# Koya River Water Quality Assessment with a Focus on Physiochemical Properties and Heavy Metals

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*Abstract*–**Human activities can have impacts on nearby river water characteristics. Consuming water can alter the environment and living organism's health. Due to various types of pollution sources in the catchment, the objective of this study was to examine both chemical and physical properties of Koya River and its main tributaries. Both point and non-point pollution sources have their inputs to the river including raw sewage and runoff from municipal solid waste landfill and industrial and agricultural areas. Overall, six samples were taken from the point sources of the river catchment. Samples analyzed important water quality parameters including heavy metals and bacteriological. Most of the selected parameters show a positive result, for instance very high bacteria and high part per million of some heavy metals, high suspended solids, very turbid water, which exceeds the World Health Organization Guideline 2017. In the long term, the river water quality may worsen, as human activities will increase with population growth, and yet there is no plan in place to control the pollution course.**

*Index Terms*—**Environment, Health, Heavy metals, Koya River, Physiochemical properties, Water quality.**

## I. Introduction

Water is one of the most vital resources in the planet. Within water recourse sources, rivers can be the oldest one that used by human. This resource is strongly associate with living organism well-being; therefore, conserving water is anyone responsibility. Naturally, water contains some impurities, for instance, suspended and dissolved solids, and gases and also it may contain a number of microorganism with deferent types [1]. Changing in the impurities and microorganisms levels leads to water pollution, besides the national regulation World Health Organization (WHO) and FAO guidelines are used for assessing water quality [2]. In this current study, the WHO guideline 2017 is considered to find the variations [3].

The physiochemical parameters and heavy metals are vital for assessing river water quality [2,4]. High level of conductivity value is a sign of water pollution, which is a physical parameter usually affected by total dissolved solids (TDS) and salinity [5,6], and also, a high range of total suspended solids (TSS) and turbidity could potentially lead to water quality declining [7]. Suspended particles and cloudiness of water are reducing sunlight to reach river bed, thus impacting emerged vegetation then altering total aquatic life and freshwater ecosystems services in general. Turbidity also linked with dissolved oxygen (DO) which is frequently used to evaluate the water quality on reservoirs and rivers [8]. DO is crucial to estimate the effect land use types such as industrial input and municipal effluent to environment, and through examining DO, sustainability of freshwater ecosystem services can be assessed. Another parameter which is highly considered in river water studies is bacteria, especially *Escherichia coli* bacteria; their presence in water supplies indicates possible fecal contamination [9].

Moreover, the heavy metals are central to a water quality study, especially when it is associated with human and agricultural consumption. They can have significant impact on health. The health effects associated with exposure to barium and its compounds are depending on how well the specific barium compound dissolves in water. Barium compounds such as barium nitrate, barium carbonate, barium chloride, barium hydroxide, barium sulfide, and barium acetate dissolved in water can cause adverse health effects. Drinking large volumes of water with dissolved barium compounds may cause death or paralysis. Drinking small volumes of barium or its compounds for a short time may potentially cause difficulties in breathing, increasing blood pressure, minor blood changes, changes in heart rhythm, stomach irritation, muscle weakness, changes in nerve reflexes, swelling of the brain, and damage to the heart, kidney, spleen, and liver [10,11]. Iron as another heavy metal is naturally existing in the environment thus exists in water. Increasing and decreasing in living organisms body could lead to health disorder. The typical daily American/Western European dietary intake of Fe is approximately 15 mg/day, and only about 10% of which actually absorbed by the

