Open Access Library Journal
2023, Volume 10, e10395
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Effects of Industrial Wastewater Effluents on Irrigation Water Quality around Bompai Industrial Area, Kano State, Nigeria

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How to cite this paper: Hussaini, A.B., Cao, J.L., Yateh, M. and Wu, B. (2023) Effects of Industrial Wastewater Effluents on Irrigation Water Quality around Bompai Industrial Area, Kano State, Nigeria. *Open Access Library Journal*, **10**: e10395.
https://doi.org/10.4236/oalib.1110395

Received: June 16, 2023
Accepted: July 18, 2023
Published: July 21, 2023

Abstract

Smallholder farmers in Nigeria's Kano State struggle with a lack of irrigation water, particularly during dry seasons. An alternative is to irrigate their crops using water sources that have been contaminated by industrial water. Sadly, there is a high probability that the wastewater may contain a significant amount of toxins. This study examines the impact of industrial wastewater effluents on irrigation water quality around Bompai industrial areas of Kano State, Nigeria. Samples of water were taken from September to November at the peak of irrigation activities. Samples were collected randomly across the width of the river, from the upstream, midstream and downstream. The samples were taken to Bayero University Kano for analysis and determine pH, electrical conductivity (EC), total dissolved solids (TDS) and trace elements Standard methods were used to determine these characteristics. The result indicated that parameters at various sampling locations are within the permissible limits except for pH, EC, TDS, Mg and Pb which are above the irrigation water quality compliance of the World Health Organization (WHO) and Federal Environmental protection agency (FEFA). According to the results of this study, the water at Bompai that has been exposed to industrial wastewater effluents is contaminated, and continuing use of this water could have a negative impact on the quality of the soil and crops.

Subject Areas

Environmental Sciences

Keywords

Industrial Wastewater, Irrigation Water Quality, Soil Pollution, Crop Yield Reduction, Wastewater Treatment

1. Introduction

Soil and water pollution leads to the degradation of the natural environment and unsustainable use of resources turning into environmental problems of worldwide concern. The demand for agricultural soils and water resources is rising as a result of climate change, increase in global population, rapid urbanization, and industrialization, The intensive use of these resources leads to the degradation of the soil and contamination of irrigation water bodies with chemicals, industrial waste, and other unsustainable practices [1].

It can be dangerous to use water source contaminated by industrial effluent as irrigation water since it may affect the quality of the soil and the crops produced. Heavy metals and other pollutants that are frequently found in industrial effluent have been demonstrated to have a lasting impact on irrigated soil [2].

Smallholder farmers in Nigeria's Kano state struggle with a lack of irrigation water, particularly during dry seasons. An alternative is to irrigate their crops using water sources that have been contaminated by industrial wastewater. Sadly, there is high possibility that the wastewater contains a significant amount of toxins. Thus, it is important to evaluate the industrial wastewater's quality and suitability for irrigation. The assessment of the techniques' environmental viability and knowledge of the effects of wastewater on agricultural production and yield are two other crucial factors. Irrigation plays an important role in crop production and agricultural development in arid and semi-arid regions [3]. And water quality problems in irrigation such as salinity. Salinity affects crop production because crop roots have great difficulty extracting enough water and nutrients from saline solution. Consequently, crop production is limited because no sufficient water can reach the root zone of the crops alongside the increase of the ratio of sodium to calcium and magnesium. When sodium-rich water is applied to soil, some of the sodium is taken up by clay and the clay gives up calcium and magnesium in exchange. Clay that takes up sodium becomes sticky and slick when wet and has low permeability.

Due to a lack of treatment facilities in many low-income nations, wastewater is frequently dumped into water bodies with little or no treatment. Three-fourths of the cities in Asia, Africa, and South America now routinely use wastewater for agriculture [4]. Long-term irrigation with low-quality water upsets the natural order and degrades farmland's ecology. The physical, chemical, and biological characteristics of the soil are also considerably altered by the application of wastewater. High salinity effluent irrigation made soil secondary salinization and substantially increased total and sodium alkalinity in the soil, leading to soil hardness and a decline in soil permeability [5].

