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Research

The Impact of Air and Water Pollution on Biodiversity in Urban Ecosystems in the City of Tikrit

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Abstract: The study was initiated with sampling surface water from several sites in the city of Tikrit to assess the environmental status of the surface water, water quality analysis irrespective of the environment, and the environmental water pollution in the local ecosystem. Physical and Chemical analysis of the water showed that the water tended to become acidic, where the PH value was recorded below the minimum allowable. This meant indicators such as organic matter decay and sewage leaking. Turbidity levels were high and outside the limits, which indicates the presence of a large amount of suspended particles such as bacteria, clay and algae, clear signs of organic pollution and the possible contamination of microbes. Results also showed high electrical conductivity indicating presence of high concentration of dissolved salts, presumably result from runoff along with industrial waste or fertilizers. These salts overwhelm water quality and adversely affect biodiversity. It turned out that dissolved oxygen (DO) concentration was very low, indicating intense organic breakdown using oxygen up and contributing to an aquatic habitat that does not welcome aquatic life. Nutrient analysis revealed high concentrations of nitrates 28 mg/L, phosphates (2.1 mg/L), and ammonium (1.6 mg/L) that are strong indicators of organic pollution that is caused by sewage release or intensive use of fertilizers. These nutrients contribute to eutrophication leading to excessive growth of algae, reducing the oxygen levels and directly endangering aquatic life. As for the heavy metals, they found high and dangerous levels, where lead concentration was 0.12 mg/L, and is 12 times higher than the acceptable limit, and mercury and cadmium amounted to 0.005 and 0.015 mg/L respectively. All of them are over international standards, toxic and cumulative, which is a real threat to public health, especially children and pregnant women. The city's air environment was also not in good condition with high PM2.5 and PM10 concentration were also reported in the middle of the day especially due to traffic congestion and industrial activities contributing to high air pollution leading to poor air quality and health of the residents. The study also demonstrated the clear decrease in biodiversity, with the less polluted placing recording higher diversity in flora, insects and birds, with many species disappearing in the heavily polluted areas, in particular, sensitive organisms such as amphibians. All these are summed results of a condition of robbing in the process of gradual environmental destruction, because the ecosystems have lost the ability to self-renew and drastically process the pollution natural way. Organic pollution metallic Air pollution has reached alarming levels which need to be fixed immediately through improving the sewage infrastructure, regulating the industries and checking the pollution regularly in water, air to keep the population and environment safe from pollution.

Keywords: Ecosystems, Air, Water, Pollution, Tikrit

Introduction

Water is thought to be one of the most essential natural resources, on which life depends. It is a fundamental part of the ecosystem and one of the main pillars for human, economic and social development [1]. However, this essential resource is coming under increasing pressure as a result of unregulated human activities and, especially in the urban areas experiencing rapid urban expansion

and growing populations. These factors have resulted in increasing amounts of pollutant and decrease in water quality [2].

Despite of its high importance, due to unregulated human activities, this vital resource is currently experiencing increasing pressure, especially in urban areas that are experiencing rapid urban growth with non-stop population growth[3]. These factors have caused a rise in water use and exasperation of pollution issues through discharge of wastewater, intensive application of agricultural fertilizers and pesticides or waste disposal from industry into the water sources [4]. All this have contributed to the degradation of water quality which has serious threaten the health of human, biodiversity and the sustainability of environmental resources [5].

Figure 1. Pollused water discharge into a stream with a city in the backdrop, which depicts a case of water pollution in cities [6].

Over the last few decades, water pollution has emerged among the most notable environmental issues to develop cities in particular in the lack or insufficiency of infrastructure to receive wastewater treatment and free disposal of industrial and agricultural waste [7]. Surface water contamination like in rivers, streams and drainage channels can be viewed as a very acute environmental concern since it has a direct effect on human health, biodiversity, and ecosystem sustainability [8]. Tikrit City is not an exception because numerous urban and agricultural settings in the city have been reporting increased environmental dilemmas in regard to the degradation of water quality [9]. There are also places where sewage systems are not integrated and the high agricultural activities help to leak vast quantities of nutrients and pesticides to water bodies besides the potential occurrence of uncontrolled industrial discharge [10]. Also, the research of water pollution is not confined to chemical or physical matters but also concerns the examination of its long-term environmental, health, and social outcomes. Water contamination might cause extinction of some microorganisms whose existence underlies the food chain in the water ecosystems [11]. It also interferes with ecological balance by tampering with the biodiversity, lessening the area where plants grow, and spreading water borne diseases, including cholera, typhoid, and liver and kidney diseases caused by heavy metals [12].

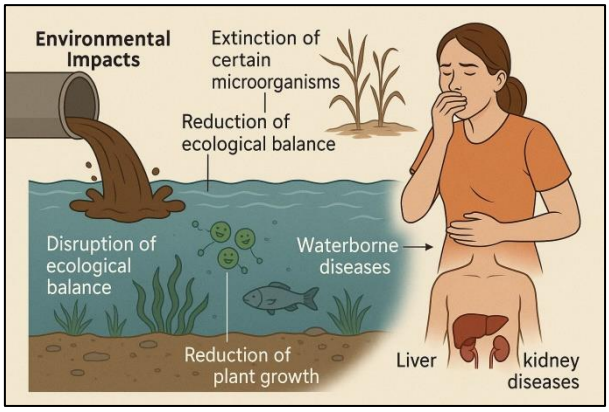

Figure 2. Effects of water pollution on the environment and human health.

