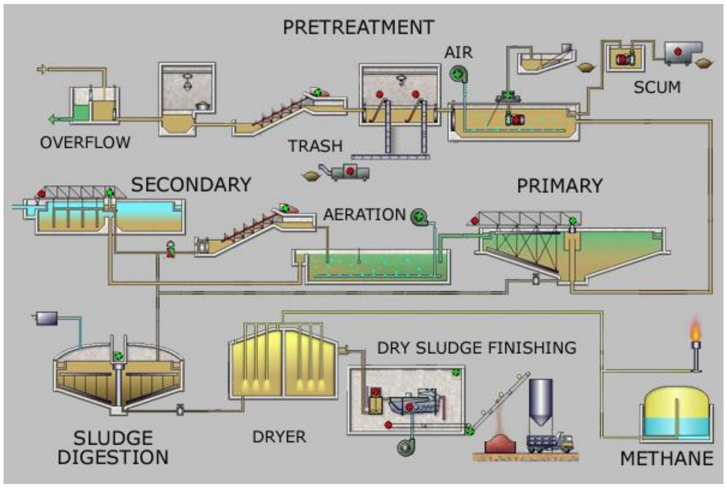
|DOI:10.15680/IJMRSETM.2023.1001021|

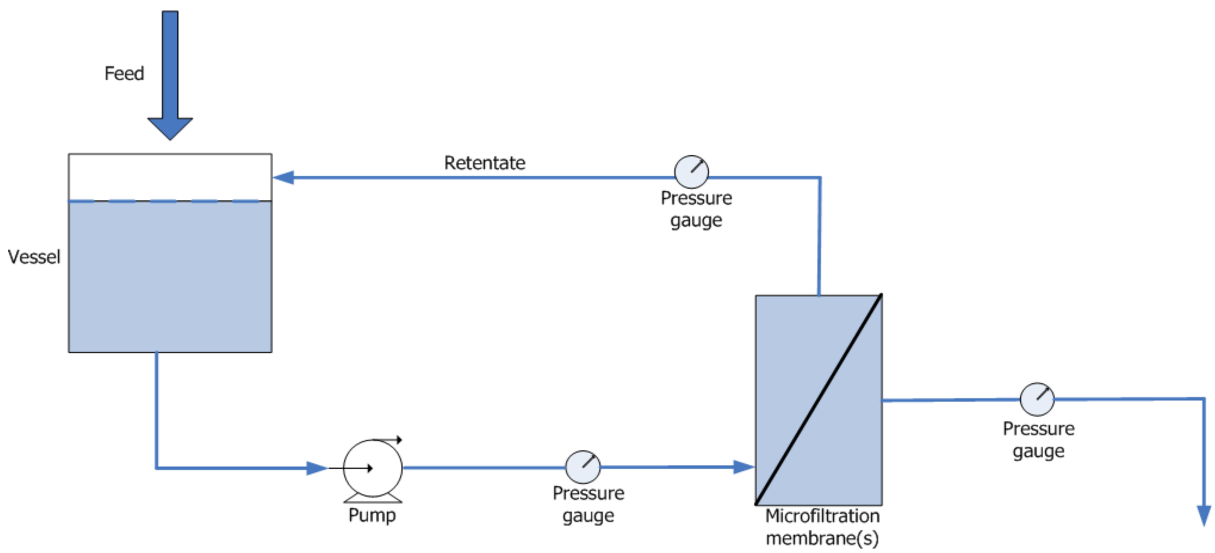
present in the sewage grow and multiply, constituting the biological solids, or biomass. These grow and group together in the form of flocs or biofilms and, in some specific processes, as granules. In several treatment processes, the biological floc or biofilm and remaining fine solids can then be settled as a sludge, leaving a liquid substantially free of solids, and with a greatly reduced concentration of pollutants.[15]



Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic processes. The organisms involved in these processes are sensitive to the presence of toxic materials, although these are not expected to be present at high concentrations in typical municipal sewage.[16]

Tertiary treatment

Advanced sewage treatment generally involves three main stages, called primary, secondary and tertiary treatment but may also include intermediate stages and final polishing processes. The purpose of tertiary treatment (also called "advanced treatment") is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving water body or reused. More than one tertiary treatment process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called "effluent polishing". Tertiary treatment may include biological nutrient removal (alternatively, this can be classified as secondary treatment), disinfection and removal of micropollutants, such as environmental persistent pharmaceutical pollutants.[17]



| ISSN: 2395-7639| www.ijmrsetm.com| Impact Factor: 7.580 | A Monthly Double-Blind Peer Reviewed Journal |

|| Volume 10, Issue 1, January 2023 ||

|DOI:10.15680/IJMRSETM.2023.1001021|

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to allow discharge into a highly sensitive or fragile ecosystem such as estuaries, low-flow rivers or coral reefs. Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, greenway or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.[18]

Sand filtration removes much of the residual suspended matter. Filtration over activated carbon, also called carbon adsorption, removes residual toxins.Micro filtration or synthetic membranes are also used, for example in membrane bioreactors which also remove pathogens.[19]

Settlement and further biological improvement of treated sewage may be achieved through storage in large human-made ponds or lagoons. These lagoons are highly aerobic, and colonization by native macrophytes, especially reeds, is often encouraged.[20]

IV.CONCLUSIONS

Increasingly, people use treated or even untreated sewage for irrigation to produce crops. Cities provide lucrative markets for fresh produce, so are attractive to farmers. Because agriculture has to compete for increasingly scarce water resources with industry and municipal users, there is often no alternative for farmers but to use water polluted with sewage directly to water their crops.[21] There can be significant health hazards related to using water loaded with pathogens in this way. The World Health Organization developed guidelines for safe use of wastewater . They advocate a 'multiple-barrier' approach to wastewater use, where farmers are encouraged to adopt various risk-reducing behaviors. These include ceasing irrigation a few days before harvesting to allow pathogens to die off in the sunlight, applying water carefully so it does not contaminate leaves likely to be eaten raw, cleaning vegetables with disinfectant or allowing fecal sludge used in farming to dry before being used as a human manure.[22]

Water reclamation (also called wastewater reuse, water reuse or water recycling) is the process of converting municipal wastewater (sewage) or industrial wastewater into water that can be reused for a variety of purposes. Types of reuse include: urban reuse, agricultural reuse (irrigation), environmental reuse, industrial reuse, planned potable reuse, de facto wastewater reuse (unplanned potable reuse).[23] For example, reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater (i.e., groundwater recharge). Reused water may also be directed toward fulfilling certain needs in residences (e.g. toilet flushing), businesses, and industry, and could even be treated to reach drinking water standards. The injection of reclaimed water into the water supply distribution system is known as direct potable reuse, however, drinking reclaimed water is not a typical practice. Treated municipal wastewater reuse for irrigation is a long-established practice, especially in arid countries. Reusing wastewater as part of sustainable water management allows water to remain as an alternative water source for human activities. This can reduce scarcity and alleviate pressures on groundwater and other natural water bodies. [24]

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| ISSN: 2395-7639| www.ijmrsetm.com| Impact Factor: 7.580 | A Monthly Double-Blind Peer Reviewed Journal |

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|DOI:10.15680/IJMRSETM.2023.1001021|

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