Urban agricultural operations are now acknowledged as an essential source of food, nutrition and income for the urban poor due to the rapid population growth in cities. However, irrigation is challenged with a lack of water, and the experience of using polluted rivers for irrigation is becoming a common practice near urban areas. In Nigeria, water contamination affects both rural and urban areas. Many factories are situated along river banks and discharge their waste into the rivers, which operate as open sewers. The issues brought on by the country's lack of sufficient resources pose a risk to the health of nearly 40 million people [6].

For crops to be successfully produced, both high-quality irrigation water and effective irrigation management are essential [7]. However, even when all other factors and traditional methods are favorable or ideal, the quality of irrigation water may still have an impact on crop yields and the physical characteristics of the soil. Different crops need different irrigation water qualities, consequently, testing the irrigation water prior to choosing the site and the crops to be grown is critical [8]. Certain water sources' quality may change considerably over time or during specific times, such as dry or wet seasons [9]. Thus, it is advised to take more than one sample at various times. Unbalances in electrical conductivity (EC), alkalinity, sodium and boron content frequently restrict plant growth. High EC levels prevent numerous established crops from growing roots and germinating. The root medium's pH is directly influenced by alkalinity. As the alkalinity of irrigation water rises, so does the pH of the root medium. Excessive sodium concentrations can interfere with the intake of magnesium, calcium and potassium. When irrigation water contains relatively high levels of boron, leaf necrosis happens. Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and micro-pollutants [10].

The ecology of Kano, the Nigeria's second-most industrialized city, is deteriorating at a rate never seen before. Heavy illness burdens are linked to industrially contaminated air, soil and water. This can be one of the factors contributing to the country's present lower life expectancy when compared to developed countries [11]. The city of Kano is expanding swiftly. According to statistics from the 2006 census, the population of the Kano city is currently little under 4 million. Water source pollution poses a serious risk, particularly in the absence of sufficient rainfall that could help to dilute and wash away hazardous substances. Environmental protection and water quality in Kano are gravely threatened by industrial contamination. For instance, it has been reported that the water from almost all the boreholes in the Bompai industrial estate has been contaminated by the deposition of waste from food industries [12]. The likelihood of industrial wastewater discharge has been identified as a significant environmental risk in the area and may represent the biggest threat to city farming.

Poor quality of irrigation water can have negative effect on crop yield and suitability for irrigation [13]. Water suitable for irrigation purposes have been defined and limits of pollutants have been set by international regulatory bodies [14]. In this study, water samples from irrigation resources around Bompai Industrial Area, Kano state, Nigeria were taken to analyze some of the physical and chemical characteristics. The results were compared with regulation limits set by international bodies like World Health Organization (WHO) and FEDERAL Environmental Protection Agency (FEFA) to evaluate its quality, suitability for irrigation and potential impacts on soil and crops.

2. Materials and Methods

2.1. Study Area

Kano, the largest city in northern Nigeria, is located at (110˚59.981N, 0080˚31.491E) (Figure 1) and has a population density of 2.66 people per hectare. Bompai industrial area is in Kano state. Textile, tannery, chemical-related, iron and steel and related sectors make up the majority of the city's industries. The main source of river pollution in Kano City is industrial activity, which releases tons of effluent into the waterways. The water is utilized for the irrigation of vegetables, cereals, tubers, and fruits via a drainage system. The choice of sampling sites is within this industrial area.

2.2. Sampling and Sample Treatment

On the assumption that the waters of the rivers are well-mixed, three sample locations were selected across the width of the industrial area, from the upstream, midstream and downstream parts of the river. All samples were collected at the peak of irrigation activities from the Bompai industrial area canal basin, from August to October 2022. Prior to sampling, a permanent sampling station was established for this study to obtain a consistent sample from different point