Give a clear picture of the amount of pollutants in these waters[13]. An exact scientific procedure was followed and that involved taking samples of water in streams, drains and canals flowing through different urban centers and also making laboratory tests to find out the values of different indicators[14], including:

pH (Acidity)
Electrical Conductivity (EC)
Turbidity
Dissolved Oxygen (DO)
Concentrations of nutrients (Nitrate, Phosphate, Ammonium)

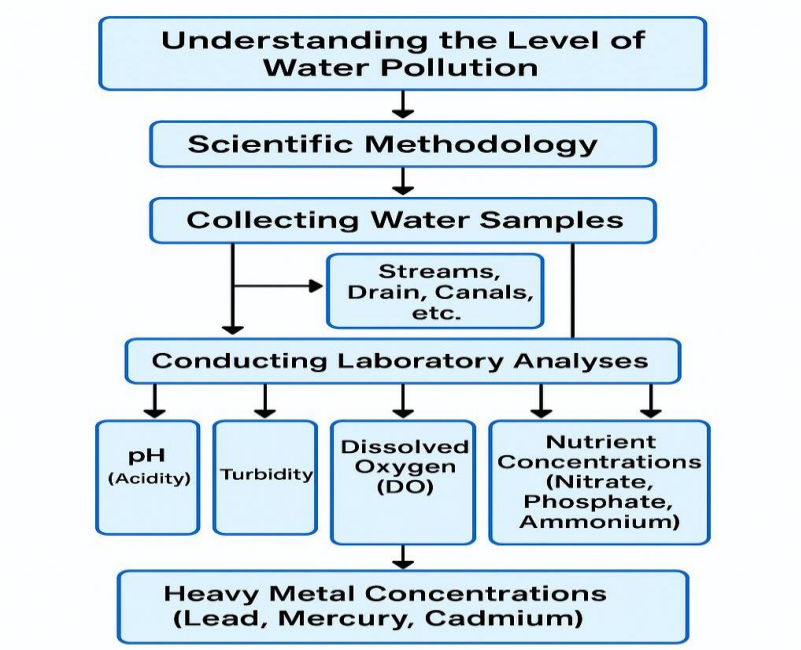

Figure 3. Field sampling the level of water pollution of water quality.

The significance of the research is the fact that it will contribute to the presentation of precise and current scientific information regarding the situation with water pollution in the city [15] at present. This will allow concerned agencies to make evidence-based decisions on water resource management and environmental protection policies [16]. The results of the study also aid in gaining an insight on the correlation between human activity and source of pollution, and the accumulative impacts of the two on the aquatic ecosystem [17]. This knowledge can help to formulate proper water treatment techniques and lower the health and environmental hazards caused by continuous uncontrolled pollution [18].

Materials and Methods

Study Site:

Tikrit city has been chosen as the area of application of this study because it is a geographically diverse city and has urban, industrial, and agricultural areas.

The city is split into the three significant areas which vary in the levels of pollution:

Zone 1 (Low Pollution): the city is situated on the outskirts of the Tigris River, with a vast vegetation cover and the lack of sources of pollution.

Zone 2 (Moderate Pollution): It falls in residential areas, which are moderately impacted by traffic emissions and domestic wastes.

Zone 3 (High Pollution): This zone covers the industrial areas and the zones around sewage discharge network and waste disposal sites.

Air Pollution Measurement:

The air measurements were carried out in the Tikrit city to determine the degree of air pollution through observing the concentration of fine particulate matter PM2.5 and PM10. It was started with the selection of different locations inside the city to cover the whole area as well as high-traffic points, industrial areas, and residential areas.

There were air quality monitoring devices installed on open areas at human standing height of 1.5 to 2 meters[19]. Modern instruments that were employed in the study were founded on the laser technology or gravimetric methods, which could determine the concentrations of particles with accuracy.

The measurement was spread in 24 hours and the hourly readings were obtained to establish the time of maximum pollution particularly during midday when human activities are high and traffic jam results.

The average concentration of PM2.5 and PM10 on daily basis was estimated after data collection and compared to the WHO recommendations of 15 ug/m3 of PM2.5 and 45 ug/m3 of PM10[20]: 15 ug/m3 of PM2.5 is the average concentration of the pollutant and 45 ug/m3 of PM10 is the average concentration of the pollutant. The review showed that the concentration in most sites was beyond the allowed level and this reflected a grave environmental problem that should be addressed.

Biodiversity

surveillance of the city of Tikrit was done through a scientifically precise field methodology which utilised special tools and techniques that were used to gather credible information on plant and animal cover in various locations with varying degrees of pollution levels.

Study of Plant Diversity

It was the Quadrat Method- one of the most popular methods of ecological research to determine vegetation cover. Actually, standard quadrats of 1x1 meters were used and randomly allocated within each of the study areas (low, moderate, and high pollution). The plant species within each quadrat were enumerated, and the density of the particular species (i.e., the number of individuals) was taken. Also, percentage of area that each plant species occupies within the quadrat was computed in order to establish the abundance and distribution of the vegetation[21]. In this way, it is possible to trace the changes in plant diversity linked with the environmental variations and levels of pollution.

Study of Animal Biodiversity

This animal survey was categorised into three large groups which included birds, insects and amphibians[22].

