CHARACTERIZATION OF INDUSTRIAL EFFLUENT AND ITS IMPACT ON SOIL PROPERTIES AROUND BHANDARA INDUSTRIAL AREA

THESIS

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Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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IN

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By

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DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled **"CHARACTERIZATION OF INDUSTRIAL EFFLUENT AND ITS IMPACT ON SOIL PROPERTIES AROUND BHANDARA INDUSTRIAL AREA"** or the part there of has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University of scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis entitled **"CHARACTERIZATION OF INDUSTRIAL EFFLUENT AND ITS IMPACT ON SOIL PROPERTIES AROUND BHANDARA INDUSTRIAL AREA"** submitted in partial fulfilment of the requirements for the degree of **"Master of Science in Agriculture (Soil Science and Agricultural Chemistry)"** of the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **CHUTE DIPALI YASHWANTRAO** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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Table of Contents

Sr. No.	Particulars	Page
A	List of Tables	
B	List of Figures	
C	List of Plates	
D	List of Abbreviation	
E	Thesis Abstract	
I	Introduction	1
II	Review of Literature	9
III	Material and Methods	28
IV	Results and Discussion	40
V	Summary and Conclusions	61
VI	Literature cited	64
*	Vita	

(A) List of Tables

Table No.	Title	Page No.
1	Seasonal variation in chemical characteristics of effluent and well water as influenced by industrial effluents.	43
2	Seasonal variation in micronutrients and heavy metals content in effluent and well water as influenced by industrial effluents.	47
3	Seasonal variation in oxygen demand of water as influenced by industrial effluents.	49
4	Fertility status of soil as influenced by industrial effluents.	51
5	Micronutrient and heavy metals status of soil as influenced by industrial effluents.	53
6	NPK, micro nutrient and heavy metal content in leaf sample of food grain crop at maturity stage as influenced by industrial effluents.	56
7	NPK, micro nutrient and heavy metal content in leaf sample of vegetable crop at maturity stage as influenced by industrial effluents.	58
8	NPK, micro nutrient and heavy metal content in leaf sample of fruit crop as influenced by industrial effluents.	60

(B) List of Figures

Fig. No.	Title	After page
1	Location map of study area in Bhandara, Maharashtra, (India)	29
2	Location map of study area.	29

(C) List of Plates

Plate	Caption	After page
1	Location of well water sampling	30
2	Location of river water sampling	30
3	Location of industrial effluent sampling	30
4	Location of effluent carrying stream sampling	30
5	Location of confluence water sampling	30

(D) Abbreviations

@	-	at the rate
BOD	-	Biological oxygen demand
COD	-	Chemical oxygen demand
dSm^{-1}	-	Decisiemens per meter
EC	-	Electrical Conductivity
et al.	-	etalia (and others)
Fig.	-	Figure
g	-	Gram
$me\ L^{-1}$	-	Milliequivalent per litre
$mg\ L^{-1}$	-	Milligram per litre
viz.	-	Namely
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
Fe	-	Iron
Mn	-	Manganese
Zn	-	Zinc
Cu	-	Copper
DTPA	-	Diethylene Triamine Penta Acetic acid
Org. C	-	Organic Carbon
US-EPA	-	United States, Environmental Protection Agency
SAR	-	Sodium adsorption ratio
NEQS	-	National Environmental Quality Standard
FAO	-	Food and Agricultural Organization
IS	-	Indian Standards

(E) **THESIS ABSTRACT**

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ABSTRACT

The study was conducted on Characterization of industrial effluent and its impact on soil properties around Bhandara industrial area to estimate the characteristics of industrial effluents, effluents mixed river water and well water for irrigation and to assess the possible impacts on soil properties and composition ofcrop plant during the year 2015-16. A total 10 samples, out of which 5 industrial effluent mixed water samples and 5 well water samples were collected from the vicinity of the industrial area during pre monsoon and post monsoon season. These samples were analyzed for pH, EC, cations, anions, biological oxygen demand (BOD), chemical oxygen demand (COD), micronutrient(Fe, Mn, Cu and Zn) and heavy metal content (Pb, Cd, Ni, Cr). The industrial effluents which was moderately high saline indicating unsuitable for irrigation, as it may develop sodicity in soil by its continuous use.The COD,BOD, micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Pb, Cd, Ni and Cd) in effluent was found within the permissible limits of NEQS except industrial effluent and effluent carrying stream. Soils receiving effluent irrigation and crops grown were containing higher proportion of micronutrients and heavymetals as compared to soils and crops receiving well water and contaminated river water irrigation. The soils receiving industrial mixed effluent irrigation were found rich in available N, P, K and organic carbon as compared to soils receiving well water irrigation.

Chapter I

INTRODUCTION

1.1 Background information

India needs to produce 380 million tonnes of food grains per annum in 2025 as against the present 206 million tonnes to feed 1.4 billion expected populations under resource constraints. The scope for increase in production through horizontal expansion of area is negligible. Due to competition from other more paying sectors of economy, the fresh water availability is bound to decrease for agriculture.

Moreover due to economic development of society towards urbanization and industrialization, huge quantities of effluents are produced, which are used for the irrigation in urban areas for crop production. In India, the share of fresh water available for the agriculture use is estimated to decrease from the present level i.e. 85 to 74 percent in 2025, due to increasing demand from users sectors (Veerabadran, 2003)

Water and nutrients are the major inputs for crop production. Rapid industrialization, mushrooming population and greater urbanization in the last five decades have resulted in utilization of significant quantities of fresh water available for the agriculture is dwindling. It is predicted that most of the Asian countries will face severe problem related to water availability by 2025 (Singh, 1999).

A long term and indiscriminate use of sewage water may prove hazardous to human health since it contains variable amount of metallic cations and various bacteria and viruses contaminating the soil and the plants being grown on them. India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Singh, 2003).

Predominance of industrial waste brings in chemical pollutants, which may be toxic to plants at higher concentrations. The problem of environmental pollution due to toxic metals has begun to cause now in most major metropolitan cities. The toxic heavy metals entering the ecosystem may lead to geo-accumulation, bioaccumulation and bio-magnifications. Most crops, those grown in peri-urban agriculture, need specific amount of NPK for maximum yield, once the recommended level of NPK is exceeded, crop growth and yield may negatively be affected. Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological system and their deficiency or excess could lead to a number of disorders.

In many areas of developing countries, untreated wastewater flows through channels into rivers where it is diverted by subsistence farmers to small plots of vegetables include carrots lettuce, cabbage and others which are easily consumed as salad. The public health risks of using such contaminated streams for irrigation are obvious(Mead and Griffin, 1998; WHO 2004). However, treated effluent can be used for irrigation under controlled conditions to minimize the transfer of pathogenic and toxic contaminants in to agricultural products, soils surface and groundwater (Batarseh*et al.*1989).

Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in bio-system through contaminated water and soil. Therefore, as better understanding of heavy metal sources their accumulation in the soil and the effect of their presence in water and soil on plant systems seems to be particularly important issue of present day research on risk assessments.

Heavy metals such as zinc, cadmium, copper, lead, nickel and chromium are present in all soil but are usually found at low concentrations. Baseline concentrations vary depending on soil type, soil parent material and type of heavy metal are usually in the range 0.1-200 mg kg^{-1}. Enhanced concentrations are found in soil-from naturally mineralized areas, but more commonly arise where heavy metals have become dispersed as a result of human activity since heavy metals are used in wide variety of industrial processes.

The pathways by which heavy metals contaminate the soil vary from direct pathway via mining, waste disposal and agricultural activity as well as more indirect pathways such as atmospheric deposition. Their impacts depend on the use of affected land. Heavy metal contamination of agricultural land can have serious impact on crop growth and crop quality and in urban areas is often concern in terms of population of underlying aquifers. If the contamination is confined to industrial areas, then the concern is less than if, widely dispersed. Therefore, the reduction of the dispersion of heavy metals in the environment is a major concern in most industrial societies. Once contaminated it is extremely difficult and expensive to decontaminate soil.

The relationship between soil contamination and crop contamination is complicated and depends on many soil and plant factors. Critical factor are the ability of soil to absorb the heavy metals and thereby maintain a low concentration in the soil solution and the interaction between various heavy metals, e.g. Cd uptake can be affected by competition from other metals such as Zn and Cu. Soil pH strongly affects the amount of adsorption – absorption of most trace metals is much lower under acid condition potentially resulting in greater plant uptake and greater toxicity.

Soil contaminated by heavy metals pose a threat in new ways (1) directly through their toxic effect on the growth of crops thereby reducing crop yields and (2) indirectly by entering the human food chain could adversely impact on human health. Even a reduction of crop yield by just a few percent could lead to a significant long term loss in production.

Heavy metals may also have deleterious effects on the microbial functioning of soil, grain with important long term consequence. Zinc, for example, can reduce grain yield as well as reducing microbial activity especially of nitrifying organisms (those organisms that convert ammonium to nitrate). Zinc is usually not present in toxic amount in the food crop indeed it is an essential element at low concentrations but the crop may suffer at high zinc concentrations. Cadmium on the other hand can be taken up by crops in sufficient quantities to be of concern for human health before it impacts on crop growth. In humans, excessive cadmium can lead to renal failure.

Therefore, the protection of soil from heavy metal pollution is an essential aspect of maintaining soil and food quality.

The main sources of heavy metals to vegetables, cereals and fruit are their growth media (soil, air, nutrient solutions) from which these are taken up by roots of foliage. Most of our water resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These include land surface washing and industrial and sewage effluents.

Importance of study

With the ever increasing demand on irrigation water supply, farmlands are frequently faced with utilization of poor quality irrigation water. In many parts of country, wastewater, which are disposed to wells, ponds, streams and treatments plants are used as a source of irrigation water as well as drinking. But, continued application of poor quality irrigation water can reduce the yield of farmlands.

Water quality for agricultural purpose is determined on the basis of the effect of water on the quality and the yield of the crops, as well as, the effect of the characteristic changes in the soil (FAO, 1985). The most commonly encountered soil problems used as a basis to evaluate water quality are those related to the salinity, water infiltration rate, toxicity and a group of other miscellaneous problems (Wilox, 1966).

Soil and ground water resources are critically important components of the earth's biosphere and are directly related to human health. Soil plays an important role, not only in the production of food and fiber, but also in the maintenance of environmental quality. Groundwater is increasingly relied upon as a source for drinking water and many other industrial uses. Thus, soil and groundwater contamination by toxic chemicals, such as trace metals, is an environmental concern.

Use of wastewater in agriculture is a public concern due to possible phyto-toxicity and/ or incorporation of metal cations into the food gradients. Excess nitrogen and phosphorus in effluents can leach and pollute groundwater under continuous sewage effluent use for long leach and pollute ground water under continuous sewage effluent use for long periods (Chaney, 1990).

The impact of long term use of poor quality water on soil health, groundwater pollution and food chain contamination is governed by water quality and site-specific soil, climate and crop conditions (Minhas and Gupta, 1992). Therefore, it is pertinent to be in touch with such problems for better environmental health.

1.3 Objective of study

The present study on "Characterization of industrial effluent and its impact on soil properties around Bhandara industrial area" was conducted with the following objectives.

1. To study the properties of industrial effluent.
2. To assess the properties of soils around the Bhandara industrial area.
3. To evaluate the content of micronutrients and heavy metals in crop.

1.4 Hypothesis

Bhandara city and around area is growing faster with population and industries. It is fondly called as "District of Brass city" owing to the presence of large brass products industry. Bhandara is also famous for the Ordnance factory. The main crop grown in the district is paddy, other important food crops are wheat, gram, pigeon pea and sesame. The area under maize, pigeon pea, sugarcane, turmeric, and mango is also increased. The total area under paddy is about 74%.

Many thousand hectors of agricultural land are being irrigated with untreated sewage water and effluents. The limited research work on effect of sewage water on soil properties and toxic heavy metals accumulation in soils of industrial area around Bhandara city was carried out. In this view, it is necessary to study the impact of heavy metal accumulation on water quality and soil health on industrial area of Bhandara city.

Scope and limitation

It is well recognized that prevention of contamination of agricultural land should have the highest priority of all strategies to protect soil, crop, and water quality and ultimately human and animal health. However, where soil contamination has occurred, strategies are needed to control the transfer of contaminants from soil through the food chain to animal or humans.

A comprehensive study on the contamination profile of pesticides and heavy metals in the environment, especially soils and water sources, is necessary. This information, which is currently sparse and limited, is important for the formulation of environmental management strategy. As a first step, the accumulation of baseline information of the setting up of an organized database on the extent and nature of environmental contamination should be developed. Also, development of reliable, scientifically sound indicators of ecological change is necessary. These indicators of environmental changes should be monitored intensively, often, and over long periods of time.

Consideration for remediation strategies should be similarly and simultaneously developed according to the specific nature of the contamination and the ecosystem components involved. Equal emphasis should be given to preventive and remedial measures. Bioremediation should be given priority as a safe and cost-effective approach, but systems that work in tandem with physical and other methods should not be ignored. Environment-friendly pesticides and fertilizers with appropriate application technology and formulation should be considered.

Research on natural products and after native control methods should also be given emphasis such as biological control, resistant crops, cultural practices sterilization, physical control methods and irrigated pest control. The qualitative and quantitative characterization of the effluent, ground water and soil may help in detecting the pollution load in these resources, which is helpful in planning irrigation practices and use of groundwater resources for various purpose. This may help in planning restorative and improvement measures by way of improved farm management practices and to protect human health by way of consumption of good quality food.