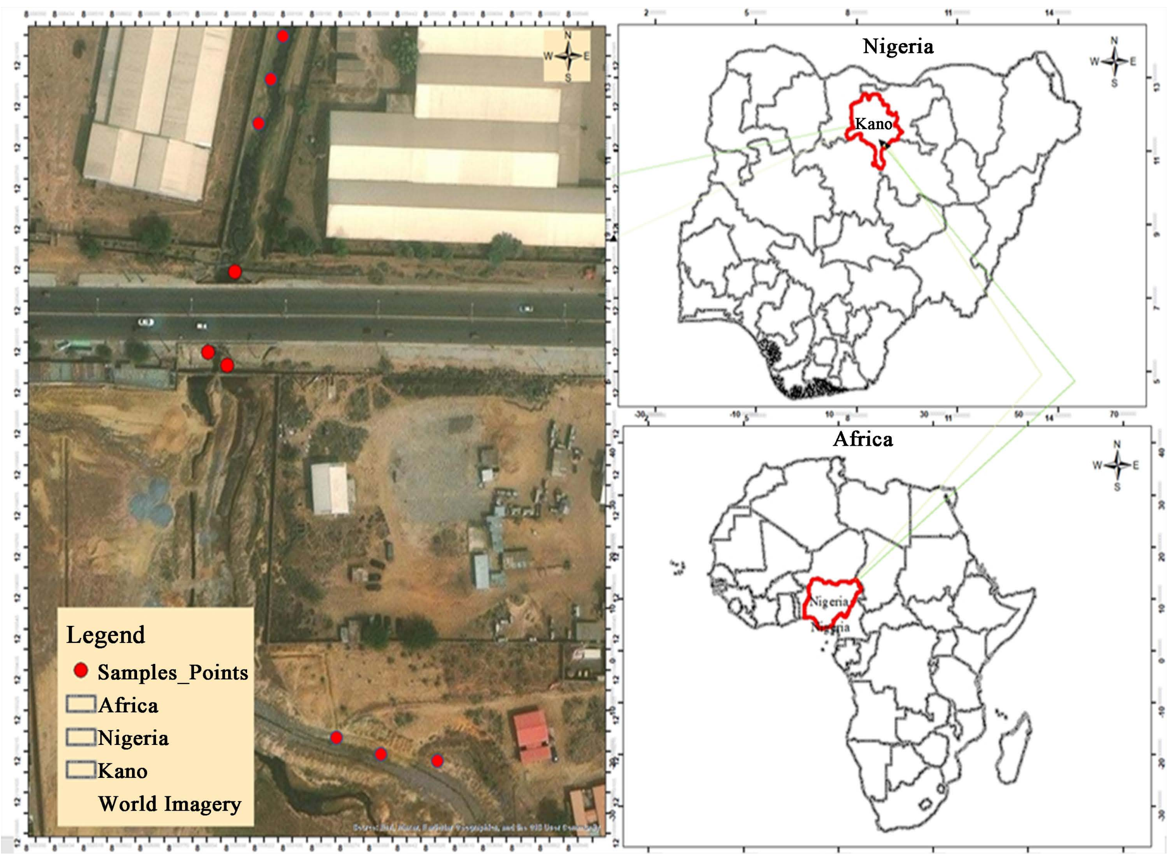

Figure 1. Map of sampling locations at Bompai Industrial area.

source as shown in Figure 2. Water samples were collected in this period in the mid-afternoon when discharges are at peak from industrial sources. The samples were taken to Bayero University Kano for analysis in Centre for Dry Land Agriculture (CDA).

2.3. Equipment and Materials

The following equipment and materials were used to measure the constituents of the industrial wastewater characteristics pH, EC, TDS, and trace elements as shown in Table 1.

Sample Storage and Preparation: Ice block, Cooler, Plastic bottles, Labels.

Measurement Instruments: Conductivity Meter DIST 3 New, Eco test pH meter/USEPA 8156.

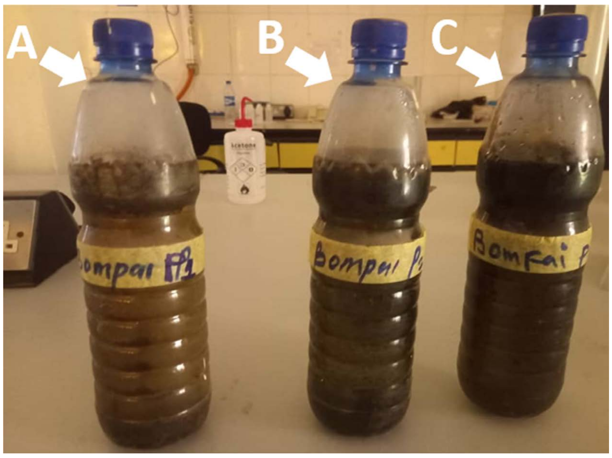

Figure 2. Pictures of the wastewater samples collected at Bompai and their appearance; (A) Phase 1; (B) Phase 2; (C) Phase 3.