Birds: Birds were observed through the field binoculars at various intervals during the day (morning and evening). The species and the number of birds of a particular species was noted. This information indicates the impact of pollution and anthropogenic activities on the avian diversity.

Insects: They have been caught with the help of light traps and night traps that attract insects in the nearby environment. The insects were then categorized by species and enumerated. The insects are one of the most sensitive organisms to changes in the environmental quality, which is why they are considered a good ecological indicator.

Amphibians: This included frogs and salamanders which were observed by simply searching direct in wet places and around water sources particularly after rainfall when the frogs and salamanders are most active. All three areas (low, medium and high pollution) were subjected to these field procedures so that there was a chance to compare the biodiversity across the environments with different levels of pollution. The approach offers a distinct scientific image connecting environmental pollution with the loss of biodiversity to make environmental protection decisions and sustainable urban planning.

Procedure of the measurement and analysis of concentrations of the pollutant gases in the air

A fine field methodology was used in monitoring the concentration of pollutant gases in the air of Tikrit city to ascertain the precision and reliability of the data. To begin with, some points were identified to cover the diversity of the areas in the city, such as residential places, industrial places, and places that are around major roads.

Specialized measurement instruments were placed at every location to measure pollutants in the air. There were handheld gas analyzers with the ability to measure the levels of different gases, including carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ground-level ozone (O3).

Determination of the concentration of the pollutant gases in the atmosphere had been conducted with the help of the sophisticated specialized analyzers at different points in the city of Tikrit. These instruments depended on the sensitive type of technologies, i.e. electrochemical types, which identify gases such as carbon monoxide (CO), nitrogen dioxide (NO2) and sulfur dioxide (SO2) by reacting the target gas with certain materials in the gadget. This reaction produces electrical signals that are proportional to the concentration of the gas that can be read accurately[23].

In the case of ground-level ozone (O3), it was measured by the UV photometric ozone analyzers that are based on the ozone capacity of absorbing UV (ultraviolet) light. The gadget measures the concentration of ozone by the amount of UV radiation absorbed, which provides accurate and dependable data even at low levels of concentration[24].

The measurements involved three time intervals of the day, namely morning, noon, and evening, to take into account the changes of the gases concentration in the day. The monitoring equipment was placed at a height of 1.5 to 2 meters or the average human breathing zone making sure that the readings were true to the possible human exposure [25].

The data was collected over a period of seven consecutive days and it gave a complete and credible dataset of the level of air pollution under varying periods of time and varying environmental conditions.

After gathering the data, it was downloaded, and the analysis conducted with the help of the specific statistical software. The outcome was further compared to the guidelines of air quality guidelines by the World Health Organization (WHO), to determine whether the level of the measured gases were within the acceptable levels[26]. This comparison was also used to identify the possible health and environmental effects of the air pollution in the city.

Water Pollution Analysis:

The water pollution report was conducted in a systematic and accurate manner to make sure that they were able to derive the accurate data that could describe the environmental factors in the city of Tikrit.

The team of research workers started with the field survey, and the water samples were gathered at the diversity of water sources, such as small streams, drainage channels, and irrigation canals, which run through urban, agricultural, and industrial territories of the city.

These sampling points have been chosen with care to help cover a variety of environmental factors and possible degrees of pollution and this means that the study would help to sample the entire range of water quality changes across Tikrit.

Upon collection of the samples they were put in special sterilized containers either of plastic or glass and stored in low temperature (approximately 4degC) with the help of portable cooling boxes. This was to maintain the chemical and biological characteristics of the water and ensure that no reactions or degradation of the water occur that will interfere with results[27]. The collection and the analysis were also done within a short period to reduce the impact of storing.

The analysis was initiated in the laboratory whereby the pH level was measured using a sensitive electronic pH meter, to establish whether the water was acidic or alkaline[28]. Following this, the electrical conductivity (EC) was determined by conductivity meter that indicated the level of

dissolved salts in the water which is normally linked with the sources of pollution like industrial and agricultural runoffs[29].

The turbidity was determined with the help of Turbidimeter which suggests the existence of suspended particles whether organic or composed of inorganic matter. Turbidity is an indicator of the poor water quality level because it impacts on the light penetration and disturbs aquatic life[30].

The oxygen level was measured by a DO meter because oxygen is the most vital element in the survival of aquatic life[31]. In order to analyze the chemical, sophisticated laboratory procedures were used in determining the concentration of chemical elements like nitrate (NO3-), phosphate (PO43-), and ammonium (NH4+)[32].

Concerning the heavy metals such as lead (Pb), mercury (Hg), and cadmium (Cd), the concentrations of those were determined through the Atomic Absorption Spectroscopy (AAS) because of their high toxicities, even at low levels, and their long term environmental and health effects[33].

The results of all analyses were done in replicates so that the precision of the results could be well determined and that the margin of error could be reduced. Quality benchmarks and comparison to references were used upon the internationally accepted guidelines including those of World Health Organization (WHO)[34]. These steps helped the researchers to receive the full and accurate estimation of the water pollution intensity in the Tikrit city and to define the water pollution sources and estimate their influence on the environment and health of people.

Statistical Analysis

All the data gathered in the course of the study were input to the statistical analysis program SPSS that is applied to conduct accurate and systematized data analysis. An Analysis of Variance (ANOVA) was then used to analyze the statistical differences in the various areas in regards to pollution level and biodiversity to establish whether there was significant difference within the various areas.