Use of wastewater in agriculture is gaining importance now aday, because of its value as a potential irrigant and a nutrient donor. Use of wastewater for irrigation makes it possible to conserve water and nutrients. But the indiscriminate use of industrial effluent for irrigation to agricultural crops may cause soil and groundwater pollution problems in the long run when they are not properly handled before and after their application to land.

The present investigation comprised of the study of contaminated water bodies during pre-monsoon and post monsoon period, the impact of effluent irrigation on soil and groundwater quality of the selected study area.

This study is limited to few sites for sewage, ground water and soil quality assessment and may limit the scope for further extrapolation of these results areas. However, holistic approach pertaining to sewage-soil-groundwater model is required for detailed investigation and for extrapolation of the results in extensive areas. For meeting site specific objectives, factors like water quality parameters, soil characterization, crop tolerances and rainfall pattern have to be given due consideration.

Chapter II

REVIEW OF LITERATURE

In this chapter it has been made to summaries a brief review of the work done in respect of the project entitled "Characterization of industrial effluent and its impact on soil properties around Bhandara industrial area" literature has been briefly reviewed under fallowing heads.

2.1 Characteristics of the industrial effluent

2.2 Impact of industrial effluent on soil

2.3 Impact of industrial effluent on ground water

2.4 Impact of industrial effluent on crops

2.1 CHARACTERISTICS OF THE INDUSTRIAL EFFLUENT

Kausal *et al.* (1993) reported that the sewage effluent contains variable amount of heavy metals like Pb, Cd, Cr and Ni.

Allaoui(1998) reported that in developed and developing countries, industrial effluent generally undergoes the equivalent of secondary treatment prior to disposal to the water bodies, whereas in many developing countries, the effluent may be discharge after primary treatment or without any treatment.

Midrar *et al.* (2003) recorded that the continuous application of industrial effluent in irrigation may be due to heavy metals build up in soils to undesirable and phyto-toxic levels. So long term effluents irrigation would be risky from environmental point of view.

Weigel *et al.* (2004) and Calamari *et al.* (2003) found that pharmaceutical wastes also reach industrial effluent, (Thomas and Hilton, 2004). Stated that the, industrial effluent contains organic matter, nutrients (N and P), pathogenic organism, heavy metals, pesticides and pharmaceutical wastes, and hence, its discharge to water bodies deteriorates their water quality. Toxic chemicals and pathogenic microorganism in untreated effluent have a potential for deleterious health effect and disease transmission.

Bustamante *et al.* (2005) collected twenty-one samples of winery and distillery effluents from different Spanish winery and distillery industries. They analyzed electrical conductivity, pH, redox potential, density, organic charge (total, volatile and suspended solids, oxidisable organic C and polyphenols) and contents of plant nutrients and heavy metals. The winery wastewater (WW) and viasse (V) showed an acidic pH, a high organic load and notable polyphenol, macronutrient and heavy metal contents.

Kanu *et al.* (2006) reported that wastewater from Brewery industry originates from liquors pressed from grains and yeast recovery and have the characteristics odour of fermented malt and slightly acidic. He found that Brewery effluents are high in carbohydrates, nitrogen and cleaning and washing reagents have been proved water pollutants.

Lokeshwari and Chandrapa (2006) studied that industrial effluent is the main source of pollution of water body and irrigation with effluent contaminated water containing variable amount of heavy metals leads to increase in concentration of metals in the soil and vegetation.

Saif *et al.* (2006) studied on heavy metals contamination through industrial effluent and reported that Zn, Cu, Fe, Mn, Cd, Cr, Ni and Pb in waste water samples were 0.005 to 5.5, 0.005 to 1.19, 0.04 to 2.4, 0.004 to 5.62, 0.02 to 5.33 and 0.05 to 2.25 mg L^{-1} respectively. These values are higher than the required values in Mn, Cd, Ni and Pb respectively.

Sail *et al.* (2006) studied effluents from different industries, sewage and normal tap water samples were collected and analyzed for pH, electrical conductivity (EC), total soluble salts (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, cations and anions and heavy metals. The effluents of ghee and textile industries are highly alkaline. EC and TSS loads of ghee and textile industries are also above the National Environmental Quality Standards (NEQS), Pakistan. All the effluents had residual sodium carbonates (RSCs), carbonates and bicarbonates in amounts that cannot be used for irrigation. Total toxic metals load in all the effluents is also above the limit i.e. 2.0 mg/L. copper in effluents of textile and sewage, manganese in ghee industry effluent and iron contents in all the effluents were higher than NEQS. BOD and COD values of all the industries are also above the NEQS.

Tariq *et al.* (2006) studied on characteristics of industrial effluent and reported that the characteristics of effluents varied with industry. The pH of aluminum industry was beyond the limit whereas other industries were having pH within permissible limit. The BOD was above the permissible limits in almost all of the effluents. Among heavy metals Cd, Cr, Cu, Fe and Zn were within the permissible limits in all but Mn, Ni and Pb were beyond the permissible limit.

Singh and Singh (2006) studied on heavy metals of industrial effluents and reported that As, Cd, Cr and Pb were not found in waste water samples, while some of the following heavy metals ranged from Cu (0.0-0.4 mg/L), Mn (0.0-0.4 mg/L), Ni (0.01-0.07 mg/l) and Zn (0.68-60.84 mg/L) Copper, iron, manganese and zinc were found above the standard limit recommended by IS.

Dash *et al.* (2009) studied the properties of sewage water of Bhubaneswar city. He found that SW samples were non saline, acidic in reaction (pH 6.5-6.89), EC ranged between 0.88-1.55 dSm^{-1} and had optimum level of BOD (48-55 mg L^{-1}). The concentration of cations Ca, Mg, Na, K ranged between 8.51-9.98, 6.0-6.55, 1.85-4.35 and 0.8-1.29 me L^{-1} respectively. Concentration of carbonate and bicarbonate of SW was 0.20 and 7.89 me L^{-1} in summer, nil and 7 me L^{-1} in monsoon season respectively. The DTPA extractable Fe, Mn, Zn, Cu ranged between 1.5 to 1.8, 0.20 to 0.22, 1.50 to 2.50 and 0.06 to 0.10 respectively. The DTPA extractable heavy metals Pb, Cd, Cr, Ni ranged between 4.04 to 4.60, 0.16 to 0.20, 0.02 to 0.40 and 0.50 to 0.74 mg L^{-1} respectively.

Das (2009) studied effluent quality factors (grouping) and effluent attributes using principal component analysis on 23 chemical attributes representing 20 different industrial units. She observed that salt type (variance 20%), salt stress (variance 17.8), heavy metals impact and potassium effect were more critical factors. Further analysis of individual attributes within these factors evaluated discriminating attributes those best served as effluent quality indicators in the order Pb>Cd>TDS (Total dissolved solids)>Mg

Prabhu (2009) recorded that the untreated industrial effluent is the main source of pollution of river water containing variable amount of heavy metals lead to increase in concentration of metals in soil and vegetable, which is grown using the polluted water.

Kharche *et al.* (2011) found that the pH of sewage water of Ahmednagar city of Maharashtra was neutral to slightly alkaline (7.4 to 8.4) which was within safe limits of 6.0 to 8.5.The EC (0.97 to 1.77 dSm^{-1}), BOD (100-210 mg L^{-1}), chemical oxygen demand (COD) (700-940 mg L^{-1}), total dissolved solids (400-1200 mg L^{-1}) values of effluents were higher than the recommended limits prescribed by FAO (1985). The concentration of Fe (4.81-7.26 mg L^{-1}), Mn (0.45-1.17 mg L^{-1}), Zn (0.63-2.00 mg L^{-1}), Cu (0.024-1.18 mg L^{-1}) and B (2.11-5.75 mg L^{-1}) was higher in sewage effluents indicating that they are good source of plant micronutrients which help in mitigating emerging problems of their deficiency that are otherwise overcome by application of costly chemical fertilizers.

2.2 IMPACT OF INDUSTRIAL EFFLUENTS ON SOIL

Ajmal and khan (1984) studied the physico-chemical properties of effluent from Mohan Meakin Breweries Ltd, Ghazlabad, U, P and its indirect effect on soils cultivated with pea and wheat. He observed that the effluent was acidic in nature and had high COD and BOD. The effluent was rich in ammonia-nitrogen, nitrite-nitrogen, phosphorus and potassium, so that its application to the soil increased the values of available nutrients in the soil. The upper soil had high values of N, P, K and organic matter compared with the lower soil in the pots used. The perturbance was observed in the available potassium of the soil, when 100% effluent was used for irrigation followed by 75%, 50% and 25%, and the values of organic matter, ammonia-nitrogen and phosphorus also increased significantly. The pH of the soil decreased gradually with increasing concentration of the effluent Depletion was noted in the $CaCO_3$ content of the soil irrigated with 100% and 75% effluent, while it increased with 50% and 25% effluent. The germination of pea and wheat seeds was restricted to 80% and 90%, respectively, when 100% effluent was used for irrigation; whereas germination was quick with 50% and 25% effluent. The growth of the plants was slow with 100% effluent while it was enhanced by using 50% effluent for irrigation.

Neilson *et al.* (1991) studied the effect of wastewater irrigation on soils and found that the wastewater irrigated soils had higher P, K and lower Ca and Mg. wastewater irrigation also increased extractable sodium throughout the soil but insufficient to adversely affect the plant growth. Soil pH and EC also increased through this did not cause alkalinity or salinity problems.

Cumming and Tausett (1992) observed that the bio-availability, transport and toxicity of metals depend not only on the physical and chemical forms in which the metal is present but also on local factors in the environment. For example, pH is an important determining factor in the bioavailability of metals in soil. The bioavailability and mobility of metals such as zinc, lead and cadmium is greatest under acidic conditions, while increased pH reduce bioavailability. The type of soil, such as clay and sand content and its physical properties also affect the migration of metals through soils.

Yang *et al.* (1995) observed that as far as the impact of environmental pollution is concerned, heavy metals are known to be the most harmful. Once heavy metal enters the environment, they are very difficult to remove. Especially when heavy metals are carried into the soil, they will accumulate there with time, and enter into the biosphere or the food chain, causing harm to human health. The presence of trace metals in metal-contaminated soils affects chemical and biological characteristics of the soil.

Howe and Wanger (1997) compared the soil properties of pulp mill effluent irrigated field and an unirrigated field in Northern Arizona. He found that Saltbush plants, Atriplex condescends (Pursh) Nutt. Growing in the two fields were compared for differences in sodium, magnesium, calcium, nitrogen and phosphorus content. Overall concentrations of all measured elements except calcium and cadmium were significantly elevated in the soil that was irrigated with effluent. Sodium concentration and pH were elevated in the upper soil horizon, whereas phosphorus concentrations were elevated uniformly. Difference in electrical conductivity and magnesium concentrations between the effluent-irrigated field and unirrigated field increased with depth. Saltbush plants sampled from the irrigated field had higher concentrations of phosphorus and sodium, and lower calcium concentrations that plants sampled from the unirrigated field.

Kumar *et al.* (1998) studied the soils of Sikandarabad, Uttar Pradesh influenced by mixed industrial effluent of various industries. He observed that pH of irrigated soil varied from neutral to alkaline in reaction with a range of 7.1 to 9.5. Among the cations Na was observed in higher amounts followed by Ca, Mg and K. Average content of Fe and Mn in surface layer was 50.9 and 84.2 mg kg^{-1} of soil respectively. Organic carbon was 23 g kg^{-1} in surface layers.

Reddy and Rao (2002) studied the effect of industrial effluent irrigation on soil from Maize Research Station, Amberpeth, Hyderabad (India) and observed that the continuous use of effluent for irrigation resulted in increased contents of silt and clay of the soil resulting in higher CEC. The essential nutrients such as N.P, K, Ca, and Mg were high in these soils and are useful for availability to plant. The accumulation of DTPA extractable and total micronutrients and heavy metal was observed in effluent-irrigated pilots. Similarly, their content with increased depth was less due to low mobility of these metals. They found that the continuous irrigation with raw effluent over the years led to accumulation of soluble salts and the heavy metals in soils.

Agrawal *et al.* (2003) conducted experiment the with treated sewage water and tube- well water. The treated sewage irrigated soil sample showed relatively lower pH and EC but higher organic carbon, available N, P, K and Mg in comparison to tube- well irrigated soil. Ca and S contents were relatively low in treated sewage water irrigated soil samples compare to tube-well irrigated soil.

Tiwari *et al.* (2003) collected the surface soil samples from six location of treated sewage water (TSW) adjoining tube well (TW) irrigated areas and analyzed for organic carbon, EC, pH, Available N, P, K and S and exchangeable Ca, Mg on the basis of mean values, treated irrigated sample showed relatively lower pH and EC but higher organic carbon, available nitrogen, phosphorus, potassium and magnesium in comparison to tube well irrigated soils. Calcium and Sulphur contents were relatively low in treated sewage water irrigated soils. The fertility status of TSW irrigated soil was better than TW irrigated soils.