Table 1. Materials and methods for physicochemical analysis.

ANALYZED PARAMETER	MATERIALS FOR TEST/METHOD	PROCEDURES
pH	Eco test pH meter/USEPA 8156	With the standard solution, calibrate at pH values 4.7 and 9.2
EC	Conductivity Meter DIST 3 New	With the standard solution, calibrate using 0.01N KCl
Ca and Mg+2	Titration/USEPA 8222	Using burettes, pipettes, and other volumetric glassware, standard solutions are prepared using analytical and distilled water
Na+	Flame photometer/1381-E	The characteristics of ions being determined by measuring the intensity of absorbance of light due to the electron's excitation
Heavy metals (Mn, Pb and Zn)	Atomic absorption spectroscopy/USEPA 2201	Atomic absorption spectrometer

Laboratory Glassware: Burette, Pipette, Volumetric glassware.
Spectroscopic Techniques: Atomic Absorption Spectroscopy/USEPA 2201.
Flame Photometry.

2.4. Physicochemical Analysis of Water Samples

Each water sample's pH was calculated using the Eco test pH meter/USEPA 8156, which was calibrated between 4.7 and 9.2 using a standard solution. Using 0.01N KCl, the Conductivity Meter DIST 3 New was calibrated. Each water sample's electric conductivity (EC) was assessed using the standard solution. Burettes, pipettes, and other volumetric glassware were used to make standard solutions using analytical and distilled water for the analysis of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and heavy metals. Formulas recommended by the FAO [4] were used to compute total dissolved solids (TDS). The standard approach was used to assess the physicochemical properties of the water samples that were collected. All test were carried out in triplicate subject to physicochemical analyses.

2.5. Determination of pH

The procedure of determination of pH of the industrial wastewater for this study involves the following steps: The water sample is properly mixed and stirred using a glass rod. By using a watch glass, sample of water equal to 40 ml (5 ml more or less) is added to the beaker. The temperature of the water is allowed to stabilize by placing the sample to stand for 1 hour. In between this time stirring can be done. After 1 hour, the temperature of the water is measured and the temperature was adjusted in the pH meter. Hence the pH meter shows temperature similar to that of the sample. All the adjustment to the apparatus was performed and fixed before the test was conducted. The standard solution was used to standardize the pH meter. The temperature was adjusted as mentioned in the above procedure. Next, the electrodes were inserted into the water sample. The beaker was turned and adjusted so that there is good contact between the electrodes and the water.

Before starting the reading, the electrode was placed in the solution for more than 30 seconds. This time period is required for the proper stabilizing of the meter to have proper reading. In pH meter that have an automatic reading system, a signal will be provided to tell that the meter was stabilized. Once the reading was shown, it must be read to the nearest tenth of the whole number. The apparatus was maintained after each use. The electrode used was washed thoroughly with distilled water. Film around the electrodes was cleared. Wiping of the electrodes was avoided as this will result in polarization which will result in slow response of the experiment.

2.6. Electrical Conductivity Test

The KCl reference solution was used to calibrate the conductivity meter in accordance with the manufacturer's instructions in order to determine the cell constant. A suitable volume of the thoroughly mixed wastewater sample is added to a clean, dry container. We make sure the container is big enough for the EC probe to fully submerge in the sample during measurement. The EC meter was then turned on, and we gave it some time to stabilize at the lab or testing environment's ambient temperature. After thoroughly submerging the EC probe in the wastewater sample, we read the EC meter and wait for the value to stabilize. Then we record the EC value in micro siemens per centimeter (μS/cm) that is shown on the meter.

2.7. Graphical Representation.

Origin pro statistical software version 2023 was used to determine the descriptive statistics to obtain the means and Graphs.