Results

Table 1 indicates clearly that the level of fine particulate matter PM2.5 and PM10 in the city of Tikrit is very high and went way above the levels of permissible levels of PM2.5 and PM10 as stipulated by the World Health Organization (WHO) during the day. Midday PM2.5 of 58 micrograms per cubic meter, or over three times the permissible limit (15 ug/m 3) was found whereas PM10 was 102 ug/m 3, or more than three times the permissible limit (45 ug/m 3).

It points to extreme air pollution which is a significant health threat to the population more so at midday when there is high concentration of the particulate. The tiny particles are able to get deep in the breathing system and lead to long term health issues that include heart disease, lung illnesses and asthma.

The mean of the daily concentration of PM2.5 was 51.6 ug/m3 with PM10 of 94 ug/m3 meaning that they were under continuous high amounts of pollution. This calls for the immediate action to enhance the quality of the air and cut down on the sources of the emission like vehicles emissions and other industrial practices, [35],[36].

Along with any health effects, this enormous pollution affects biodiversity and local ecosystems which explains why there is a serious need to monitor the environment and to have sustainable development plans in order to ensure that the environment and the people remain safe.

Table 1. Average Concentration of Fine Particulate Matter (PM2.5 and PM10).

Time	PM2.5 (μg/m³)	PM10 (μg/m³)
Morning	45	85
Noon	58	102
Evening	52	95
Daily Average	51.6	94
WHO Limit	15	45

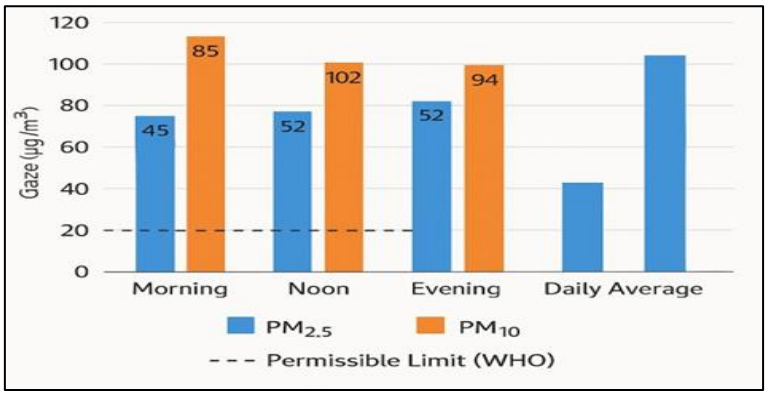

Figure 4. Average concentration of particulate Matter(PM2.5 and PM10).

Table 2 indicates that the highest level of plant diversity is observed in the zones with low pollution when 12 species of plants were identified with several predominant ones such as clover (Trifolium spp.) and common reed (Phragmites australis), a high density of up to 180 individuals and a high plant cover of 45%. This means that there is a healthy and stable aquatic environment which supports the growth of plants and it is a good environment to other living organisms[37].

In the moderately polluted regions, there was a decline in the number of plant species up to 9 with the density becoming 135 individuals and the plant cover declining to 33. Unfavourable effect of pollution on the plant diversity can also be traced in the prevalence of the dominant species in this area, such as common reed and Alhagi maurorum, as the diversity changes and the structure of the plant community is disrupted by unfavourable environmental conditions[38].

The abundance of plant species in the most polluted regions decreased to 6, at the density of 90 individuals, and low plant cover of 20 percent. The most tolerant to the conditions of pollution are the dominant species, including common reed (Phragmites australis) and maidenhair fern (Adiantum capillus-veneris), which demonstrates the impact that elevated levels of pollution have on the diversity of plants and stress the ecosystem[39].

Such findings support the fact that pollution is inversely related to the biodiversity in which higher pollution levels cause the loss of biological diversity and altering the strength of the ecosystems within the city of Tikrit[40].

In the less polluted areas, 8 bird species were observed having 24 individuals which included blackbird (Turdus merula) and wild goose (Anas platyrhynchos) which conducts to a healthy balanced environment that favors the existence of avian species. The species count in the moderately polluted regions reduced to 5 species and 15 individuals, including such species as the blackbird and the starling (Sturnus vulgaris). The number of species in the very polluted spots was only 3 consisting of 9 individuals, which were dominated by the starling, showing pollution effects of the loss of bird varieties.

The same observation was witnessed in the case of insects where 15 species and 150 individuals were reported in the low pollution places such as the beetles and butterflies which are health indicators of the environment. In the averagely polluted regions, there were only 11 species and 110 individuals comprising of beetles and flies. Diversity also dropped in the extremely polluted regions to 7 species and 70 individuals, with insects, such as flies and mosquitoes, some of which would favor polluted environments, predominant.

Table 2. Comprehensive Comparison of Biodiversity in Different Areas of Tikrit City.