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stomach. Foodstuff iron content varies greatly from rich iron contents (red meat) to poor iron contents (milk). Exposure to excess iro ntypically in patients who receive numerous transfusions for many years leads to numerous pathological consequences. By contrast, iron deficiency also causes serious health consequences [12]. Acute iron (Fe) overload resulting from intentional or unintentional overdose is also potentially life threatening. Chronic iron overload can damage the heart and liver and be lethal [13]. Mercury, manganese, calcium, and sodium occur natural though soil and rock erosion, but human activity can add to it through industry [14]. Overtaking these elements, brain, kidney, and fetus development, skin, eyes, and mucous membranes can be damaged, and also poisoning, increasing blood pressure, arteriosclerosis, edema, hyperosmolarity, and confusion are expected [15-18]. Arsenic is found in water worldwide and comes from the Earth crust rocks. Arsenic can have devastating impact on health when ingested as drinking water or having a food with high concentration of arsenic [19]. High level of arsenic may result in fatality, but low level can cause skin discoloration or result in small corns and warts when exposed for a long time [20]. However, Some of the heavy metals are health essential in their limit sets, such as sodium and calcium, but dismissing the limit can have negative impacts on health. This why most of the water quality study focus on heavy metals contribution.

Lack of data is the main obstacle of scientific study in the developing countries; for example, no hydrochemistry data have been recorded on Koya River. Although the river is believed to be polluted, no past study has been conducted to confirm this statement. In the last century, Koya River water was used for domestic consumption, irrigation, fishing, and recreation [21]. Due to human intervention, its water quality has undoubtedly changed. Various pollution sources are found in the river catchment, which is altering river ecosystem. Municipal solid waste landfill composition is a serious point source of pollution; a mature landfill leachate can introduce heavy metals, altering pH, elevate conductivity, and TSS and nutrients [22]. The entire town sewage water is discharged to the river without treatment. Sewer and town runoff can escalate chemical and biochemical oxygen demand, heavy metals concentration, as well as TSS and other physical parameter alteration [23]. Agriculture, chicken farms, and slaughterhouse as non-point source pollution can impact river basin condition, due to applying fertilizers, pesticides, herbicides, and other liquid and solid waste discharge [24]. Other pollution sources identified in the catchment include petroleum refineries and industrial area surface runoff of the town and highways. The sampling locations were chosen based on pollution sources of the River around Koya and named the location base on the main pollutants on the upstream tributaries.

## II. Materials and Methods

The samples were collected from six main attributes of the river. Laboratory tube has been used during collecting the samples and kept under a temperature of 21°C throughout the tests. The well-known inductively coupled plasma mass spectrometry technique has been used to test the samples at a modern scientific laboratory for heavy metals. Only 15 critical heavy metals have been examined because of their impacts on living organisms. For conductivity, salinity, DO, and TDS, the conductor meters were used. PH meters were used for PH and density meters for density; furthermore, ultraviolet mass spectrometers have been used for TSS, turbidity, sulfate, and oil in water (OIW). Finally, the laboratory results were compared with national and WHO guideline 2017 to determine the level of contamination and compliance.

### *A. Study area*

Koya is a small town located in the Kurdistan Region of Iraq. Koya River passes through Koya in its own catchment area. It covers an area of approximately 579.18 $km^2$ and collects most of its water from Haibatswltan, Bawajy Mountains, and Koya plains. It flows into Small Zab that meets in Sartka Village. Heezop River is in the north, Chamaswr in the east, Shallxa in the west, and Sheewaswr catchment located to the south of Koya River Catchment [1]. The map shows the study area location. Table I shows the sampling point coordination and elevation (Fig. 1).

## III. Result and Discussion

The results of this study will be divided into two sections, water physiochemical properties and heavy metals. Both will be discussed separately to avoid confusion with the data and figures.

### *A. Section One: Water physiochemical properties*

This includes all chosen parameters except heavy metals. Table II shows that eight of ten examined parameters are significant when compared with the WHO 2017 guideline [5]. Only pH and sulfate are within the standard limit. Based on Table II, significant parameters will be interpreted.