Rattan *et al.* (2004) studied the long- term effect of sewage irrigation on heavy metal content in soils, plants and groundwater and result indicated that sewage effluent contained much higher amount of P, K, S, Zn, Cu, Mn and Ni compared to groundwater. While, there was no significant variation in Pb and Cd concentrations in these two sources of irrigation water and metal content were within the permissible limits for its use as irrigation water. There was an increase in organic carbon content ranging from 38 to 79% in sewage-irrigated soils as compared to tube well water- irrigated once. On an average, the soil pH dropped by 0.4 unit as a result of sewage irrigation. Sewage irrigation for 20 years resulted into significant build-up of DTPA-extractable Zn (208%), Cu (170%), Fe (170%), Ni (63%) and Pb (29%) in sewage-irrigated soils over adjacent tube well water-irrigated soils, whereas Mn was depleted by 31%. Soils receiving sewage irrigation for 10 years exhibited significant increase in Zn, Fe, Ni and Pb, while only Fe in soils was positively affected by sewage irrigation for 5 years. Among these metals, only Zn in some samples exceeded the phytotoxicity limit. Fractionation study indicated relatively higher buildup of Zn, Cu, Fe and Mn in bioavailable pools of sewage- irrigated soils.

Patel *et al.* (2004) studied heavy metals content and their availability in soils irrigated with effluent waters around industrial cities of Gujarat and observed that the COD value of effluent from Ankleshwar site was extremely high, while BOD values were within safe limits in all cases. The effluents from Ankleshwar site were the most polluted with respect to different elements viz., Fe, Cu, Mn, Cd, Ni, Co and Cr. Heavy metals such as Cu, Pb, Zn and Cd were most available in different soils. However soils continuously irrigated with effluents showed highest Cu availability and Mn, Cu, Cd and Ni moderately available, while Fe and Cr indicated low availability. The relative availability of Pb was highest in soils near Ahmedabad and Ankleshwar irrigated with sewage mixed with industrial effluent. Among different soil properties, organic carbon showed significant positive correlation with most of the trace and heavy metals and was found to be most influential parameter on availability of these elements followed by soil pH and EC. The content of Cr in different crops grown on polluted soils was very high in spite of its low level in all the soils.

Deshmukh *et al.* (2004) conducted a pot trial experiment to study the effect of different solid industrial wastes as a source of organic matter in vertisols using onion as a test crop. He found that the sludge's increase the pH and EC in post-harvest soil, organic carbon content, available major nutrients (N, P, K) and micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Pb, Cd and Ni) were also found to increase with the usage of different sludge's. Pressmud treatments were proved minimum pollution hazard with less accumulation of heavy metals in soils.

Lokeshwari and Chandrappa, (2006) studied that industrial effluents is the main source of pollution of water body and irrigation with effluent contaminated water containing variable amount of heavy metals leads to increase in concentration of metals in the soil and vegetation.

Heidarpour *et al.* (2007) reported that soil sample were collected from depth of 0-15, 15-30 and 30-60 cm. and were analyzed for salt content, EC, soluble sodium (Na), soluble calcium (Ca), soluble magnesium (Mg), total nitrogen (TN), phosphorus (P), He found that Mg of the first layer of soil (0-15 cm) were significantly greater with subsurface irrigation. The EC, Ca, Mg of second and third soil layer irrigated with wastewater were less as compared with groundwater. The amount of K in the first and second soil layer irrigated with waste water was significantly greater than those irrigated with groundwater. There was no significant effect on soil, Na, P, and N due to irrigation with wastewater.

Taywade and Prasad (2008) studied the sewage-water-irrigated and adjoining non-irrigated soils (3 pedons in each group) along Nag river of Nagpur district, Maharashtra for their morphological, physical and chemical as well as microbial characteristic. The sewage-water-irrigated soils in general had higher pH, organic carbon and $CaCO_3$. The pH of sewage-water-irrigated soils ranged from 8.3 to 9.1 and the non-irrigated soils from 7.9 to 8.7 in different horizons. The organic carbon was more than 9.09 g kg^{-1} in sewage irrigated soils whereas it ranged from 2.4 to 8.09 g kg^{-1} in non-irrigated soils. The $CaCO_3$ content ranged from 32 to 129 g kg^{-1} in the sewage irrigated soils and the corresponding values in associated rainfed soils were 15 to 107 g kg^{-1} in different horizons.

Dash *et al.* (2009) studied the effects of continuous use of sewage water on soil properties of Bhubaneswar city. He found that the available N, P, K content of sewage irrigated soils was higher than normal soil. The DTPA-extractable Fe, Mn, Zn, Cu ranged between 63.3 to 122.2, 13.4 to 62.6, 3.6 to 11.6 mg L^{-1} in sewage water irrigated soils and 60.6, 15.1, 0.8, 0.8 mg L^{-1} in normal soil respectively. DTPA extractable heavy metals in SW soils was in order of Ar>Se>Pb>Cr>Ni>Hg>Cd.

Bhanu Prakash *et al.* (2010) studied the spatial distribution of heavy metals and micronutrients such as Pb, Cd, Ni, As, Fe, Mn, Zn and Cu in soils irrigated with urban sewage of Bangalore city. He found that the content of plant available As, Pb, Cr, Ni, Cu, Fe, Mn and Zn in surface soils (0-15cm) collected from polluted areas of east phase were 2.49, 2.19, 0.09, 1.83, 1.04, 26.49, 17.81 and 0.97 mg kg^{-1} soil, whereas soils of west phase recorded 2.21, 2.79, 0.10, 2.56, 1.29, 21.37, 20.69 and 1.34 mg kg^{-1} soils respectively. The cadmium content was below detectable level in majority of samples.

Liu yen- Yiu and Hayness (2010) investigated the effects of irrigation with dairy factory wastewater on soil properties at two sites that had received irrigation for >60 years. He found that the long-term wastewater irrigation resulted in an increase in pH, EC, extractable P and extractable Na and K and ESP.

Giri *et al.* (2014) characterized the industrial effluents of paper and pulp industries and their impact on soil properties and chemical composition of crop plants in Uttarakhand State of India. He reported that the pH of the effluent samples from Century Paper Mill varied 7.38

to & 7.65. The pH values of the effluent samples from Cheema Paper Mill varied from 7.48 to 7.56.The EC of paper mill effluent varied from 0.79 to 1.74 dSm^{-1}. The highest value of EC observed near the source because of high concentration of dissolved salts which decreased progressively with distance due to dilution as well as adsorption of metal ions on soil colloids or by precipitation reducing the concentration of these ions in the effluent. The BOD value of effluent varied in the range of 306 to 408 mg/L whereas, COD varied in the range of 647 to 4357 mg/L. The observed values of BOD and COD in the effluents were higher than the recommended value of 100 mg BOD/L and 2500 mg COD/L as prescribed by CPCB (1975). High COD value might be due to the presence of oxidisable organic compounds in the effluent.

2.3 IMPACT OF INDUSTRIAL EFFLUENT ON CROPS

Plants are essential component of natural ecosystems and agro-systems and are the terrestrial food chain. When grown on polluted soils, they become a potential threat to human and animal health, as they may accumulate toxic element (e.g. metals) in their tissue, as dramatically illustrated by the painful itai-itai disease that affected farmers on a long-term diet of cadmium contaminated rice. Risk associated with polluted soils are contamination of food chain and phytotoxicity. They are closely related to the bioavailability of toxic elements and primarily to the phyto-availability. Crops differ remarkably in metal uptake and in tolerance of soil metal. Trace metals causes decrease in several growth parameters such as germination, height, leaf growth and number of tillers. Nutrient uptake and crop yield decreased with increased concentration of trace metals. Decreased in some of the physiological parameters such as chlorophyll content and transpiration rate was also reported. Many pot experiments were conducted to determine how soil parameters and other elements influence the transport of trace metals in soil-crop ecosystem (Adriano, 1986;Chen,1996).

Day *et al.* (1975, 1979) observed that wheat (*Triticum aestivum* L.) and sorghum (*Sorghum bicolor* L.) grains grown with the effluent contained more protein than those produced after irrigation with well water fortified with equivalent amounts of N, P and K. Similar observations were reported by others (Crities, 1975; Walkar, 1976; Day and Tucker, 1977) with alfalfa (*Medicago sativa* L.) barley (*Hardenum vulgare* L.) and pasture grass when industrial effluent were used for irrigation.

Singh *et al.* (1991) observed an increase in heavy metal contents with industrial effluent as irrigation water to Berseem. Among the heavy metals, the concentration of Cu, Fe, Mn, Cd, Pb and Ni was higher in Berseem plants irrigated with industrial effluent.

Adhikari *et al.* (1998) studied the polluent metal contents of vegetables irrigated with sewage water of Calcatta city. He collected and analysed 5 vegetable crops viz. cauliflower, mustard, spinach, gourd and radish. The content Fe, Zn,Cu, Mn of different parts of vegetables ranged from 800 to 4000, 50 to 150, 60 to 52 and 9 to 25 mg kg^{-1} respectively. Content of Pb was higher in cauliflower leaf followed by mustard, spinach, gourd and raddish. Cd was detected in cauliflower leaf and root, modified root of radish and its all part of mustard and gourd. Cr has also been detected in some parts of vegetables but concentration was below permissible level of 10 mg kg^{-1}.

Barman *et al.* (2000) studied different parts of 10 plants species in fields irrigated with mixed industrials effluents in Uttar Pradesh. The concentration of heavy metals in almost all plant species grown on polluted soil were higher than in the plants grown on unpolluted soil. Heavy metal accumulation (soil: plant) was in the order iron (84%), copper (81.3%), cadmium (9.4%). High accumulation of metals, perticularly iron and chromium was found in *Alternanthera sessilis* and *Cynodon dactylon.* high concentration of cadmium, lead, chromium and nickel were observed in wheat and mustard.

Lone *at el.* (2003) studied the effects of irrigation with sewage and tube well water (or mixture of both) contaminated with heavy metals and micronutrients contents of vegetables (okara fruits, from plants grown during march, 2000). The highest amounts of heavy metals in spinach leaves was found in the treatment with sewage water and lowest was with tube well water. In spinach, Ni content was the highest, followed by Pb, Cr and Cd. All micronutrients increased in amount of leaves and fruits treated with sewage water and mixture of tube well and sewage water.

Abdul Gahfoor *et al.* (2004) reported that the lead content (13.5 mg kg^{-1}) in vegetable crops (Spinach) grown in urban soil with sewage irrigation.

Malik *et al.* (2004) reported that the extent of micronutrient (Zn, Cu, Fe and Mn) and heavy metal (Cd, Cr, Co, Ni and Pb) accumulation in some sewage water irrigated soils and crops (viz. cereals, fodders, vegetables, pulses, cash crops and oil seed crops). There were generally higher concentrations of micronutrients in sewage irrigated soils than non-irrigated soils. Heavy metal content was rather varied but their concentrations in the soil samples were found within safe limits. Pb was not detected in any of the crops. Cd and Ni concentration was maximum in fodder crops. While Cr and Co were maximum in oil seed crops. Zn, Cu and Fe were found maximum in vegetables, while greater concentration of Mn was observed in fodder crops. Pulses had least concentrations of heavy metals and micronutrients.

Sarswat *et al.* (2005) studied that the micronutrients accumulation in treated sewage water (TSW) irrigated soils in vegetables crops. The TSW-irrigated soils contained 6.02-66.8, 8.4-84.4, 2.4-6.4 and 2.0-20.4 mg/kg, DTPA extractable Fe, Mn, Zn and Cu respectively, whereas, the adjoining surface soils irrigated with tube well water (TW) contained 10.0-35.5, 22.4-45.2, 2.8-3.2 and 3.6-7.6 mg kg^{-1} respectively. The TSW- irrigated vegetables contained relatively higher amounts of micronutrients than the TW- irrigated vegetables, where in okra, cauliflower, radish and broad beans had higher amount of Zn, Fe, Cu and Mn respectively, in their edible parts. Only TSW and TW- irrigated potato showed lower manganese levels than the critical deficiency limit.

Bashir Ahmad (2006) conducted the study to evaluate the effect of sewage water on spinach yield. Total of 70 spinach growers were interviewed from Rahim Yar Khan District, Pakistan. He was found that application of the sewage water to spinach vegetable has a sustainable positive effect on its yield. However, different studies indicate that continuous use of such type of water depletes soil fertility and productivity in the long run.

Bhise *et al.* (2007) compared the soil properties under five land use systems viz. soyabean – gram, sugarcane-paddy, paddy-wheat, vegetables and agri-horticulture, irrigated with waste water from Nag river from past 20 years with unirrigated soil (control) under pegionpea system. The soil were characterized and analyzed for morphological, physical and chemical properties, available micronutrients and heavy metals. All the soils were very deep, clayey (with high water holding capacity), calcareous and alkaline (pH 7.9-8.5). Irrigation using waste water improved the availability of Ca, Mg, K, Zn, Cu, Mn, and Fe under all the land use systems besides improving the soil organic carbon content in soyabean- gram, vegetables and sugarcane –paddy systems. Continuous irrigation using waste water had an adverse effect on EC, ESP, soluble cation (Na/K and Na/Mg) ratios.

Datta *et al.* (2007) recorded the Cd content 0.28 to 0.50 mg kg^{-1} in different vegetable crops in sewage irrigated soil.