Biological Element	Indicator	Low Pollution Area	Moderate Pollution Area	High Pollution Area
	Number of plant species	12	9	6

	Density (number of individuals)	180	135	90
Plants	Vegetation cover (%)	45	33	20
	Dominant species	*Trifolium spp* , *Phragmites australis*	*Phragmites australis* , *Alhagi maurorum*	*Phragmites australis* , *Adiantum capillus-veneris*
	Number of species	8	5	3
	Number of individuals	24	15	9
Birds	Common species	Blackbird (*Turdus merula*) , Mallard (*Anas platyrhynchos*)	Blackbird (*Turdus merula*), Starling (*Sturnus vulgaris*)	Starling (*Sturnus vulgaris*)
	Number of species	15	11	7
	Number of individuals	150	110	70
Insects	Most abundant species	Beetles (Carabidae), Butterflies (Lepidoptera)	Beetles (Carabidae), Flies (Diptera)	Flies (Diptera), Mosquitoes (Culicidae)
	Presence	Yes	limited	NO
	Number of individuals	12	5	0
Amphibians	Recorded species	Green frog (Pelophylax ridibundus), Newt (Triturus vulgaris)	Green frog (Pelophylax ridibundus)	_

The amphibians are most vulnerable species, and they are more abundant in the low-pollution regions (12 individuals of the green frog Pelophylax ridibundus and the newt Triturus vulgaris). In medium-pollution regions, there were very few individuals their number amounting to 5 of the same species, and in highly polluted regions there were none at all. This is the cause of water pollution on these vulnerable organisms; and it shows a decrease in the quality of the environment.

Alterations in insect composition where flies and mosquitoes predominate in polluted regions reveal that there are more favorable conditions that promote harmful species that are likely to cause diseases, to the detriment of the population health [41].

With these results, it is evident that pollution has a direct impact on the health and balance of the ecology, and it requires immediate environmental response to decrease the sources of pollution and enhance the quality of water and air in order to sustain and preserve biodiversity and guarantee local environmental sustainability[42].

Table 3 findings reveal that Table 3 shows a fluctuation in the concentration of air pollutants in Tikrit City, where some of them are above the WHO or international environmental standards. This is an indicator of the existence of emission sources which are active and human impact is evident[43].

Carbon Monoxide (CO):

It was found that the mean concentration was 4.5 parts per million (ppm) per day, which is lower than 9 ppm, which should be the maximum limit. This is an indication that the present concentrations of CO are not a threat. Nevertheless, it is probable that it will be more concentrated in places of traffic or at peak times because CO is a marker of incomplete combustion of the fuel in vehicles and generators[44].

Nitrogen Dioxide (NO_2):

It registered a daily concentration of 52 parts per billion (ppb), which is three times the allowed concentration (40 ppb). This shows the evident pollution by car emissions and industries. NO2 is also said to cause irritation to the breathing system and also causes the formation of acid rain and ground level ozone pollution[45].

Sulfur Dioxide (SO2):

It was found to be 18 ppb, which is very near the allowable level of concentration (20 ppb). This gas is released during combustion of fossil fuel particularly in industries and power generators. On higher levels it may cause some respiratory issues, eye irritation and adverse impact on plants and soil[46].

Ground-level Ozone (O3):

It was 70 ppb, which is higher than the stipulated limit of 60 ppb, and is likely to increase during the midday hours because of the photochemical interaction between the nitrogen oxides and the volatile organic compounds in the presence of sunlight. Ozone at the ground level is secondary and a hazardous pollutant, which is extremely dangerous to the health of the lungs and plant tissues[47].

Table 3. Average Concentration of Pollutant Gases.

Gas	Daily Average	Permissible Limit	Observation
Carbon Monoxide (CO)	4.5 ppm	9ppm	Within permissible limits
Nitrogen Dioxide (NO_2)	18ppb	20ppb	Close to the permissible limit
Ground-level Ozone (O_3)	70ppb	60ppb	Exceeds limit, peaks at midday

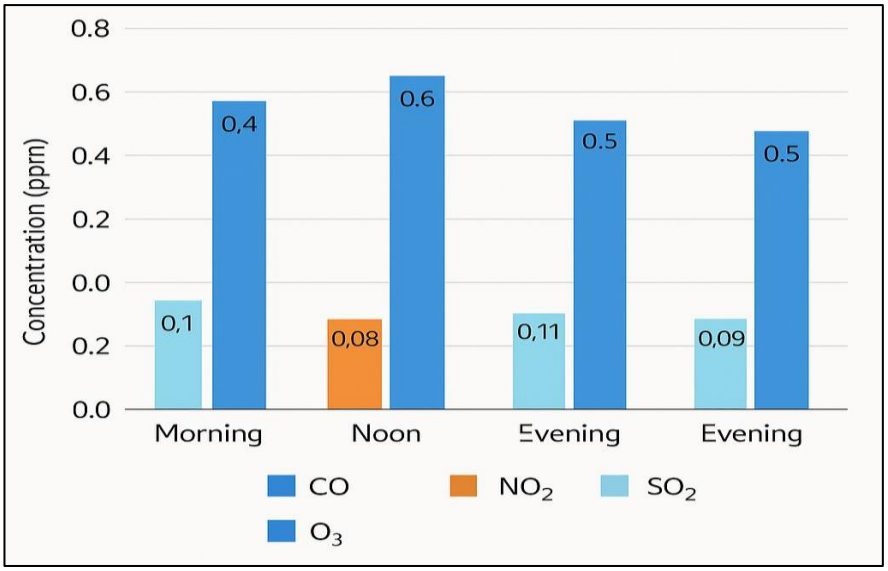

Figure 5. Average concentration of pollutant Gases.

Table 4 shows the analysis of the basic physical and chemical properties of water samples comprising different locations in Tikrit City.

pH Level:

The mean PH was 6.4 and was slightly acidic and below the recommended range of 6.5-8.5 by WHO standards. Such acidity can have an adverse impact on aquatic life and enhance the dissolution of harmful metals and thus the water becomes more dangerous to the environment and human health[48].