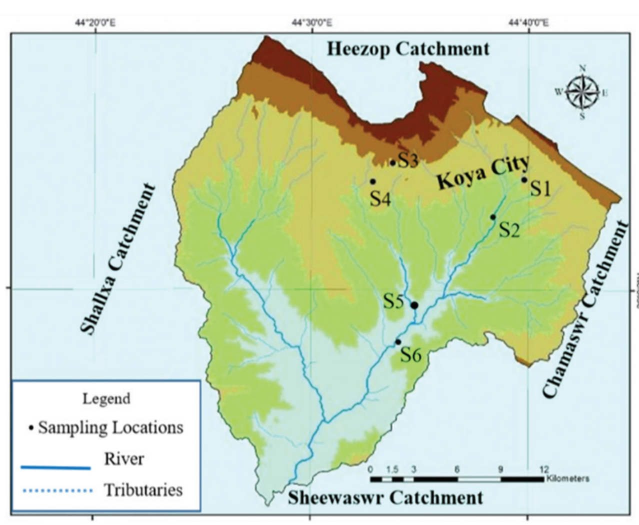


Fig. 1. Koya river catchment map and sampling locations.

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*Conductivity*

High conductivity value is a sign of water pollution. In this current study, conductivity value is higher than the WHO from five of the samples, and the average is 4 times higher than a used guideline. Fig. 2 shows the conductivity value of all the samples. The worst sample is sample number 1, that nearby the landfill, which is 8040 uS/cm, whereas the WHO guideline is 600 uS/cm. The high range of conductivity may occur due to high level of TDS, salinity, sodium, calcium, and manganese, especially in sample number 1 (Table II and III). Moreover, because all the lands are cultivated agricultural fertilizers, pesticides and herbicides can have impact on rising conductivity value.

*TDS and salinity*

TDS and salinity both are related to dissolved solids and minerals, either naturally occurring or human intervening [5,6]. As shown in Fig. 3, only three samples of TDS and two samples of salinity exceed the WHO standard, which is sample number 1, 5, and 6 for TDS, sample number 1 and 5 for salinity, whereas sample number 6 is just below the WHO. Location number 1 is altered by the aged landfill leachate, but location number 5 high value resulted in the existence of limestone rocks in the upstream [21]. However, some of samples were below accepted range, but the average is still higher than the WHO standard.

TABLE I
Sample Location Coordinates and Elevation

| Samples | Location coordinates | Elevation |
|---|---|---|
| S1 | N 36 04.091 E 044 39.265 | 532 m |
| S2 | N 36 02.736 E 044 38.401 | 496 m |
| S3 | N 36 03.887 E 044 33.649 | 582 m |
| S4 | N 36 04.102 E 044 33.097 | 590 m |
| S5 | N 35 59.016 E 044 34.838 | 401 m |
| S6 | N 35 58.804 E 044 34.654 | 398 m |

*OIW*

OIW is a parameter used to detect the amount of OIW. In this current study, OIW does exceed the WHO standard in all samples except in location number 5, where oil is not detected. Location number 1 has recorded 7 part per million (ppm), which is because of landfilling mechanical waste of the industrial area without treatment. Sample number 4 demonstrates the peak value, because of the nearby refinery impacts, whereas location number 6 high value is due to highway passing through the upstream and occasional road tanker oil spills (Fig. 4).

*Turbidity*

High level turbidity of water shows pollution resulting suspends particles, runoff sediment, and algae. Unlike the other parameters, turbidity is high in all the samples with some fluctuation; location number 5 has recorded the peak value due to realizing slaughtered animals blood, but location number 3 is least turbid due to having a few natural springs in the valley. Location numbers 1, 2, 4, and 6 also very turbid, because of their dark color water, the agricultural runoff from nearby lands, and algae. The average of all the samples is 16 times higher than the WHO safe range. High turbidity could potentially lead to water quality problems and make it difficult to use without pretreatment [7] (Fig. 5).

*DO*

DO is essential for aquatic life such as fish. Table II shows that all the samples have adequate DO because of the topography where the streams pass though, which make the water cascading and contact with air then obtain oxygen from this process. Only sample number 1 presents negative reading, because the stream water flows slowly. The DO average is acceptable when compared with the WHO guideline.