Mahamane (2007) noted that the accumulation of Pb was higher (10.55 mg kg^{-1}) in vegetables irrigated with raw sewage water as compared to well water irrigated vegetables (7.41 mg Kg^{-1})

Dash *et al.* (2009) studied the impact of sewage water irrigation of Bhubaneswar city on essential nutrients and heavy metal content in leaf of crop plants. He collected and analyzed leaves of rice, mustard, sunflower, maize, tomato, grain, lady's finger and water hyacinth. The leaf of crop plants grown in SW soils had toxic amounts of Fe, B and Mo. Toxic concentration of Zn and Cu were present in cabbage and cauliflower only. The concentration of Cd, Pb and Cr in rice, mustard, sunflower, maize, tomato, grain mar, cabbage, cauliflower, brinjal and lady's finger were below upper level of phytotoxicity. Maximum accumulation of Co was in cabbage and cauliflower. Grain amaranthus and water hyacinth contained higher most Ni and Se.

Singh *et al.* (2012) concluded that the yield of rabi crops irrigated with well water along with fertilizer was found to be better as compared to application of wastewater with a recommended dose of fertilizer. The test weight of seeds of rabi crops like wheat, gram, palak, methi and berseem was significantly higher in sewage treatment and was in the range of 1.40-16.70 whereas in well water irrigation it was ranged from 1.23 to 16.23. The crop yield obtained with the irrigation sources of well water and sewage water shows the variation in the crop yield. Amongst the vegetable, palak recorded 9.36 q ha^{-1} in sewage water whereas 9.02 ha^{-1} under well water irrigation.

Chauhan (2014) collected the plant samples grown in contaminated J. P. cement factory area Madhya Pradesh. The results revealed that Pb (8.9 mg/kg), Cd (2.39 mg/kg) and Cr (5.25 mg/kg) concentration in all vegetables (highest for spinach) exceeded the permissible limits. Pb concentration in all vegetables from both contaminated sites were exceedingly high whereas at control site (tube well water), was slightly high concentration. As there was also no industrial unit near the control area, it seems soil of that area naturally have high concentration of those elements which may be come from atmospheric deposition by air or other anthropogenic sources. Accumulation of Pb mainly due to J. P. cement plants due to transportation, re-suspended road dust and diesel generator sets. The reason for highest Cd accumulation in contaminated vegetables especially for greens (spinach) from cement factories was that they were Cd sensitive and relatively high cd accumulators. cd was easily taken up by food crops especially leafy vegetables.

2.4 IMPACT OF INDUSTRIAL EFFLUENTS ON GROUNDWATER

Kumar *et al.* (1998) studied the ground water quality of Sikandrabad area of Uttar Pradesh which was influenced by mixed industrial effluent of various industries. He collected water samples from ponds, hand pumps and tube wells. He observed that concentration of cations (mainly Na and K) in hand pump and tube well samples was less as compared to pond water. Concentration of heavy metals viz. Cu, Mn, Zn and Fe in water samples was rather in traces. Water samples were moderately saline and slightly sodic in nature.

Sharma *et al.* (2002) studied ground water pollution by industrial effluent where they observed the nitrate content beyond its permissible limit as 45 mg/L. The BOD, which is generally not found in groundwater at greater depth.

Saif *et al.* (2006) studied on heavy metals contamination through industrial effluent and reported that Zn, Cu, Fe and Mn in waste water samples were 0.005 to 5.5, 0.005 to 1.19, 0.04 to 5.58 and 0.01 to 1.79 mg kg^{-1} respectively.

Singh and Singh (2006) studied on heavy metals of industrial effluents and reported that, As, Cd, Cr and Pb were not found in waste water samples, while some of the fallowing heavy metals ranged from Cu (0.0-0.4 mg L^{-1}), Fe (0.1-0.4 mg L^{-1}), Mn (0.0-0.4 mg L^{-1}), Ni (0.01-0.07 mg L^{-1}) and Zn (0.68-60.84 mg L^{-1}) Copper, iron, manganese and zinc were found above the standard limit as recommended by IS.

Tripathi *et al.* (2006) studied the impact of ground water polluted through seepage of textile industrial effluents on chemical and microbial properties of the of the industrial effluents-contaminated soil and to monitor the growth of *Acacia Senegal* grown in the soil. He found that the use of contaminated well water significantly increased the pH and EC and there was reduction in soil organic matter content, available N and P.

Chandra *et al.* (2008) studied the accumulation and distribution of toxic metals (Cu, Cd, Cr, Zn, Fe, Ni, Mn, and Pb) and their biochemical effect on wheat and mustard plants irrigated with mixed distillery and tannery effluents are reported. He found that effluents and soil samples have shown high metal content than the permissible limit except Pb. Further, found that the plant samples have indicated the maximum accumulation of Fe (340 mg kg^{-1} in wheat root, 560 mg kg^{-1} in mustard leaves) followed by Mn and Zn in root >shoot>leaves>seeds.

Arumugam and Elangovan (2009) found that chlorine is an important parameter in water sample analysis. The acceptable limit for chloride content is 200 mg kg^{-1}. Due to the bleaching and dying process in the dying units, chloride is found in excess concentration near *Noyal* river and lakes.

Kalaivani and Dheenadayalan (2013) collected the waste water sample which was discharged directly into the river *Cooum*, Chennai to evaluate all heavy metal concentration. The result revealed that iron concentration in rivers has been reported to be 0.7 mg l^{-1}. The very high value of iron in this river water may be due to the result of iron are tailing from the metal workshops and mixing of untreated domestic and industrial waste. The values of zinc were found in the range 0.3 to 11.25 mg kg^{-1}. Water samples during the study period showed maximum values for summer and minimum for monsoon with momentous seasonal differences. Copper concentrations are almost similar for all the locations of all study period, although higher concentrations were observed in sw5 and sw10. High level of copper may be due to presence of industrial and domestic wastes. The alkaline pH of the medium can also be the cause of low level of copper, as heavy metals are precipitated as their salts at high pH and are deposited as sediments. The concentration of chromium in the study area ranges from 0.01 to 1.5 mg/L. High content of chromium may be due to various anthropogenic activities, industrial effluents, tanneries, old plumbing and household sewages.

Jamatia *et al.* (2014) collected waste water from Rubber Paper Park in Bodhjung Nagar Industrial area, Tripura state. He reported that the pH of the various waste water samples are found beyond the permissible ranges 6-9, which indicates that effluent generated from such type of industry is acidic in nature. The value of total dissolved solid (TDS) content is found within the range in many locations during summer and post monsoon periods. However, TDS values in two locations are found extremely worse condition during winter, the values are 3954 mg/l and 3030 mg/l respectively.

Similarly, the values of total suspended solid (TSS) are found beyond the permissible limit during winter. However, sulphide content present in the waste water samples are ranges 3 to 25 mg.l^{-1} in the entire waste water samples during post monsoon and winter. The nitrogen content present in all the waste water samples are much more than the permissible limits during all the seasons viz. summer, post monsoon and winter. The BOD value was recorded 725 mg.l^{-1} summer, 719 mg.l^{-1} in post monsoon and 1080 mg.l^{-1} winter season.

Patel *et al.* (2014) collected water samples from four sites- Causeway, Chowk, Navadi, Chowpati to asess the quality of river tapi of Surat city. The evaluation of water quality was done by analyzing different physico-chemical prameters like COD, TDS, TSS, DO, BOD, hardness, alkalinity, nitrate, nitrite, phosphate and concluded that the water quality of Causeway is less polluted, Chowk site is moderately polluted, Navadi and Chowpati sites was highly polluted.

Yadav *et al.* (2014) collected treated and untreated effluent samples from Panipat co- operative sugar mills, Haryana and revealed that the pH of the untreated effluents was 5.8, 5.6 and 5.9 and treated effluent was 7.0, 7.03 and 7.05 in January, March and May respectively. The value of Alkalinity of untreated sugar effluent is 3530, 3200 and 3255 mg l^{-1} and the value of treated effluent was 2100, 2300 and 1800 mg l^{-1} in the month of January, March and May respectively. Alkalinity of untreated and treated effluent of sugar mill is higher than the prescribed limit of BIS. High alkalinity was might be due to the discharges of large amount of carbonate ion from sugar factory. BOD of untreated effluents was 192, 189 and 175 mg l^{-1} and treated effluent showed 188, 185 and 155 mg l^{-1} in January, March and May respectively. The COD of untreated effluent was 3560, 3400 and 2195 mg/l and treated effluent was 2240, 2230, and 1040 mg l^{-1} in January, March and May respectively. COD of untreated and treated effluents exceed the BIS limit. COD of sugar mill effluent is high because the presence of high amount of organic waste.

Mahawar and Akhtar (2015) reported that the sewage effluents of textile mill located near Kota city in Rajasthan was slightly to moderate basic in soil reaction ranged from 7.2 to 7.9. BOD was ranged from 488-1090 mg l^{-1} and COD was ranged between 110-800 mg l^{-1} and magnesium hardness ranged between 120-1450 mg l^{-1}. Total hardness ranged from 230-2250 mg l^{-1}. Oil and grease effluent samples ranged from 21-43.6 mg l^{-1}. The results indicated that the concentration of heavy metals was found to be high which might be due to the use of mordents and synthetic dyes. The results also indicated that the application of textile/polluted water affect physico-chemical properties of soil.

Chapter III

MATERIAL AND METHODS

The present investigation entitled "Characterization of industrial effluent and its impact on soil properties around Bhandara industrial area" was undertaken during the year of 2015-16 to evaluate the quality of industrial effluent, irrigation water, soil and vegetation from various sites of Bhandara industrial area.

The sampling locations were selected on the basis of effluent discharge outlets, cultivated area and irrigation sources. The existing iron and steel, textile industries discharge their effluents of varying quality into a main kaccha drain which flows along agricultural fields and finally joins the river wainganga. The preliminary survey suggested that the effluent discharged into the drain is treated or untreated as also reported by the local people. The Waingnaga river is tapped at different locations and pumped through electric motors for irrigation purpose.

Agricultural crops like wheat, rice, green vegetable are being irrigated with iron and steel industrial effluent by flooding the land, without judging the loading rate or actual requirements. Although majority of the farmers expressed profitability of the use of the effluent for irrigation, some of the respondents reported that the yields are retarded since last few years while weeds and pest's infestation became severe for some specific crops and vegetables.

The farm produce from these areas sold in Bhandara and near villages, which are either consumed by human beings or animals. If the practice of effluent irrigation continues for longer period, without knowing pollutant load, this may lead to chemical degradation of lands and possible entry of pollutants/ toxicants in the food chain of people and animal consuming the farm produce on these lands. Thus an attempt was made to study the impact of industrial effluent irrigation on soil, crops and groundwater. The details of materials used and methods or techniques adopted during the period of investigation are given in this chapter under appropriate heads.

3.1 General characteristics of study area

3.1.1 Locations

The area selected for the present study covers the part of Warthi industrial area (Sunflag Iron & Steel Co. Ltd.) of Bhandara District of Maharashtra State, which is one of the largest industrial area in India. Study area lies in between latitude $21^0$21'14" and longitude $79^0$38'45" on survey of India topo sheet No. 55L/13. Bhandara district also famous for ordinance factory, It spans a total area of 175.63 hactares with the main objective to promote industrial growth and attract foreign direct investment.

The villages selected for sampling were Warthi, Pandharabodi, Jamni and Sirsi.

3.1.2 Climate and weather condition

The climate of the selected study area is characterized by hot summer and dry weather conditions except during southwest monsoon extending from June to September, classified under sub-tropical climate. Mean annual temperature of the area is 25.9^0C and the total rainfall is about 1327 mm. The average maximum temperature is 33.7^0C in kharif (June-September), 31.5^0C in rabi (Oct-Jan.) and 38.8^0C in summer (Feb-May). The weather is very extreme in all season with temperature in summer as high as 45^0C and winter as cool as 8^0C.

3.2 Methods

The various methods followed during the present investigation are described in brief are as under following heads.

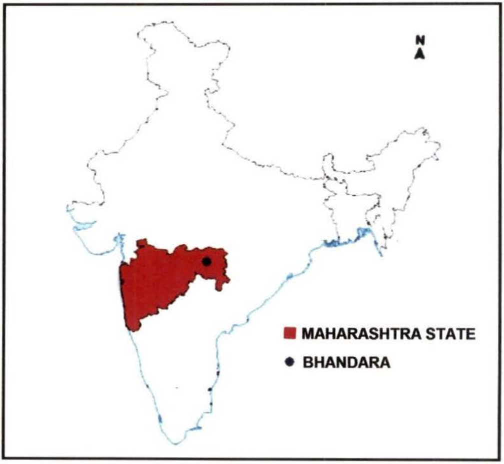

Fig. 1 Location map of Bhandara District in India

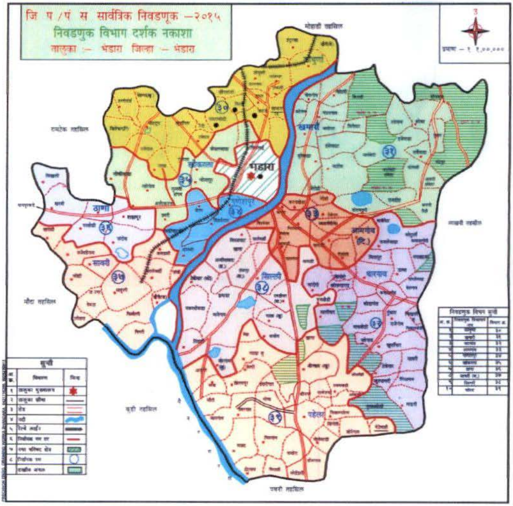

Fig. 2 Location map of Study Area

3.2.1 Selection of water sampling sites

To assess the iron and steel industry effluent quality and ground water quality of the study area 10 samples were collected from 10 different locations. Sampling locations were selected after every 1-2 km approx. in order to study the overall impact.