3. Results and Discussion

3.1. Effects of pH on Irrigation Water Quality

The pH values of the effluents were found to be below irrigation quality compliance, below the minimum permissible limits of WHO of 6.6 - 8.5. The findings showed that in Phases 1, 2 and 3, the pH values were 1.87, 1.84, and 1.85 respectively. The vicinity of the chemical production, tannery, metal plating and food processing industries may be to blame for the low pH value. Acidic chemicals are used in the tanning industry for processing, and their use in industrial processes can cause effluent to have a low pH. Wastewater can become more acidic as a result of industrial processes that use strong acids or acidic chemicals. Sulfuric, hydrochloric, and nitric acids are often used in the metal plating industry for metal cleaning, pickling, and etching, which may result in a pH decrease. Organic acids are also employed in food processing, chemical synthesis, and fermentation in addition to these applications, organic acids can occur, such as acetic acid from the production of vinegar and formic acid from tanning leather. The release of these effluents causes the wastewater to become more acidic.

In industrial wastewater, there aren't enough alkaline elements to balance the acids already present. This may result in a low pH level. The acidity of the effluent cannot be properly neutralized in the absence of enough alkaline substances. These findings point to a lack of wastewater treatment in the Bompai industrial region, with Mg levels beyond WHO and FEFA permitted limits as shown in **Figure 3**. Mg levels in wastewater effluents will be decreased by raising the pH using alkaline materials such as sodium hydroxide (caustic soda), potassium hydroxide, calcium hydroxide (lime), and ammonium hydroxide.

3.2. Trace Elements

The concentration of Magnesium was found to be above the permissible limits (**Figure 4**). In phase 1 the level of Mg was 2.52 (mg/L) and it became highly concentrated in phase 2 up to 237.9 mg/L and reduced to 2.927 mg/L at phase 3.

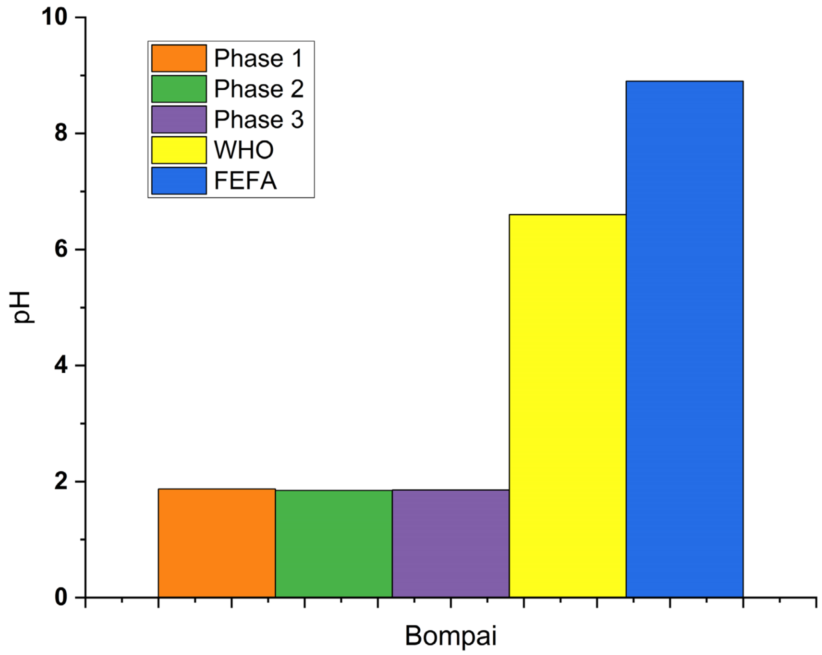

Figure 3. Level of pH of water samples of all the phases of Bompai industrial area with WHO and FEFA limits.