*E. coli bacteria*

This bacteria has to be negative to consider as safe, but in this current study, the average of the bacteria is positive (Table II); this is due to fecal contamination from sewage,

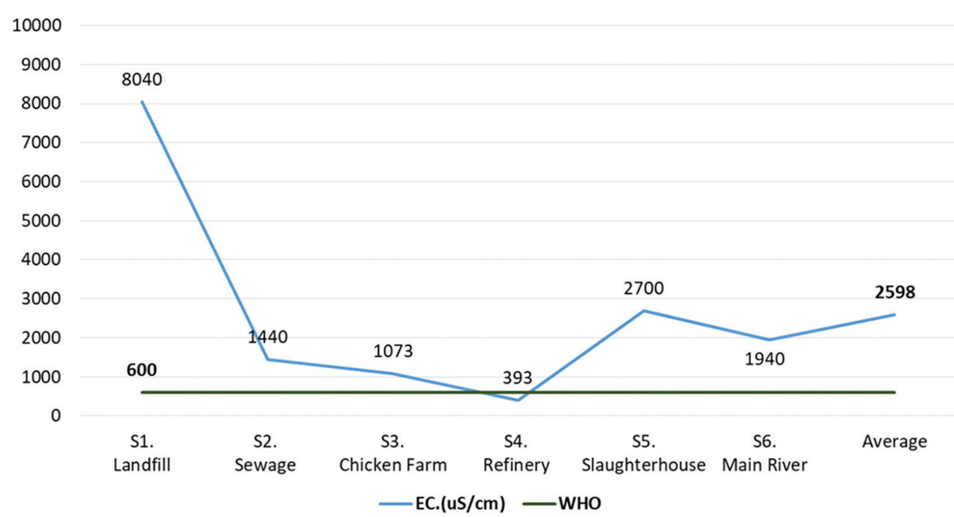


Fig. 2. Conductivity values compare with the World Health Organization guideline.

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TABLE II
KOYA RIVER WATER PHYSIOCHEMICAL PROPERTY VALUES

| Parameters | WHO | S1. Landfill | S2. Sewage | S3. Chicken farm | S4. Refinery | S5. Slaughter house | S6. Main river | Average |
|---|---|---|---|---|---|---|---|---|
| pH | 6.5–8.5 | 7.3 | 7.32 | 7.4 | 7.1 | 7.1 | 7.35 | 7.261 |
| EC (uS/cm) | 600 | 8040 | 1440 | 1073 | 393 | 2700 | 1940 | 2598 |
| TDS (ppm) | 1000 | 4600 | 710 | 600 | 200 | 1500 | 1060 | 1445 |
| Salinity (ppm) | 1000 | 4450 | 700 | 530 | 180 | 1600 | 980 | 1406 |
| TSS (ppm) | 500 | 640 | 116 | 15 | 4 | 443 | 90 | 218 |
| OIW (ppm) | 0.2–2 | 7 | 2 | 2 | 26 | 0 | 14 | 8.5 |
| Turbidity (ppm) | 5 | 52 | 94 | 13 | 70 | 214 | 46 | 81.5 |
| DO (ppm) | 5 | 0 | 100 | 20 | 30 | 40 | 20 | 35 |
| Sulfate (ppm) | 250 | 0.217 | 0.039 | 0.001 | 0.005 | 0.066 | 0.025 | 0.058 |
| *E. coli's* | Neg(−) | Pos(+) | Pos(+) | Neg(−) | Pos(+) | Pos(+) | Pos(+) | Pos(+) |

WHO: World Health Organization, TDS: Total dissolved solids, TSS: Total suspended solids, *E. coli's: Escherichia coli,* ppm: Part per million