3.2.2 Collection and preservation of samples

Two effluent carrying samples were collected from their discharge points. Three river water samples were collected from different locations extending 4-5 km away from the source. Remaining five samples were taken from the dug well to study the ground water quality. These 10 samples were collected and analyzed twice, during June 2015 (pre-monsoon) and September 2015 (post monsoon) to study the seasonal variation. These water samples were analyzed for physico-chemical properties and heavy metals. The water samples were collected in plastic bottles directly from effluent carrying drain, river and dug wells. The collected water samples were stored in the dark at laboratory conditions for future uses. For the analysis of COD and heavy metals the preservatives used were conc. H_2SO_4 and conc. HNO_3 (98%) respectively.

3.2.3 Effluent and water analysis

3.2.3.1 Determination of physic-chemical properties of water

a) pH

The pH of the samples were determined using a glass electrode (Electrometric Method) pH meter (APHA, 1975).

b) Electrical conductivity (Sm^{-1})

The electrical conductivity was determined by using conductivity meter (APHA, 1975).

Plate No. 1: Location of well water sampling.

Plate No. 2 : Location of river water sampling

Plate No. 3 : Location of industrial effluent sampling.

Plate No.4 : Location of effluent carrying stream sampling.

Plate No. 5 : Location of confluence water sampling.

Interpretation of irrigation water quality based on EC measurement

EC (dSm^{-1} at 25^0C)	Water class	Interpretation
<0.25	Low salinity (C_1)	Safe with no likelihood of any salinity problem developing
0.25-0.75	Medium salinity (C_2)	Need moderate leaching
0.75-2.25	High salinity (C_3)	Can not be used on soils with inadequate drainage, since saline conditions are likely to develop
2.25-5.0	Very high salinity (C_4)	Unsuitable for average condition

c) Carbonate and Bicarbonate (CO_3 and HCO_3)

It was determined by titrating against standard sulphuric acid (H_2SO_4) using phenolphthalein and methyl orange indicators (APHA, 1975).

d) Chloride (Cl)

Chloride was determined in neutral or slightly alkaline solution by titrating with standard silver nitrate, using potassium chromate as an indicator. Silver chloride was quantitatively precipitated before red silver chromate (APHA,1975).

e) Sulphate

It was determined by Turbidimetric method APHA (1975)

f) Sodium (Na)

It was determined directly by flame photometer method (APHA, 1975).

g) Potassium (K)

It was determined directly by flame photometer method (APHA, 1975).

h) Calcium and Magnesium

It was determined directly by Versenate titration method (APHA, 1975).

i) Micronutrients

Water samples were analysed for micro–nutrients on atomic absorption spectrophotometer (APHA, 1975).

j) Heavy metal analysis

Metal cations (Fe, Zn, Cu, Co, Ni, and Pb) of sewage and well water were estimated according to Jackson (1967). Effluent sample (250 ml) was treated with 0.1 N conc. HNO_3 and evaporated to dryness. Dried samples were then treated with aqua-regia and evaporated to dryness. Adding few drops of HNO_3 the treated samples were finally diluted to 50 ml. Metal cations contents of these solutions were determined using Inductively Coupled plasma Spectrometer (ICP-AES) (Model-JY-24, Jobin, France).(APHA,1975)

3.2.3.2 Irrigation suitability parameters

There are two demand parameters which are determined in the effluent i.e.

a. Chemical oxygen demand

b. Biological oxygen demand

a) Chemical oxygen demand (COD)

The COD test determine the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The organic matter gets oxidized completely by $K_2Cr_2O_7$ in the presence of H_2SO_4 to produce CO_2 + H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with Fe $(NH_4)_2(SO_4)_2$. The dichromate consumed gives the oxygen required for oxidation of the organic matter (APHA, 1975).

b) Biological Oxygen demand (BOD)

The BOD test is based upon determination of dissolved oxygen, consequently accuracy of result is influenced greatly by the care given to its measurement. BOD may be measure directly by adjusting sample at 20^0 C and aerated with diffuse air to increase or decrease the dissolved gas content of the sample to near saturation. Two or more BOD bottles are filled with sample, at least one is analyzed for dissolved oxygen immediately and other are incubated for 5 days at 20^0C. After 5 days the amount of dissolved oxygen remaining in incubated samples is determined and the 5^{th} day BOD is calculated by subtraction of 5^{th} day result from those obtained on zero day (APHA, 1975).

3.2.3.3 Irrigation suitability parameters

a) Sodium Adsorption Ratio (SAR)

USSL (1954) proposed the SAR as a more reliable criterion for evaluating Na hazard in irrigation water. This index quantifies the proportion of sodium to calcium and magnesium ions in a sample. Calcium will flocculate (hold together), while sodium disperses (pursues apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems (Bauder *et al.* 2006). The precipitation of calcium carbonate as a scale in distribution lines, boilers, water heaters and other equipment is a common observation. The same reaction can take place when irrigation water is applied to soil. As calcium precipitates, the ratio of sodium to calcium increases, with corresponding increase in the SAR values. Bicarbonate water, therefore, considered to accentuate sodicity hazard as determined from

SAR. Sodium adsorption ratio (SAR) is calculated from the following equation.

$$SAR = \frac{Na}{[(Ca + Mg)/2]^{1/2}}$$

Relative proportion of Cations

Class symbol	Class of water	SAR value	Suitability
S_1	Low sodium water	<10	Can be used on all soils
S_2	Medium sodium water	10-18	May be used on coarse texture soils
S_3	High sodium water	18-26	Ordinarily unsuitable
S_4	Very high sodium	>26	Unsuitable water

3.2. Collection and processing of soil samples

Five surface soil samples at a depth of 0-15 cm were collected from the irrigated soils. About 1.0 kg representative soil sample from each of the 15 cm layer was collected in cloth bag for laboratory characterization. The bulk soil samples were allowed to air dry and then weighed. A wooden mortar and pestle was used to crush soil aggregates to pass through a 2 mm sieve. For determination of organic carbon and free calcium carbonate, grind samples were passed through 0.5 mm sieve and then stored in polythene bags.

3.2.2.1 Soil analysis

Determination of chemical properties of soils

a) Soil reaction (pH)

The soil pH was determined by digital pH meter using glass electrodes and 1:2.5 Soil: Water ratio as described by Jackson, (1967).

b) Electrical conductivity (EC) (dSm^{-1})

It was determined with conductivity meter using 1:2.5 soil water suspension as described by Jackson, (1967).

c) Organic carbon

Organic carbon was determined by the Walkely and Black rapid titration procedure. Ground soil samples passed through a 100 mesh sieve was used for estimating organic carbon. Soil sample were oxidized by potassium dichromate (1N) and the conc. H_2SO_4 was used to generate the heat of dilution. The amount of dichromate unutilized was determined by back titration with standard ferrous ammonium sulphate solution (0.5N), (Walkley and Black, 1934)

d) Free calcium carbonate

It was estimated by rapid titration method using phenolphthalein indicator as described by Piper, (1966). The soil was treated with a known volume of 0.5 N HCL to neutralize all the carbonates. The unutilized HCL was back titrated with standard NaOH of 0.25 N using phenolphthalein as an indicator.

e) Available nitrogen

It was determined by alkaline potassium permanganate method as described by Subbiah and Asija, (1956).

f) Available phosphorus

The soil was extracted with Olsen's reagent 0.5 M $NaHCO_3$ of pH 8.5 and from the extract available P was estimated calorimetrically as per Jackson, (1967).

g) Available potassium

The available K (exchangeable and water soluble forms) was determined by flame photometer method using neutral ammonium acetate as extractant (Jackson, 1967).

h) Available micronutrient

These micronutrients were estimated by the method described by Lindsey and Norvell, (1978). Total 10 g soil was shaken in 20 ml 0.005 M DTPA buffer solution (Diethylene triamine penta acetic acid) containing 0.1 M calcium chloride adjusted to pH 7.3 with HCl solution for two hours and then filtered and filtrate was subjected to measurement on Atomic Absorption Spectrophotometer (AAS) at different wave length for Fe, Mn, Zn and Cu.

i) Heavy Metals

The heavy metal contents in soil (i.e. Cr, Ni, Pb and Cd) were determined by acid digestion. Representative of soil samples were taken for heavy metal analysis. Exactly 0.2 g of sieved sample (<2mm) was taken for digestion with digestion mixture of nitric acid and perchloric acid in 1:4 ratios. The digestion takes place on hot plate in digestion chamber. The samples were allowed to get digested until the soil particle become white in color. After cooling it, the digested contents were filtered using Whatman filter paper no. 42 and subsequently make up the volume to 100 ml using deionized water. The solution of the aliquot were subjected to heavy metal analysis (i.e. Cr, Ni, Pb and Cd) using Atomic Absorption Spectrophotometer (AAS).

3.2.3 Collection of plant samples, processing and storing

Total five plant samples were collected from the cultivated fields (each of food grain, vegetable and fruit crop) which were grown on the soils irrigated with effluents drain water, effluent mixed river water and dug well water. The plant samples were collected at maturity stage of crop (for food grains and vegetables) and put in perforated paper bags. Freshly collected plant samples were firstly washed under tap water to remove contamination of dust, residues of spray etc. followed by rinsing with dilute HCL (0.001 N) and distill water. The washed samples were dried in a hot air oven at 60^0C for 48 hours and ground in a stainless steel mill to pass through a sieve of 40/60 mesh.

3.2.3.1 Plant analysis

a) Total nitrogen

It was estimated by Kjeldhal's method as described by Piper (1966).

b) Preparation of di-acid extract

Plant extract was prepared by pre-digesting the plant samples with conc. HNO_3 and then digesting the content with di-acid mixture (Nitric acid and Perchloric acid) in the ratio of 9:4 as described by Jackson (1967). This plant extract was analysed for the determination of following properties.

c) Total phosphorus

It was determined by Vanado-molybdate yellow colour method as described by Jackson, (1967).

d) Total potassium

It was estimated by Di-acid extract on flame photometer method as described by Jackson, (1967).

e) Digestion of samples

One gram finely ground plant sample was taken in 100 ml conical flask and 10 ml di-acid mixture was added to it, i.e. 9:4 mixture of HNO_3: $HCLO_4$. Contents of the flask were mixed by swirling. The flask was placed at low heat on hot plate in digestion chamber. Then the flask was heated at higher temperature until the production of red fumes of NO_2 released. The contents were further evaporated until the fumes of NO_2 released. Until the volume is reduced to about 3 to 5 ml but not to dryness. The completion of digestion was confirmed when the liquid became colorless. After cooling the flask, 20 ml of deionized or distilled water was added. Volume was made up with 100 ml deionized water after the solution was filtered through Whatman No. 1 filter paper.

f) Micronutrients and heavy metals

Micronutrients and heavy metals Fe, Mn, Zn, Cu, Pb, Cr, Cd, and Ni were determined using Atomic Absorption Spectrophotometer from the above digested solution. (Page *et al.*1982).

3.3 Flame photometry

The principle involved in flame photometry or flame emission spectroscopy is that when a solution containing a metallic compound is aspirated into a flame (e.g., acetylene burning in air) a vapour containing the metal atoms will be formed. Some of these metal atoms in gaseous state, may be raised to an energy level, which sufficiently high to permit the emission of radiation, which is characteristic of the metal under investigation.

Flame photometer was used for analysis of sodium and potassium concentration in irrigation water, exchangeable cations in soil, available potassium in soil and macronutrient in crop. Sodium and Potassium have an easily excited flame spectrum of sufficient intensity for detection by a photocell.

3.4 Atomic Absorption Spectroscopy (AAS)

This technique involves the study of the absorption of the radiation (usually in the UV region) by the neutral atoms in the gaseous state. Thus in the AAS, the sample is first converted into an atomic vapour and then the absorption of atomic vapour is measured at a selected wavelength which is characteristic of each individual element. AAS determines the presence of metals in liquid samples. Metal include Fe, Cu, Pb, Zn, Cd, Cr, Ni, Mn. It also measures the concentrations of metals in the samples. In their elemental form, metals will absorb ultraviolet light when they are excited by heat. Each metal has a characteristic wavelength that will be absorbed. The AAS looks for a particular metal by focusing a beam of UV light at a specific wavelength through a flame and into a detector. The sample of the interest is aspirated into the flame. If the metal is present in the sample, it will absorb some of the light, thus reducing its intensity. The instrument measures the change in intensity. A computer data system converts the change in intensity into an absorbance.

3.5 Spectrophotometer

Soil available phosphorous, which can be correlated with the response of crop to phosphate fertilizer, was extracted with alkaline $NaHCO_3$ (Olsen method). Analysis of available phosphorus in soil determine by spectrophotometer.

Chapter IV

RESULTS AND DISCUSSION

The results of the present investigation on "CHARACTERIZATION OF INDUSTRIAL EFFLUENT AND ITS IMPACT ON SOIL PROPERTIES AROUND BHANDARA INDUSTRIAL AREA" are tabulated and discussed under the following heads.