Electrical Conductivity (EC):

The mean EC was 1250 uS/cm, which is above the allowable range of 1000uS/cm. This value is high and this is an indication of high quantity of dissolved salts or inorganic contaminants that may be caused by agricultural runoff, sewage discharge or industrial activity within the region[49].

Concerning turbidity, it was 14 NTU and this is higher than the recommended level (below 5 NTU). This means that there is a lot of suspended solids probably of soil, waste, or runoff and it makes water less transparent, decreases the quality of water, and interferes with the process of photosynthesis of organisms living in water[50].

The level of Dissolved Oxygen (DO) was 3.2mg/L, which is less than the recommended minimum (more than 5mg/L). This would mean that there is low capacity of the water to sustain aquatic life since the oxygen scarcity directly reduces the cellular respiration of living organisms, which may result in destruction of aquatic ecology [51].

Table 4. Basic Physical and Chemical Properties of Water.

Parameter	Average Value	WHO Permissible Lin	Evaluation
pH Level	6.4	6.5-8.5	Slightly acidic
Electrical Conductivity (EC) µS/cm	1250	< 1000	Relatively high
Turbidity (NTU)	14	< 5	High
Dissolved Oxygen (DO) mg/L	3.2	> 5	low

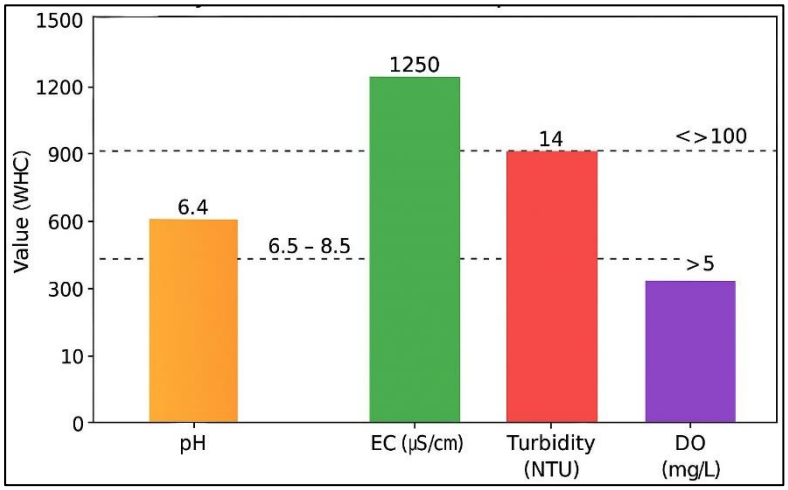

Figure 6. Basic physical and chemical properties of water.

Table 5 shows the concentration of some nutrients in the water which are direct indicators of the levels of organic pollution particularly sewage or excessive use of farm fertilizers.

The former one is the nitrate (NO3-), which yielded 28 mg/L, which is much higher than the allowable level of 10mg/L. The excessively high growth is an indication of the existence of nitrogen-rich sources of pollution, including sewage discharge or high amounts of nitrate fertilizers used in the agricultural industry[52]. In the case of phosphate (PO43-), it was at 2.1mg/L exceeding the safe level of 0.5 mg/L. This means that pollution is largely due to phosphate fertilizer or domestic wastewater and industrial wastewater. Phosphates cause eutrophication in water, which causes excessive growth of algae and low levels of oxygen, putting aquatic organisms at a risk[53].

As of ammonium (NH4+), the concentration was 1.6mg/L and the maximum value allowed is not more than 0.5mg/L. The ammonium level is a clear indication of pollution by recently degraded organic matter and is commonly linked with direct sewage discharge in water bodies. It is a grave environmental pointer, which points to the lack of efficiency or failure of treatment systems[54].

Table 5. Nutrients and Indicators of Organic Pollution.

Compound	Concentration (mg/L)	Permissible Limit	Evaluation
Nitrate (NO_3^-)	28	< 10	Very high
Phosphate (PO_4^{3-})	2.1	< 0.5	High

Ammonium (NH_4^+)	1.6	< 0.5	High, indicator of sewage

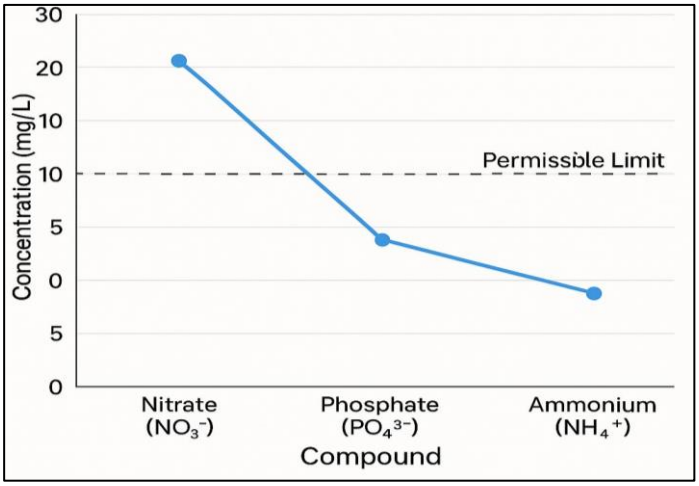

Figure 7. Nutrients and indicators of organic pollution.

Table 6. Heavy Metals Concentration.