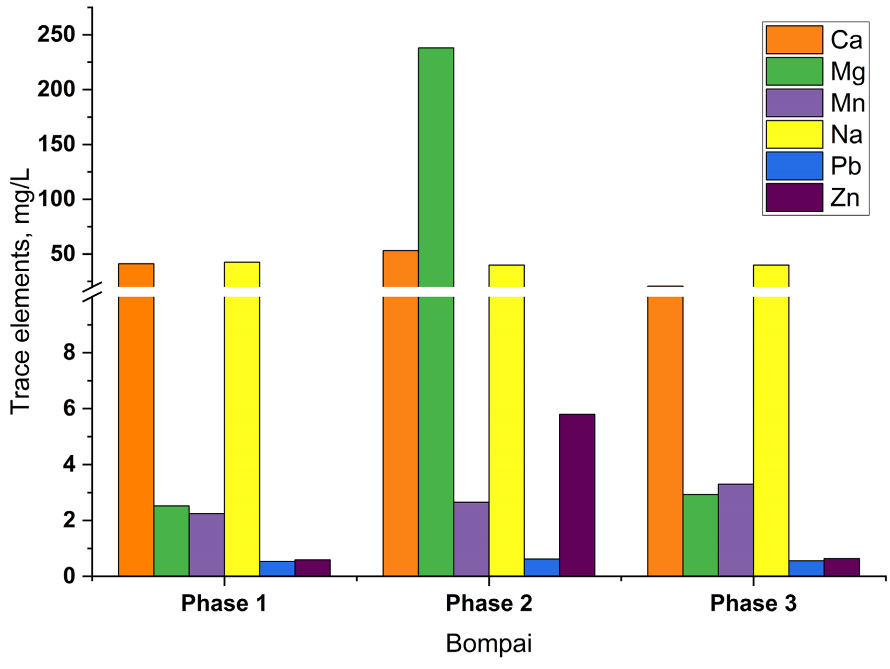

Figure 4. Levels of Trace elements and heavy metals in water samples taken from 3 phases of Bompai industrial area.

This could be attributed to other sources from another industry in the area, there are textile industries that use magnesium as a reagent for fabric dying and later is released as wastewater [4]. Tannery industries in the Bompai industrial region wash and treat leather using cleaning agents or chemical additives; these additions may contain compounds containing magnesium. These substances can cause greater amounts of magnesium when they are utilized and disposed of in wastewater. This activity may lead to high amounts of Mg in the samples taken in the second phase.

The level of Pb is above the permissible limits and Pb is regarded as a harmful substance, and it is listed by the USEPA (United States Environmental Protection Agency) as potentially hazardous to most forms of life [15]. In addition, a study on the level of heavy metals in crops in Sharada that were irrigated with river water polluted by industrial wastewater supported that. Onions and lettuce had the highest concentrations of Pb, while okra had the lowest concentration [16]. These plants are typically eaten raw or cooked, and because of the food chain, these hazardous metals eventually enter the bodies of humans and other animals. lead is easily absorbed and accumulates in many parts of plants [17]. Some farmers in Bompai industrial area have discovered that the growth of their produce has been impeded over time. This could be explained by the high content of lead in irrigation wastewater. Lead in the soil can harm plants in a number of ways, including by causing chlorosis and necrosis. Chlorosis, a condition where the plant's leaves turn yellow or white due to not enough chlorophyll, can be brought on by high lead concentrations. In extreme circumstances, lead toxicity can also result in necrosis, or tissue death, in the plant's leaves and other parts [18]. Human health is seriously at danger when lead-contaminated crops are consumed. Lead is a poisonous heavy metal that can harm a number of bodily organs and systems. Chronic lead exposure from tainted food can result in lead poisoning, which can harm the nervous system and cause developmental problems (particularly in children), cognitive impairment, and other health issues [19]. People are rejecting crops grown in Bompai industrial regions owing to safety concerns as a result of the effects of industrial effluent, which has financial repercussions for farmers. As consequently, there will be a fall in the productivity of the agricultural sector. The level of Ca, Na and Zn in the Bompai industrial area are found to be within the permissible limit of WHO of (75, 200, 5.0 Mg/L).