4.1 Seasonal variation in chemical characteristics of effluent and well water as influenced by industrial effluents

4.2 Seasonal variation in micronutrient and heavy metal content in effluent and well water as influenced by industrial effluents

4.3 Seasonal variation in oxygen demand of water as influenced by industrial effluents

4.4 Chemical properties and fertility status of soil as influenced by industrial effluents

4.5 Micronutrient and heavy metal content in soil as influenced by industrial effluents

4.6 NPK, micro nutrient and heavy metal content in food grain, vegetable and fruit crop as influenced by industrial effluents

4.1 Seasonal variation in chemical characteristics of effluent and well water as influenced by industrial effluents

Use of sewage water in agriculture has been an age-old practice and contribute to a reduction in stress on the utilizable water resources. It will not only reduce disposal problems of sewage but also contribute towards the up-gradation of soil fertility as contains appreciable amount of macro and several micronutrients (Mitra and Gupta, 1999).

4.1.1 pH and EC

The data regarding chemical characteristics of effluent water and well water samples are presented in table 1. The pH of the various industrial effluents varied from 7.6 to 8.3 during the pre monsoon season which were lower during the post monsoon season. The pH values for effluent water were within the permissible limits given by NEQS (National environmental quality standards). In case of well water the pH values varied from 7.02 to 7.09 during pre monsoon season which were also lower during the post monsoon season. The pH values for well water were found within the permissible limits as compared with CPCB standards. Kharche *et al.* (2011) found that the pH of sewage water of Ahmadnagar city of Maharashtra was neutral to slightly alkaline (7.4 to 8.4) which was within safe limits of 6.0 to 8.5 as suggested by United States Salinity Laboratory Staff (USSL, 1954).

Nasrullah *et al.* (2006) who found that the pH of the eight different industrial units including chemical, marble, soap, oil, textile, ghee, and steel industries were varied from 7.60 to 8.48, while the sample from Frontier Steel Mills has the highest pH value of 8.48. All the pH values were in the permissible limit as suggested by NEQS (6.0 to 10.0).

Electrical conductivity is a function of total dissolved solids (TDS) as ion concentration, which determines the quality of water (Hem, 1989). The EC values of effluent water ranged from 0.42 to 1.67 dSm^{-1} during the pre monsoon season. However all the EC values in effluents were within the safe limit except for that in industrial effluent having very high salinity. In case of well water the EC values were ranged from 0.32 to 0.69 dSm^{-1} during pre monsoon season. Irrigation water having EC values less than 1.5 dSm^{-1} is considered safe for crop. The result showed that the average concentration of EC has gone up in the post monsoon samples, which implies that salt leaches to the groundwater during the monsoon season.

Giri *et al.* (2014) found that the electrical conductivity of paper mill effluent varied from 0.79 to 1.74 dSm^{-1} at 25^0C. The highest value of EC observed near the source was because of high concentration of dissolved salts which decreased progressively with distance due to dilution as well as adsorption of metal ions on soil colloids or by precipitation reducing the concentration of these ions in the effluent.

Nasrullah *et al.* (2006) reported that the EC of marble industry effluent were ranged from 0.258 to 0.865 dSm^{-1}. The highest EC was registered near the main drain.

4.1.2 Chloride and sulphate

The chloride and sulphate content in effluent water ranged from 1.39 to 5.80 me L^{-1} and 1.70 to 5.20 me L^{-1} during the pre monsoon season which were lowered in the post monsoon season. However the chloride and sulphate content in well water were ranged from 1.36 to 1.83 me L^{-1} and 0.53 to 2.08 me L^{-1} during the pre monsoon which were lowered during the post monsoon season. The results showed that the chloride and sulphate content in tube well water were lower as compared to the effluent.

Results revealed that the chloride of effluent sample were higher than the recommended level of 4 me L^{-1} (FAO 1985). Higher chlorides and sulphates have also been observed by Maiti *et al.* (1992) in Culcuta city sewage effluents.

4.1.3 Cations (Na^+, K^+, Ca^{2+}, Mg^{2+})

The data regarding the cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) is presented in table 1. revealed that, the cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) were ranged from 0.83 to 10.15, 0.012 to 0.42, 1.11 to 4.30 and 1.22 to 3.10 me L^{-1} respectively during the pre monsoon season which was lowered during the post monsoon season. Among the cations, Na^+ was dominant in effluents which was higher than 3 me L^{-1} as per the guidelines of FAO (1985). Similar finding are reported by Dash *et al.* (2009) higher concentration of cation observed in summer season than monsoon. Whereas the cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in well water were ranged from 0.52 to 2.18, 0.003 to 0.18, 1.26 to 1.81 and 0.76 to 1.80 meL^{-1} respectively during pre monsoon season which were lowered during the post monsoon season. The result showed that, the cation content in effluent water were higher than the well water.

Table No. 1. Seasonal variation in chemical characteristics of effluent and well water as influenced by industrial effluents

Sr. no.	Location	Season	pH	EC (dSm^{-1})	Na^{+} meL^{-1}	K^{+} meL^{-1}	Ca^{++} meL^{-1}	Mg^{++} meL^{-1}	$CO3^{-}$ meL^{-1}	$HCO3^{-}$ meL^{-1}	Cl^{-} meL^{-1}	$SO4^{--}$ meL^{-1}	SAR
1)	Industrial effluent	Pre monsoon	8.3	1.67	10.15	0.42	4.30	3.10	1.20	7.30	5.80	5.20	5.28
		Post monsoon	8.1	1.48	8.96	0.24	3.8	2.43	1.01	6.12	5.41	4.30	5.08
2)	Effluent carrying stream	Pre monsoon	8.2	1.23	7.09	0.31	3.12	2.80	0.96	6.26	4.22	4.12	4.12
		Post monsoon	7.9	0.90	5.23	0.26	3.09	2.22	0.75	5.09	3.14	3.9	3.21
3)	Confluence effluent carrying stream & river	Pre monsoon	7.9	0.87	4.21	0.18	2.32	2.54	0.08	6.02	3.08	4.02	2.70
		Post monsoon	7.8	0.72	3.09	0.023	2.14	1.98	0.06	4.63	3.02	2.12	2.15
4)	Wainganga river flowing in industrial area	Pre monsoon	7.7	0.66	2.86	0.030	2.23	1.82	-	4.92	2.67	2.78	2.01
		Post monsoon	7.6	0.58	1.98	0.018	2.09	1.16	-	3.82	2.51	2.02	1.50
5)	Wainganga river sample approx. 2-3 km from industrial area	Pre monsoon	7.6	0.42	0.83	0.012	1.11	1.22	-	2.81	1.39	1.70	0.77
		Post monsoon	7.4	0.38	0.51	0.009	1.01	0.82	-	2.1	0.97	1.62	0.53
6)	Well water adjoining effluent carrying stream	Pre monsoon	7.9	0.69	2.18	0.18	1.81	1.80	0.08	3.98	1.83	2.08	1.62
		Post monsoon	7.8	0.52	1.59	0.13	1.53	1.12	0.01	3.01	1.72	1.62	1.38

Sr. no.	Location	Season	pH	EC (dSm^{-1})	Na^+ me L^{-1}	K^+ me L^{-1}	Ca^{++} me L^{-1}	Mg^{++} me L^{-1}	$CO3^-$ me L^{-1}	$HCO3^-$ me L^{-1}	Cl^- meL^{-1}	$SO4^{--}$ me L^{-1}	SAR
7	Well water sample 0.5 km from industrial area	Pre monsoon	7.09	0.52	2.16	0.024	1.52	1.42	-	2.99	1.8	1.8	1.63
		Post monsoon	7.07	0.48	1.33	0.014	1.43	0.92	-	2.38	1.64	1.05	0.85
8)	Well water sample 1 km from industrial area	Pre monsoon	7.06	0.47	1.00	0.018	1.48	1.19	-	2.79	1.53	0.98	0.80
		Post monsoon	7.03	0.44	0.53	0.012	1.39	0.88	-	2.32	1.49	0.81	0.67
9)	Well water sample 2 km from industrial area	Pre monsoon	7.05	0.41	0.75	0.009	1.37	0.92	-	2.65	1.43	0.78	0.60
		Post monsoon	7.02	0.37	0.35	0.004	1.22	0.63	-	2.18	1.32	0.67	0.33
10)	Well water sample 3-4 km from industrial area	Pre monsoon	7.02	0.32	0.52	0.003	1.26	0.76	-	2.08	1.36	0.53	0.58
		Post monsoon	7.01	0.28	0.22	0.002	1.08	0.41	-	1.53	1.24	0.45	0.28

Giri *et al.* (2014) reported that among the cations, the concentration of Na, K, and Ca decreased with increase in distance for effluent of Century Paper and Pulp industry, Lalkuan possibly due to their dilution or precipitation, however no such decrease was noted for Cheema Paper and Pulp industry effluent, Bijapur owing to the shorter distance of observation and possible addition of some municipal waste water in the effluent.

4.1.4 Carbonates and bicarbonates

From the data the carbonates in effluent water were ranged from 0.06 to 1.20 me L^{-1} during the pre monsoon season. However, the carbonates were absent in the well water. The bicarbonate in effluent water were ranged from 2.81 to 7.30 me L^{-1} in the pre monsoon season which were lowered during post monsoon season. However, it was ranged from 2.08 to 3.98 me L^{-1} in well water sample during pre monsoon and was also lowered during post monsoon season. The bicarbonate content was quite high in the effluent. The higher bicarbonates have also been observed by Dash *et al.* (2009). Similar results were also reported by Rattan *et al.* (2005) who found that carbonates and bicarbonates in sewage effluents which was originating from Keshopur sewage treatment plant were varied from traces to 0.8 and 4.4 to 9.8 me L^{-1}.

Giri *et al.* (2014) reported that among the anions the concentration of bicarbonate ions in the paper mill effluent regularly decreased with the distance.

4.1.5 SAR

Suitability of irrigation water depends upon total concentration and relative proportion of cations (SAR).

According to the results presented in table.1 revealed that the sodium adsorption ratio (SAR) of effluent varied from 0.77 to 5.28 meL^{-1} during pre monsoon season which was decreased during post monsoon season. While in case of well water the SAR is low which was ranged from 0.58 to 1.62 me L^{-1} and was found suitable for irrigation. Antil and Narwal (2008) found that the chemical composition of sewage waters varied from site to site which was in accordance with the type of industries discharging their effluent. Some city sewage waters where industrial effluent is discharged in to sewage system may contain toxic metals in high amounts. They further reported that the sodium adsorption ratio (SAR) ranged from 0.8 to 10.4 m $mol^{-1/2}$ $L^{-1/2}$ and some of these water are not suitable for irrigation. Similar result were also reported by Kumar and Nagar *et al.* (2014).

4.2 Seasonal variation in micronutrient and heavy metal content in effluent and well water as influenced by industrial effluents

The results obtained on micronutrient and heavy metals content (Fe, Cu, Zn, Mn, Cd, Cr, Pb and Ni) in various industrial effluents and well water near industrial area are presented in table 2. The results showed that, the micronutrient and heavy metal content (Fe, Mn, Zn, Cu, Pb, Cd, Ni and Cr) in effluent and contaminated river water in pre monsoon ranged from 0.20 to 3.08, 0.06 to 1.24, 0.018 to 1.18, 0.009 to 1.08, 0.008 to 0.054, 0.07 to 0.60, 0.036 to 1.18 and 0.48 to 1.62 mg L^{-1} respectively. These results were found within the permissible limits of NEQS (National environmental quality standards) except industrial effluent and effluent carrying stream. The conc. of micronutrients and heavy metals observed higher during the pre monsoon than the post-monsoon season. It was higher in effluent and contaminated river water than the well water.

Similar results were observed by (Sahare *et al.* 2014). They found that the mean value of Zn, Fe, Mn, Cu and Cr for industrial effluent water samples were found to be 1.38, 1.57, 0.97, 0.81 and 0.41 mg L^{-1} as against the limit of 5 mg L^{-1} for Zn, 2.0 mg L^{-1} for Mn, 3 mg L^{-1} for Cu and 2 mg L^{-1} for Cr as prescribed by CPCB (1995).

Similarly, micronutrients and heavy metals content (Fe, Mn, Zn, Cu, Pb, Cd, Ni and Cr) in well water during pre monsoon were ranged from 0.20 to 0.90, 0.03 to 0.08, 0.008 to 0.28, 0.003 to 0.020, 0.002 to 0.020, 0.001 to 0.18, 0.018 to 0.048, and 0.014 to 0.58 mg L^{-1}

respectively. The results showed that all the micronutrient and heavy metal content in well water were found within permissible limit for irrigation and may not pose any serious hazard (Ayers and Westcot, 1976). Similar results were observed by (Saif *etal.*, 2006).

The variation in the composition of sewage water within the season has also been reported by Singh and Kansal (1985) for different cities of Punjab.