TABLE III
KOYA RIVER HEAVY METAL VALUES (PPM) AND WHO GUIDELINE

| Elements | WHO | S1. Landfill | S2. Sewage | S3. Chicken farm | S4. Refinery | S5. Slaughter house | S6. Main river | Average |
|---|---|---|---|---|---|---|---|---|
| AL | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ba | 0.7 | 16.956 | 3.193 | 3.13 | 32.779 | 7.089 | 0.808 | 10.659 |
| Cd | 0.003 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fe | 0.1–0.3 | 0.64 | 0.016 | 0.014 | 0.075 | 0.144 | 0.038 | 0.154 |
| Hg | 0.001–0.006 | 0.025 | 0.03 | 0.025 | 0.027 | 0.024 | 0.025 | 0.026 |
| Ag | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pb | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N1 | 0.2–0.07 | 0.059 | 0.136 | 0.01 | 0.017 | 0.012 | 0.01 | 0.04 |
| Zn | 3 | 0.046 | 0.065 | 0.008 | 0.001 | 0.01 | 0.015 | 0.0241 |
| Mg | 50 | 31.913 | 4.361 | 10.583 | 0.006 | 33.813 | 11.254 | 15.321 |
| Ca | 50 | 95.279 | 16.091 | 18.065 | 43.812 | 34.371 | 51.425 | 43.173 |
| Na | 200 | 627.29 | 19.512 | 21.619 | 144.389 | 218.859 | 74.549 | 184.369 |
| Mn | 0.1–0.4 | 1.43 | 0.007 | 0.011 | 0.217 | 0.227 | 0.093 | 0.33 |
| Cu | 1 | 0.008 | 0.051 | 0.006 | 0.002 | 0.016 | 0.006 | 0.0148 |
| As | 0.01 | 0.051 | 0.025 | 0.011 | 0.021 | 0.014 | 0.017 | 0.023 |

WHO: World Health Organization, ppm: Part per million


Fig. 3. Total dissolved solids and salinity values compared with the World Health Organization guideline.

chicken farms, and animals waste which are living extensively in the catchment. However, sample number 5 shows negative result, and this negative result of this sample location may be due to applying additive in the slaughterhouse. Immediate action must take if this bacteria found in consuming water, either for drinking or irrigation.

### *B. Section two: Heavy metals*

The heavy metals are central to a water quality study, especially when it is associated with human and agricultural

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consumption. In this study, 15 crucial heavy metals were examined (Table III); seven of them are beyond the WHO standards. However, within these seven elements, some of the sample points heavy metal level is low, such as sample point number three, where the lowest level of heavy metals has recorded, because the water is mixing with freshwater of nearby springs and it can dilute. Whereas, sample point number 1 that affected by landfill leachates has recorded the highest level of heavy metals. Only the significant elements will be interpreted below.

*Barium*

Free barium is not found in the nature, but it can mix with other elements. In this study, barium value is quite high from all the samples, especially in location number 4 and 1, because the refinery and landfill chemical elements can interact to make different types of barium occurrence, such as $BsSO_4$ and $BaCO_3$. The least value of barium is recorded in location number 2, 3, and 6, and this is due to high flow of sewage and natural springs in the chicken farms valley. However, the average is still 15 times higher than the WHO acceptable value (Fig 6).

*Iron*

According to the WHO 2017, the safe range of iron is between 0.1 and 0.3 ppm. In this study, only location number 1 is higher than guideline, this might due to disposing scrap metals in the landfill, then it corrodes, and the rust will inter the watercourse with leachate. The rest of samples are complying with standard. Furthermore, the average is within the safe guideline limit which is 0.154 ppm (Fig. 7).

*Mercury*

High level of mercury can damage brain, kidney, and fetus development [16]. A body water cannot be used even for swimming if it is contaminated with high level of mercury, as besides ingesting, and inhalation mercury can also enter the human body through the skin. In Koya River, mercury is quite high from all the samples, but all the locations show similar values and the curve is almost steady. Mercury is naturally occurring in the region and this is why it shows least fluctuation of the sample values. Their average 0.026 ppm which is 4 times is higher than the WHO 2017 guideline (Fig. 8).