3.3. Electrical Conductivity (EC)

The electrical conductivity of the effluents was also much higher than what was allowed (*i.e.*, 600 and 500 mg/L set by FEPA and WHO, respectively) (**Figure 5**). Increased electrical conductivity suggests that the wastewater effluents are salinity-affected and unsuitable for irrigation. The findings demonstrate that the soil is heavily solidified, posing a risk to soil permeability and clogging. This prevents soil nutrients from freely moving from the soil matrix to the crop's roots system [20]. Soil salinization may result from the use of high EC wastewater for irrigation or disposal onto land. Over time, the excess salts in the wastewater can build up in the soil and impact soil fertility and plant growth. Salinized soils can reduce crop productivity and make them less suited for farming [21]. The Bompai Industrial Area is well recognized for a variety of industrial activities, including the

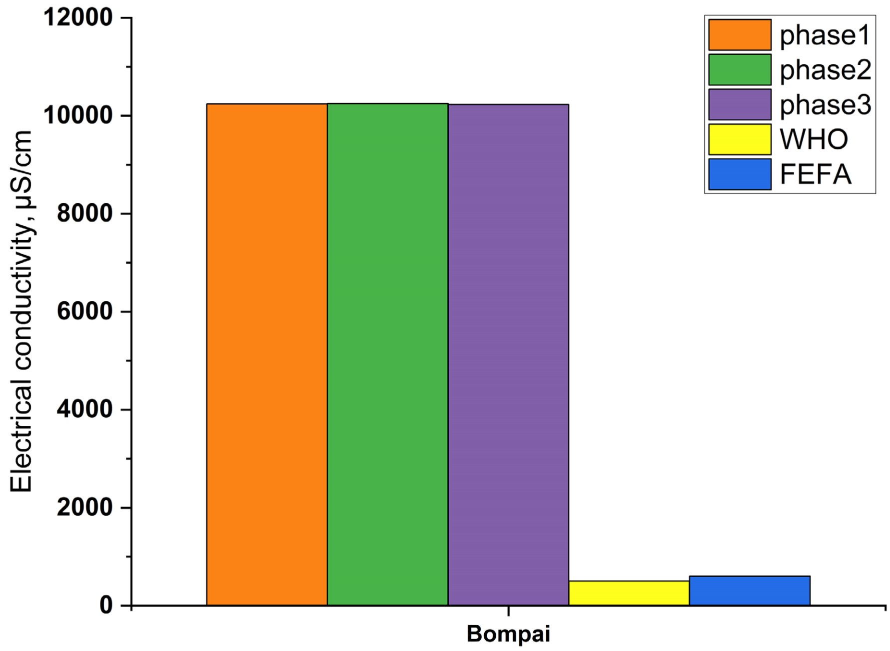

Figure 5. Levels of EC of water samples in all phases of Bompai industrial area with WHO and FEFA limits.

production of chemicals, tanneries, food processing, and textiles. These industries produce wastewater, which may be highly dissolved in salts, organic compounds, and other contaminants. The elevated EC values in the vicinity may be caused by the discharge of untreated or insufficiently treated effluent from these companies.

Farmers in the Bompai industrial area can suffer financial losses as a result of salinity-related problems brought on by high EC. Income and profitability may decline as a result of lower crop yields and subpar crops [22]. To manage salinity, farmers might need to make more investments in tools and technologies, which could put additional burden on their finances. It is crucial to regularly check the EC levels in irrigation water. To lessen the salt content, water sources with high EC might be mixed with water sources with lower EC or treated using desalination methods.

3.4. Total Dissolve Solids (TDS)

It was observed that the concentration of TDS discharged at Bompai industrial area was above the range of 2000 mg/l limit set by FEPA (**Figure 6**). Activities of metal plating industries, chemical manufacturing and textile industries may contribute to high TDS levels in the area due to the presence of dissolved solids in their process. Irrigation activities may also lead to high TDS in Bompai industrial area. TDS levels in water samples can be affected by the quality of the water used in industrial processes [23]. Naturally occurring dissolved solids or minerals may contribute to the total concentration of TDS if the water source is available. TDS levels in the water samples can also be affected by the usage of groundwater sources that may have high concentrations of dissolved solids. TDS