Table 2: Seasonal variation in micronutrient and heavy metal content in effluent and well water as influenced by Industrial effluents

Sr. No	location	Season	Fe	Mn	Zn	Cu mg L^{-1}	Pb	Cd	Ni	Cr
1)	Industrial effluent	Pre monsoon	3.08	1.24	1.18	1.08	0.054	0.60	1.18	1.62
		Post monsoon	2.68	1.09	0.96	0.75	0.030	0.40	0.86	1.05
2)	Effluent carrying stream	Pre monsoon	2.11	0.37	0.30	0.15	0.024	0.20	0.051	0.60
		Post monsoon	1.84	0.30	0.16	0.07	0.015	0.09	0.024	0.31
3)	Confluence effluent carrying stream & river	Pre monsoon	1.91	0.20	0.28	0.022	0.021	0.16	0.048	0.58
		Post monsoon	1.70	0.16	0.14	0.014	0.012	0.08	0.022	0.28
4)	Wainganga river flowing in industrial area	Pre monsoon	1.10	0.12	0.24	0.020	0.019	0.12	0.038	0.52
		Post monsoon	0.26	0.08	0.18	0.012	0.008	0.07	0018	0.22
5)	Wainganga river sample approx. 2-3 km from industrial area	Pre monsoon	0.20	0.06	0.018	0.009	ND	ND	0.036	0.48
		Post monsoon	0.18	0.04	0.016	0.008	ND	ND	0.014	0.16
6)	Well water adjoining effluent carrying stream	Pre monsoon	0.90	0.08	0.28	0.020	0.020	0.18	0.048	0.58
		Post monsoon	0.72	0.02	0.14	0.012	0.014	0.06	0.020	0.28
7)	Well 0.5 km awayfrom industrial area	Pre monsoon	0.78	0.06	0.020	0.012	0.014	0.008	0.036	0.048
		Post monsoon	0.65	0.04	0.016	0.008	0.012	0.007	0.014	0.016
8)	Well 1 km from industrial area	Pre monsoon	0.70	0.06	0.016	0.010	0.010	0.006	0.028	0.030
		Post monsoon	0.51	0.03	0.015	0.007	0.004	0.005	0.010	0.014
9)	Well 2 km from industrial area	Pre monsoon	0.45	0.04	0.014	0.006	0.006	0.002	0.020	0.022
		Post monsoon	0.25	0.02	0.012	0.002	0.001	0.001	0.08	0.012
10)	Well 3-4 km awayfrom industrial area	Pre monsoon	0.20	0.03	0.008	0.003	0.004	ND	0.018	0.014
		Post monsoon	0.15	0.01	0.006	0.001	ND	ND	0.012	0.006
	NEQS		2.0	1.5	5.0	1.0	0.5	0.1	1.0	1.0

Kharche *et al.* (2011) found that the concentration of Fe (4.81 to 7.26 mg L^{-1}), Mn (0.45 to 1.17 mg L^{-1}), Zn (0.63 to 2.00 mg L^{-1}) and Cu (0.024 to 1.18 mg L^{-1}) in sewage effluent of Ahmadnagar city of Maharashtra. However, their concentration in sewage effluents was higher than the recommended maximum concentration as suggested by Indian Standard (1982) and FAO (1985).

4.3 Seasonal variation in oxygen demand parameters of water as influenced by industrial effluents

Urban wastes carried by drains and canals to rivers worsen and broadens water pollution. High levels of pollutants in river water causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and fecal coli form and hence make such water unsuitable for drinking, irrigation and aquatic life.

Biological oxygen demand is defined as amount of oxygen required by microorganism while stabilizing biological decomposable organic matter in waste water under aerobic condition. Hence lowering in dissolved oxygen value is the measure of BOD relation. (Yadav *et al.* 2014)

The biological oxygen demand (BOD) and chemical oxygen demand (COD) of effluent samples and well water samples as influenced by industrial effluent are presented in table 3.

The biological oxygen demand in various industrial effluents ranged from 1.10 to 54.1 mg L^{-1}. Results showed that, the effluents had value of BOD within the recommended maximum concentration of 100 mg L^{-1} (FAO, 1985). Similar conclusions were also drawn by Jamitia *et al.* 2014. The BOD value in well water ranged from 1.00 to 1.20 mg L^{-1} suggesting that all the underground water samples were within safe limits compared with US-EPA standards.

Table 3 : Seasonal variation in oxygen demand parameters of water as influenced by industrial effluents

	Location	Season	COD (mgL^{-1})	BOD (mgL^{-1})
1)	Industrial effluent	Pre monsoon	184	54.1
		Post monsoon	152	50.01
2)	Effluent carrying Stream	Pre monsoon	145	46.85
		Post monsoon	138	42.22
3)	Confluence effluent Carrying stream & river	Pre monsoon	128	42.24
		Post monsoon	114	37.62
4)	Wainganga river flowing In industrial area	Pre monsoon	98	32.00
		Post monsoon	62	20.1
5)	Wainganga river sample approx. 2-3 km from industrial area	Pre monsoon	3.50	1.10
		Post monsoon	3.22	1.06
6)	Well water adjoining effluent carrying stream	Pre monsoon	3.60	1.20
		Post monsoon	3.18	1.05
7)	Well water 0.5 Km away From Pre monsoon industrial area Post monsoon	Pre monsoon	3.64	1.22
		Post monsoon	3.43	1.18
8)	Well water 1 km from industrial area	Pre monsoon	3.48	1.18
		Post monsoon	3.19	1.16
9)	Well Water 2 km away from industrial area	Pre monsoon	3.20	1.14
		Post monsoon	3.05	1.10
10)	Well water 3-4 Km away from industrial area	Pre monsoon	2.91	1.00
		Post monsoon	2.42	0.94
	NEQS standards		150	80

The COD of effluents had higher COD values ranged from 3.50 to 184 mg L^{-1} than NEQS (150 mg L^{-1}) standards, similar results reported by Mahawar and Akhtar (2015). The COD of well water and river water ranged from 2.91 to 3.60 mg L^{-1} suggesting that all the well water and river water samples were within the safe limits compared with NEQS standards. Similar finding were also reported Kharche *et al.* (2011). They found that COD (700- 940 mg L^{-1}) values of sewage effluents were higher than recommended limits as prescribed by FAO (1985).

4.4 Chemical properties and fertility status of soil as influenced by industrial effluents

Rapid industrialization and urbanization have created enormous problems of environmental pollution in terms of generating the variable quantity and quality of effluents. To safeguard the environment, these effluents have either to be treated prior to their disposal into water courses or may be used for crop production if permissible from quality point of view. However, irrigation with sewage and paper/pulp mills effluent had enriched the soil mainly with respect to N, P, K and enhanced crop yields considerably (Neelay and Dhondiya, 1985).

The fertility status of soil as influenced by industrial effluents are presented in table 4. The results obtained showed that the effluent irrigated and surface water irrigated soils in the study area are moderately alkaline in reaction with pH ranging from 8.02 to 8.06 and found to be lower in well irrigated soil which is slightly alkaline in reaction. The results are in conformity with the results of Mahawar and Akhatar (2015).

The EC values of effluent irrigated and contaminated river water irrigated soil ranged between 0.58 to 1.26 dSm^{-1} and found to be lower in the well water irrigated soils. This can be attributed to addition of solutes in soil by way of effluent irrigation. Similar findings were also observed by Giri *et al.* (2014).

It was observed that the organic carbon content of effluent irrigated and contaminated river water irrigated soil were higher (4.98 to 8.16 g kg^{-1}) than that of well water irrigated soils (2.82 g kg^{-1}).

These findings are in conformity with the work of Antil *et al.* (1999) who reported that distillery effluent irrigated soil increase in organic carbon, it may be because of presence of higher C amount in distillery effluent samples). Tiwari *et al.* (2003) also reported that, the mean organic carbon content (8.6 g kg^{-1}) in treated sewage water irrigated soil as compared to tube well irrigated soil.Available N, P and K in effluent and contaminated river irrigated soil ware ranged from

231.12 to 304.12, 8.62 to 20.10 and 298.87 to 325.20 kg ha^{-1} respectively. In well water irrigated soils available N, P and K is 184.90, 6.81 and 232.12 kg ha^{-1} respectively.

Table 4: Fertility status of soil as influenced by industrial effluents

	Sources of Irrigation water	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	Available N ($kgha^{-1}$)	Available P ($kgha^{-1}$)	Available K ($kgha^{-1}$)	$CaCO_3$ $g\ kg^{-1}$
A)	**Soil irrigated with effluent**							
	Sample -1	8.06	1.26	8.16	304.12	20.10	325.20	4.62
	Sample-2	8.04	1.20	8.12	289.14	16.65	320.22	3.87
B)	**Soil irrigated with water after confluence**							
	Sample-3	8.02	1.18	6.52	248.16	12.50	314.52	3.52
C)	**Soils irrigated with contaminated river water**							
	Sample-4	7.86	0.58	4.98	231.12	8.62	298.87	3.32
D)	**Soil irrigated with well water**							
	Sample-5	7.56	0.63	2.82	184.90	6.81	232.12	2.42

These findings are in conformity with the work of Sahare *et al.* (2014) who reported that there was an increase in available N and K content of soil in treatment receiving effluent irrigation.

Presence of free calcium carbonate denotes the calcareousness of soil. The soils irrigated with effluent and soils irrigated with water after

confluence water are moderately calcareous, whereas the soils irrigated with contaminated river water and tube well water are slightly calcareous.

4.5 Micronutrient and heavy metal content in soil as influenced by industrial effluents.

Soil is a very specific component of the biosphere. It is not only a geo-chemical sink for contaminants, but also acts as a natural buffer controlling the transport of chemical elements and substances to the atmosphere, hydrosphere, and biota. The type of soil can affect environment in terms of heavy metals and agro-chemical contamination. In general, heavy metal concentrations in soil increase with increasing proximity to and intensity of human habitation. Metal concentration in most soils remains below critical limits for agriculture, but may exceed if accumulation occurs in topsoil. Metals may also be added to soil if industrial effluent is used as fertilizer.

As far as the impact of environmental pollution is concerned, heavy metals are known to be the most harmful. There is a rapid increase in the pollution of our environment due to an increase in industrialization and developmental processes and other factors of pollution in the world today. If this increase is allowed, the problem of pollution of the environment will become more acute as the amount of pollutants being introduced to the environment continues to be on the increase. In other to keep this environmental risk in check, some safety

The data on DTPA extractable micronutrients viz. Fe, Mn, Zn, Cu and heavy metals viz. Pb, Cd, Ni and Cr in the soils irrigated with industrial effluents and well water are presented in table 5. The DTPA extractable micronutrients Fe, Mn, Zn and Cu and heavy metals viz. Pb, Cd, Ni and Cr in effluent irrigated soil ranged between 9.10 to 18.04, 6.12 to 12.94, 2.08 to 4.35, 2.01 to 3.52 mg kg^{-1} and heavy metals 2.16 to 2.58, 0.06 to 0.20, 1.18 to 1.50, 0.36 to 0.58 mg kg^{-1} respectively. Whereas, the corresponding values for the soils irrigated with the well water were 6.10, 3.20, 1.10, 1.08 mg kg^{-1} and heavy metals 1.20, 0.02, 0.70, 0.22 mg kg^{-1} respectively. The results showed that, the DTPA extractable micronutrients and heavy metals were higher in effluent irrigated soils as compared to well water irrigated soil.

Rattan *et al.,* (2005) reported that, the sewage irrigation for 20 years resulted into significant buildup of DTPA- extractable Zn, Cu, Fe, Ni and Pb in sewage irrigated soils over adjacent tube well water irrigated soils. Heavy metals persists in soils and can be adsorbed in soil particles or leached into ground water.

Table 5: DTPA Extractable micronutrient & heavy metal status of soil as influenced by industrial effluents

	Sources of irrigation water	Fe	Mn	Zn	Cu	Pb	Cd	Ni	Cr
		(mg kg^{-1})							
A)	Soil irrigated with effluent								
	Sample -1	18.04	12.94	4.35	3.52	2.58	0.20	1.50	0.58
	Sample-2	16.21	9.65	4.20	2.32	2.42	0.12	1.32	0.47
B)	Soil irrigated with water after confluence								
	Sample-3	12.18	8.82	3.16	2.12	2.38	0.08	1.22	0.41
C)	Soils irrigated with contaminated river water								
	Sample-4	9.10	6.12	2.08	2.01	2.16	0.06	1.18	0.36
D)	Soil irrigated with well water								
	Sample-5	6.10	3.20	1.10	1.08	1.20	0.02	0.70	0.22

Krishna and Govli (2004) also reported that the level of the metals in soil around the industrial area of Pali, Rajasthan, India were found to be significantly higher than their normal distribution in soil.

Antil *et al.* (2004) reported that toxic metal content (Pb, Ni and Cd) of soil increased due to irrigation with cycle industrial effluent as compared to tube well irrigated soils. Gupta *et al.* (1986) and Narwal *et al.* (1993) also found that the application of sewage water on agricultural land for long period increased the total content of Zn, Mn, Cu, Pb, Ni and Cd in soils of Haryana.

4.6 NPK, micronutrient and heavy metal content in food grain, vegetable and fruit crop as influenced by industrial effluent

The soil analysis is a better tool to assign the fertility index of the soil but leaf analysis is better for assessing the nutritional status of perennial plants (Chadha *et al.* 1973).

Micronutrients are as important as primary and secondary nutrients in plant nutrition. However, the amounts of micronutrients required for optimum crop yields are much lower. Plant analysis are excellent diagnostic tools to monitor the adverse effect of heavy metals and micronutrients. Micronutrient and heavy metal content in cereal/pulse, vegetable and fruit crop as influenced by industrial effluents are presented in table-6, 7 and 8 respectively.

4.6.1 NPK, micronutrient and heavy metal content in leaf sample of food grain crop at maturity stage as influenced by industrial effluent.

The N, P, K, micronutrient and heavy metal content in food grain crop in the soil irrigated with industrial effluent and well water are presented in table 6.