Metal	Concentration (mg/L)	WHO Permissible Limit	Evaluation
Lead (Pb)	0.12	0.01	High and dangerous
Mercury (Hg)	0.001	0.001	High
Cadmium (Cd)	0.015	0.003	Very high

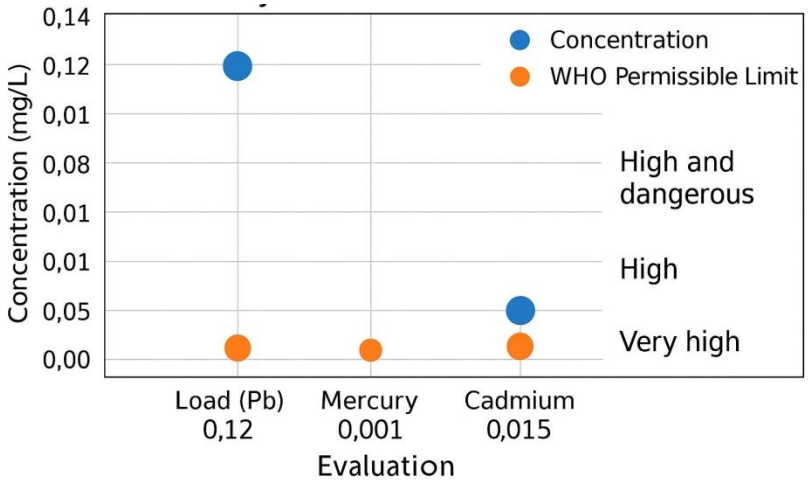

Figure 5. Heavy Metals Concentration.

Table 6 shows the analysis of the heavy metal concentration of water samples of the different sources in the city of Tikrit. These are some of the most risky pollutants of the environment because of their cumulative and high toxicity to human health and living organisms at low doses. The table evidently reveals that all the measured metals are far beyond the stipulated maximum allowable levels by the World Health Organization (WHO)[55].

It was found to be 0.12 mg/L, which is significantly greater than the acceptable level of 0.01 mg/L. Lead is a harmful heavy metal that directly influences the nervous system and, in particular, children and damages the kidney and disrupts the functioning of blood. Its high level implies the sources of industrial pollution as battery discharge water, paints, or corrosion of old water pipes composed of lead[56].

Its level was detected to be 0.005mg/L which is above the safe limit of 0.001mg/L. Mercury is among the worst neurotoxins that accumulates in living tissues particularly in the marine organisms and is spread in the food chain. It leads to neurological and reproductive problems and fetal development. Its occurrence is normally associated with the waste of chemical or medical industries[57].

Cadmium is very toxic, and it affects the kidneys, bones as well as respiratory system and is categorized as probable carcinogen in human beings. It is usually an industrial pollutant especially by the metal industries or the phosphate fertilizers[58].

Discussion

The concentration of fine PM 2.5 and PM10 in the Tikrit city has drastically surpassed the allowable concentration stipulated by the World Health Organization, which means that there is a severe and long-term air pollution issue in the city[59]. The heavy congestion of roads during the day also adds to the emission of massive volumes of fines particles due to vehicle exhausts particularly when there is no competent means of controlling the quality of fuel and engine standards. Research works like that have established that motor vehicle emissions are among the primary contributors of PM2.5 in developing cities[60].

The release of polluted particles is also uncontrolled by the uncontrolled industrial activity in the urban and suburban zones without treatment and filtration. These emissions are frequently contaminated with heavy metals, and it makes them even more dangerous to the population[61].

Moreover, climatic conditions like temperature and low velocity of air flowing over the surface during the afternoon hours predispose the presence of fine particles in the air layers near the ground surface as reported by the Intergovernmental Panel on Climate Change[62].

Low pollution areas exhibited the greatest number of plants and insects along with birds and there were also amphibians which means that the environment was stable and healthy and supports wildlife. This is in line with research that indicates that there is abundant biodiversity in areas where water and air are rich[63].

On the other hand, the number and density of species and the vegetation cover significantly decreased in moderately polluted regions, which means that the environment exerts a stress and pollution that start to restrict the ecosystem capacity to sustain the living organisms[64].

The biodiversity in areas afflicted by pollution reduced drastically, as the number of plant species dropped to 6 and the amphibians became extinct. This is in line with various studies that have affirmed that excessive pollution of industries and agriculture results in the death of sensitive species and loss of biodiversity[60].

An example of a plant such as common reed (Phragmites australis) inhabiting the polluted sites is the ability of certain organisms to adjust to the harsh environment but is in no way a replacement to overall loss of species diversity[65]. According to the availability of species such as the bulbul (Pycnonotus barbatus) in the less polluted regions, it is possible to state that the bird has a favorable environment whereas in the polluted regions, the bird is replaced by the pollution-tolerant species raven (Corvus corax) [66].

The water quality analysis findings of the city of Tikrit depict a definite decline in the physical and chemical characteristics of surface water, which implies the growing effects of contamination of the water by a variety of human activities. Such results may be applied to the environmental standards established by the World Health Organization (WHO) and other agencies[67].

The analysis indicates that the water is a little acidic and it is less than the minimum acceptable level (6.5 -8.5) as stipulated by the World Health Organization [68]. This fall in pH can be attributed to leaks of sewage, decomposition of organic matter or acid rain that disrupt the ecological balance of water bodies making life less sustainable[69].