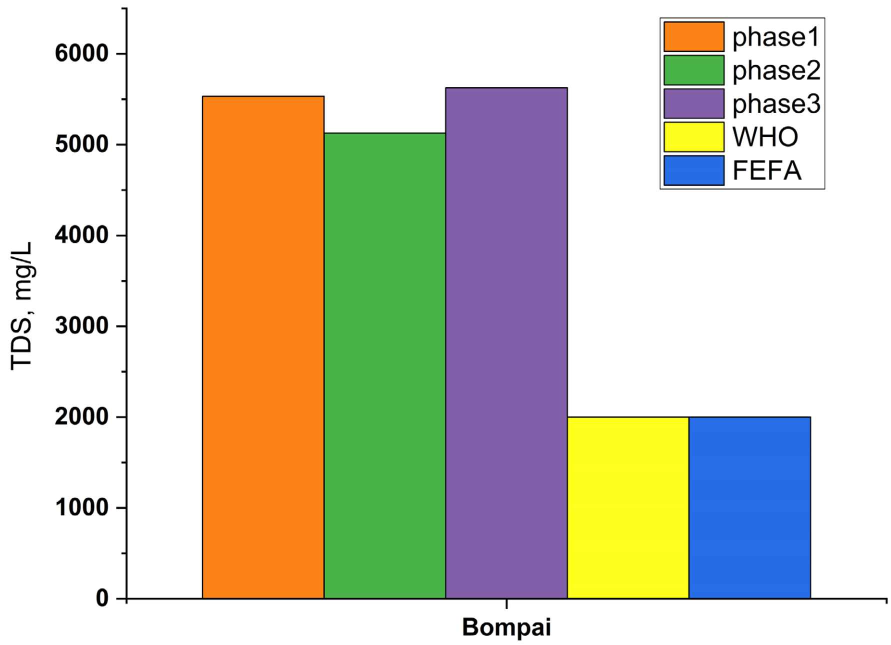

Figure 6. Levels of TDS of water samples in all phases at Bompai industrial area with WHO and FEFA limits.

Table 2. Characteristics of river water polluted by industrial wastewater effluents at Bompai industrial area and the limits of WHO and FEFA.

Parameters	pH	TDS (mg/L)	EC (μS/cm)	Ca (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	Pb (mg/L)	Zn (mg/L)
Mean value of samples	1.856	5632	10240	49.27	81.11	2.645	40.78	0.569	2.34
WHO Permissible limits	6.6 - 8.5	2000	500	75	50	-	200.0	0.050	5.00
FEFA limits	6 - 9	2000	600	200	200	5.0	200	<1	<1

levels in water samples may also be high due to agricultural activities in the Bompai Industrial Area that use chemical fertilizers and pesticides. Dissolved solids from agricultural lands can be introduced into water bodies during runoff, raising the TDS content. It may be more challenging for plant roots to get water from the soil when irrigation water has high TDS concentrations since this can increase osmotic pressure [24]. Plants will experience water stress as a result of the decreased water supply, which will harm their ability to grow and develop. To lessen the detrimental effects on crops, choose water sources for irrigation that have lower TDS concentrations. To lower TDS levels, it may be worthwhile to investigate alternative water sources or to use water treatment methods like reverse osmosis or desalination. Overall, Table 2 presents a summary of the industrial wastewater characteristics at Bompai industrial area and the limits of WHO and FEFA.

4. Conclusions

The prime objective of this research was to assess the effects of industrial wastewater effluents on the irrigation water quality of Bompai industrial area. Findings reveal that the majority of the parameters in the effluents; pH, EC, TDS, Mg and Pb are above the permissible limits of WHO and FEFA.

Overall, this research indicated that water contaminated by industrial wastewater effluents at Bompai is polluted and continuous use of this water may have subsequent negative impacts on soil and crop quality. There is a possibility of a build-up of the parameters that are within the permissible limits if the release of untreated wastewater from industries continues to be unchecked.

Authorities must act and create policies to regulate the use of wastewater for irrigation purposes to reduce the threat to health, given that the federal government has made provisions for a policy regarding projects under tax credits, industries should construct wastewater treatment plants as tax credits. Magnesium will be eliminated from wastewater discharge as well as the problems associated with low pH levels by neutralizing the pH levels by the application of basic chemicals like sodium hydroxide.

Acknowledgements

I would like to express my heartfelt appreciation to my mentor, Wu Bing, for her unwavering support and guidance throughout my journey. Her expertise and mentorship have been invaluable in shaping my skills and fostering my growth. I am also grateful to Professor Jibrin Aminu for his invaluable support in laboratory analysis, as his expertise and meticulous attention to detail have significantly contributed to the success of my research endeavors.

Conflicts of Interest

The authors declare no conflicts of interest.

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