The perusal of the data showed that the N, P, K content in effluent irrigated pigeon pea were 1.32-1.40, 0.28-0.44 and 0.82--1.02 % respectively. Whereas, it was found low in well water irrigated soil.

The micronutrients viz. Fe, Mn, Zn and Cu content in effluent irrigated pigeon pea were 65.10-73.11, 27.23-33.14, 11.20-15.29 and 16.00-20.19 mg kg^{-1} respectively. Whereas, in well water pigeon pea were varied from 30.10, 18.00, 6.10 and 10.05 mg kg^{-1} respectively, The micronutrient content was higher in soil irrigated with effluent and contaminated river than the soil irrigated with well water. Similar finding was also observed by Rattan *et al.* (2004).

The heavy metal viz. Pb, Ni, Cd and Cr content in effluent irrigated pigeon pea were 1.45-1.82, 0.18-0.23, 0.65-0.81 and 0.58-0.73 mg kg^{-1} respectively. Whereas in wheat 1.63-1.71, 0.20-0.23, 0.71-0.85 and 0.65-0.68 mg kg^{-1} respectively. The heavy metal content in well water irrigated pigeon pea were 0.62, 0.001, 0.22, 0.20 mg kg^{-1} respectively. The heavy metal content was higher in effluent irrigated soil as compared to well water. Similar findings was also observed by Dash *et al.* 2009.

Antil *et al.* (2004) reported that toxic metal content (Pb, Ni and Cd) of soil increased due to irrigation with cycle industrial effluent as compared to tube well irrigated soils.

Table 6: NPK, micro nutrient and heavy metal content in leaf sample of food grain crop at maturity as influenced by industrial effluent.

	Sources of irrigation water	Crop	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			(%)			(mg kg^{-1})							
A	**Soil irrigated with effluent**												
	Sample 1	**Pigeon pea**	1.40	0.44	1.02	73.11	33.14	15.29	20.19	1.82	0.23	0.81	0.73
	Sample 2	**Wheat**	1.26	0.24	0.96	68.00	13.28	16.80	5.50	1.71	0.24	0.85	0.68
B	**Soil irrigated with water after confluence**												
	Sample-3	**Wheat**	1.18	0.18	1.00	65.00	11.00	13.50	4.30	1.63	0.20	0.71	0.65
C	**Soil irrigated with contaminated river water**												
	Sample-4	**Pigeon pea**	1.32	0.28	0.82	65.10	27.23	11.20	16.00	1.45	0.18	0.65	0.58
D	**Soil irrigated with well water**												
	Sample-5	**Pigeon pea**	1.00	0.07	0.42	30.10	18.00	6.10	10.05	0.62	0.001	0.22	0.20

4.6.2 NPK, micronutrient and heavy metal content in leaf sample of vegetable at maturity stage as influenced by industrial effluent.

The N, P, K, micronutrient and heavy metal content in vegetable crop in the soil irrigated with industrial effluent and well water are presented in table 7.

The N, P, K content in effluent irrigated spinach were 1.40-1.52, 0.24-0.28, and 2.08-2.10% respectively. Whereas in fenugreek 1.62-1.97, 0.30-0.46, 2.51-2.78 % respectively. The N, P, K content in well water irrigated spinach were 1.02, 0.22, and 2.41% respectively. It was found in sufficient level.

The micronutrients (Fe, Mn, Zn and Cu) content in effluent irrigated spinach were 170.1-172.3, 70.05-75.5, 50.20-56.04 and 8.30-8.60 mg kg^{-1} respectively. Whereas in fenugreek 150.01-160.3, 48.1-54.05, 32.1-41.10, 32.01-41.10 and 1.60-2.10 mg kg^{-1} respectively. The micronutrient Fe, Mn, Zn and Cu content in well water spinach were 110.01, 32.02, 26.10 and 2.00 mg kg^{-1} respectively.

The heavy metal Pb, Cd, Ni and Cr content in effluent irrigated spinach were 7.20-7.50, 1.18-1.21, 6.10-6.30 and 2.08-2.38 mg kg^{-1} respectively. Whereas in fenugreek 1.20-2.08, 0.18-0.19, 1.20-2.26 and 0.80-1.01 mg kg^{-1} respectively. The heavy metal content well water irrigated spinach were 1.01, 0.2, 1.01 and 0.46 mg kg^{-1} respectively. Similar finding were also observed by Jaydev & Puttaih (2013).

Saif *et al.* (2005) reported that, waste water mixed with industrial effluent used for irrigation in vegetable growing area, the plant sample had greater concentration of heavy metals than the recommended values.

Table 7: NPK, micro nutrient and heavy metal content in leaf sample of vegetable crop at maturity stage as influenced by industrial effluent

	Sources of irrigation water	Crop	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			(%)			(mg kg^{-1})							
A	Soil irrigated with effluent												
	Sample 1	**Spinach**	1.52	0.28	2.10	172.3	75.5	56.04	8.60	7.50	1.21	6.30	2.38
	Sample 2	**Spinach**	1.40	0.24	2.08	170.1	70.05	50.20	8.30	7.20	1.18	6.10	2.08
B	Soil irrigated with water after confluence												
	Sample-3	**Fenugreek**	1.97	0.46	2.78	160.3	54.05	41.10	2.10	2.08	0.19	2.26	1.01
C	Soil irrigated with contaminated river water												
	Sample-4	**Fenugreek**	1.62	0.30	2.51	152.01	48.01	32.01	1.60	1.20	0.18	1.20	0.80
D	Soil irrigated with well water												
	Sample-5	**Spinach**	1.02	0.22	2.41	110.01	32.02	26.10	2.00	1.01	0.2	1.01	0.46

4.6.3NPK, micronutrient and heavy metal content in leaf sample of fruit crop as influenced by industrial effluent.

The N, P, K, micronutrient and heavy metal content in fruit crop in the soil irrigated with industrial effluent and well water are presented in table 8.

The N, P, K content in effluent irrigated mango were 1.80-2.02, 0.13-0.25, 1.81-2.10% respectively. Whereas in well water 1.72, 0.09, 1.73 % respectively. It was found in sufficient level.

The micronutrients Fe, Mn, Zn and Cu content in effluent irrigated mango were 71.12-82.52, 32.12-53.81, 15.10-21.10 and 6.05-10.40 mg kg^{-1} respectively. Whereas in well water 64.14, 24.08, 10.12 and 3.12 mg kg^{-1} respectively.

The heavy metal Pb, Cd, Ni and Cr content in effluent irrigated mango were 1.36-152, 0.05-0.10, 0.03-0.10 and 0.48-0.81 mg kg^{-1} respectively. Whereas in well water 1.22, 0.02, 0.01 and 0.22 mg kg^{-1} respectively. Similar finding were also observed by Sengupta *et al.* 2011.

Table 8: NPK, micro nutrient and heavy metal content in leaf sample of fruit crop as influenced by industrial effluent.

	Sources of irrigation water	Crop	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			(%)			(mg kg^{-1})							
A	Soil irrigated with effluent												
	Sample 2	Mango	1.98	0.22	2.09	82.41	46.22	21.01	10.36	1.47	0.08	0.08	0.62
B	Soil irrigated with water after confluence												
	Sample-3	Mango	1.84	0.18	1.96	78.32	38.01	18.01	8.17	1.41	0.06	0.05	0.54
C	Soil irrigated with contaminated river water												
	Sample-4	Mango	1.80	0.13	1.81	71.12	32.12	15.10	6.05	1.36	0.05	0.03	0.48
D	Soil irrigated with well water												
	Sample-5	Mango	1.72	0.09	1.73	64.14	24.08	10.12	3.12	1.22	0.02	0.01	0.22

Chapter V

SUMMARY AND CONCLUSION

The present investigation entitled "Characterization of industrial effluent and its impact on soil properties around Bhandara industrial area" was undertaken during the year 2015-16 to evaluate the quality of industrial effluents, irrigation water, soil and vegetation from various sites of Bhandara industrial area. The observations recorded during the study are summarized are concluded as under.

1) The characteristics of effluent varied with industry. The pH of the industrial effluent varied from 7.6 to 8.3 which is within the permissible limit whereas, the pH of well water varied from 7.02 to 7.9 which was also within the permissible limit.

2) Electrical conductivity of effluent water varied from 0.42 to1.67 dSm^{-1} during the pre monsoon season. Whereas, the electrical conductivity of well water varied from 0.32 to 0.69 dSm^{-1} during the pre monsoon season. Whereas, the electrical conductivity of well water has gone up in the post monsoon season.

3) The cations (Na^+, K^+, Ca^{2+}, Mg^{+2}) in effluent water varied from 0.83 to 10.15, 0.012-0.42, 1.11-4.30 me L^{-1} and 1.22 to 3.10 me L^{-1} respectively during pre monsoon season which were lowered during the post monsoon. Whereas, the cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in well water sample varied from 0.52 to 2.18, 0.003 to 0.18, 1.26 to 1.81 and 0.76 to 1.80 me L^{-1} respectively during pre monsoon which were lowered during post monsoon season.

4) The chloride content in effluent varied from 1.39 to 5.80 me L^{-1} in pre monsoon season which was lowered during post monsoon season. Whereas the chloride content in well water varied from 1.36 to 1.83 me L^{-1} in pre monsoon season which was lowered during post monsoon season.

5) The sulphate content in effluent varied from 1.70 to 5.20 me L^{-1} in pre monsoon season which was lowered during post monsoon season. Whereas the sulphate content in well water varied from 0.53-2.08 me L^{-1}.

6) The carbonate content in effluent water ranged from 0.06 to 1. 20 me L^{-1} in pre monsoon season which was lowered during post monsoon season. However carbonates were absent in well water samples.

7) The bicarbonates in effluent water varied from 2.81 to 7.30 me L^{-1}& in well water samples it varied from 2.08 to 3.98 me L^{-1} during pre monsoon season. The level of bicarbonates decline during post monsoon season, both in case of well water and effluent water.

8) The SAR (sodium adsorption ratio) of effluent water was within the permissible limit which was varied from 0.77 to 5.28 me L^{-1} however, all SAR of well water varied from 0.58 to 1.62 me L-1 and it was considered suatible for irrigation.

9) The micronutrients content (Fe, Mn, Zn, Cu) in effluent water ranged from 0.20 to 3.08, 0.06 to 1.24, 0.018 to 1.18 and 0.009 to 1.08 mg L^{-1} which were within the permissible limit as compared to NEQS standards except in industrial effluent and effluent carrying stream. While in case of well water sample the micronutrient contents were varied 0.20 to 0.90, 0.03 to 0.08 and 0.008 to 0.28 mg L^{-1} which were within the permissible limit.

10) The heavy metal content (Pb, Cd, Ni, and Cr) in effluent water were varied from 0.008 to 0.054, 0.07 to 0.60, 0.036 to 1.18 and 0.48 to 1.62 mg L^{-1} which were within the permissible limit compared with NEQS standards except in industrial effluent and effluent carrying stream. However heavy metals content in well water samples were found within the permissible limit.

11) The COD of effluent water were beyond the permissible limit compared with NEQS standards while the BOD of effluent water and well water and COD of well water samples were found within permissible limit.

12) The pH of effluent irrigated soils and well water irrigated soil varied from slightly to moderately alkaline.

13) The electrical conductivity of effluent irrigated soil samples and confluence irrigated soil were found higher as compared to that of contaminated river and well water irrigated soils.

14) The organic carbon content was higher in effluent irrigated soil (8.12 and 8.16 g kg^{-1}) than that of well water irrigated soil and contaminated river water irrigated soils.

15) The major nutrients available N, P and K were found higher in effluent irrigated soils as compared to well water irrigated soils.

16) The soils irrigated with effluents and confluence water are slightly calcareous whereas the soils irrigated with contaminated river water and well water are moderately calcareous.

17) The DTPA extractable Fe, Mn, Zn and Cu in effluent irrigated soils ranged from 9.10–18.04, 6.12- 12.94, 2.08- 4.35 and 2.01- 3.52 mg kg^{-1} which were higher than that of the well water irrigated soils.

18) The heavy metals content (Pb, Cd, Ni & Cr) in effluent irrigated soils ranged from 2.16- 2.58, 0.06-0.20, 1.18-1.50 and 0.36-0.58 mg kg^{-1} which were higher than that of the soils irrigated with well water.

19) The NPK, micronutrients and heavy metals content in food grain, vegetable, and fruit crop were higher in effluent irrigated water than soils irrigated with well water.

Conclusion :

The results indicated that the effluent mixed waste water is good potential irrigant if the level of heavy metals is monitored, as compared to industrial effluent. On the contrary soils get enriched with N, P, K and organic carbon when irrigated with effluent mixed waste water. However it is necessary to assess soil periodically to monitor the adverse effect of heavy metals.

Crops receiving effluent mixed waste water for irrigation are contaminated with heavy metals as compared to those irrigated with well water. It is therefore suggested that effluent mixed water can be used for growing vegetables, if it is pre- treated to reduce the level of heavy metals.

From the results obtained by this study it is suggested that, effluent and effluent carrying stream was highly polluted, therefore there is an urgent need to follow effluent treatment methods before their discharge to water bodies for reducing their accumulation of heavy metals and farmers should irrigate their agricultural land with dug well water instead of direct effluent irrigation in order to avoid adverse effects of heavy metal accumulation.

Chapter VI

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