The fact that electrical conductivity is high indicates that the concentrations of dissolved salts are high, and this is more than the ideal level recommended (<1000 mS/cm)[70]. The cause of this rise is normally on the surface through the runoff of agricultural fertilizers or industrial waste that contain some ions like chloride, sodium, and nitrate [71]. High salinity has the impacts of making water less suitable to human and agricultural use and also decreasing aquatic biodiversity[72].

The high turbidity level means that the volume of suspended particles i.e., clay, algae, and bacteria is too high surpassing the recommended limit of 5 NTU given by WHO [73]. The increased turbidity will decrease the way light is able to reach the water and this will disrupt the photosynthesis of aquatic plants hence the food chain is adversely affected [74]. It is also a pointer of the potential existence of detrimental microbial contaminants.

The DO is below the acceptable minimum (>5 mg/L) showing that there is a lot of organic pollution in which bacteria consume oxygen and destroy organic matter[75]. This reduction is among the gravest pointers, and it may cause submerging of aquatic organisms, and creation of ecologically dead areas with no life [76].

In addition, the high levels of nitrate (28mg/L) are directly caused by sewage discharge and excessive application of nitrogen fertilisers[77]. This does not only affect the environment, but also affects the health of the people especially when such water is taken--as nitrate changes hemoglobin to methemoglobin, which is unable to transport oxygen and thus causing inside suffocation in infants[78].

The phosphate concentration (2.1 mg/L) is a good indicator that is used to show the presence of domestic or industrial wastewater discharge[79]. It plays a critical role toward the eutrophication process, as it results in the overgrowth of algae, and the death and degradation of the alga causes massive oxygen consumption thus killing aquatic organisms and breaking the food chain[80].

In the case of the ammonium (1.6mg/L) this is a good indicator of very recent pollution since ammonium is an early byproduct of organic matter breakdown before it is reduced into nitrites and nitrates[81]. The fact that it is at this level implies that it is being discharged via the sewerage or that the ecosystem is overloaded and cannot effectively decompose organic waste [82].

The concentration of lead (0.12 mg/L) is 12 times the maximum limit which is very alarming[83]. Lead is not readily exited out of the body rather, it builds up in the bones and the brain, resulting in chronic neurological damage, particularly, in children and the unborn. This level of concentration indicates that there could be either corrosion of the aged water pipes or direct discharge in the industries[84].

Mercury (0.005 mg/L) is a very toxic element that is so uncommon but very toxic even in a trace level. It finds its way into the food chain and gets converted into methylmercury in the environment-the most toxic form[85]. Its occurrence can be attributed to medical waste, battery industries or poor disposal of electronic gadgets[86].

The phosphate fertilizers or mining and industrial waste are usually linked to cadmium (0.015 mg/L) [87]. It is stored in the kidney, induces chronic diseases and is also a probable human carcinogen[88].

The results of this research prove the existence of complex and interrelation among the measured chemical and environmental indicators that manifest a severe ecological disbalance of the surface water quality at Tikrit[89].

Among the earliest relationships that can be observed is the acidic nature of the water as evidenced by a pH value that is lower than the allowable limit[90] . This is in addition to its direct impact on aquatic organisms, which also enhances the solubility of hard metals like Lead, cadmium, and mercury resulting in high levels in the water. This, in turn, increases their level of toxicity and makes them easily passed through the food chain[91].

On another platform, the tremendous growth in organic nutrients especially nitrates and phosphates results in a process called eutrophication[92]. Microbial and algal populations are encouraged to proliferate beyond normal levels in this state leading to the quick depletion of the dissolved oxygen (DO) in the water[93]. Decline in oxygen leads to displacing the aquatic organisms with their habitable environment causing mass kill of fish and invertebrates[94].

Besides, the low level of dissolved oxygen prevents natural biological activities like aerobic decomposition of organic matter[95]. This has the effect of accumulating the harmful compounds such as ammonium which under anaerobic conditions may be converted into more toxic compounds such as nitrite or it may generate harmful gases such as methane and hydrogen sulfide[96], [97].

Such conditions are interplaying to cause what is ecologically referred to as surface water ecological collapse of water bodies, i.e. they are unable to purify themselves as a result of the normal biological processes[98].

They turn into closed, polluted systems instead of being life-supporting ecosystems, full of toxic substances and contaminants presenting an acute long-term hazard to the environment and the health of people [99].

Conclusion

The findings of the paper provide evidence that the waters of the urban area of Tikrit are undergoing a steep deterioration of the environmental quality because of a complex set of interacting factors.

The physical and chemical conditions including the low pH (acidic tendencies) and high turbidity are clear evidence that the water has not been in its original state, but rather, it has experienced some changes due to the evident human activities, including but not limited to the sewage discharge, agricultural and industrial practices.

The concentrations of organic nutrients, including nitrates and phosphates, are high, which means that the water is contaminated with organic sources probably due to the leakage of untreated sewage or high usage of chemical fertilizers. Such pollution causes eutrophication which causes the environment to be suffocated, and the water becomes unable to sustain life.

The results of the heavy metals are also quite disturbing, as the levels of lead, cadmium, and mercury are very high, and all of them are extremely toxic in any quantity. Their presence at these levels makes the water untable to humans and it presents a direct risk to the health of the citizens particularly in those who are children and pregnant women.

Moreover, the dissolved oxygen (DO) that is found to be below the acceptable levels imply that the environment is under some form of stress and aquatic organisms cannot survive in such environment. This decrease is normally caused by piling of organic matter and lack of proper natural purification processes.

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