*Calcium and sodium*

Calcium and sodium both naturally occurring elements and human activity can also add to it. Moreover, both are essential dietary elements for human body in their limit sets, but when it is higher than the limit, health can be threatened. In this current study, calcium and sodium of Koya River are showing almost the same curve fluctuation. The highest value has recorded in location number 1 and the lowest is location number 2. Location number 1 is impacted by aged landfill leachate, as various types of waste organic and inorganic and domestic and nondomestic waste have been landfilled with no supervision. This is why the element value is high in sample point number 1. The values are low in location number 2 because this branch has the highest rate of flow, and the elements can dilute. Average of both elements can regard as non-contaminated according to the considered guideline. Calcium and sodium average is

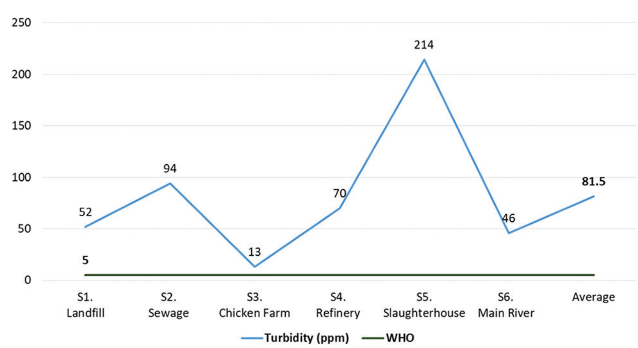


Fig. 4. Oil in water values compared with the World Health Organization guideline.

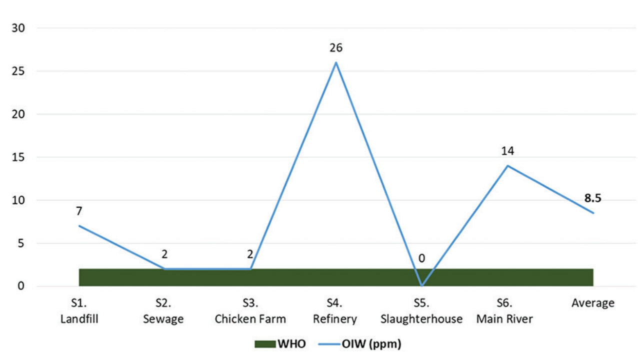


Fig. 5. Turbidity values compared with the World Health Organization guideline.

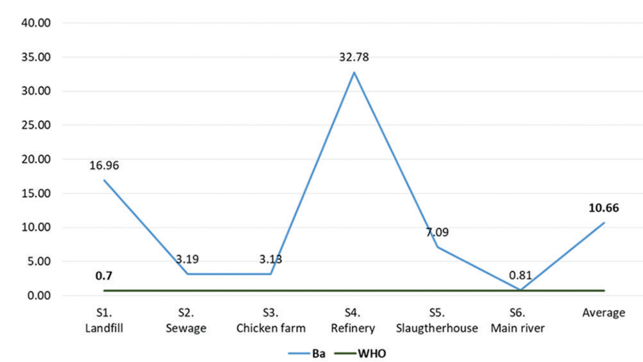


Fig. 6. Barium values compared with the World Health Organization guideline.

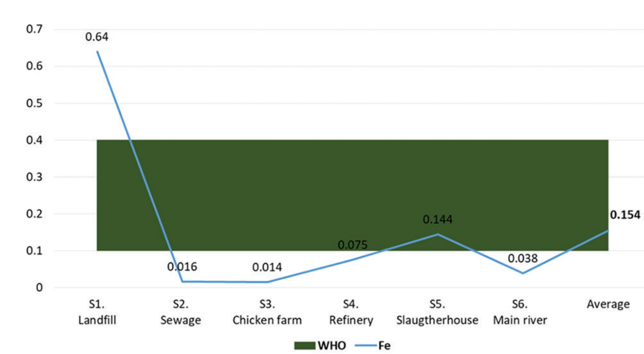


Fig. 7. Iron values compared with the World Health Organization guideline.

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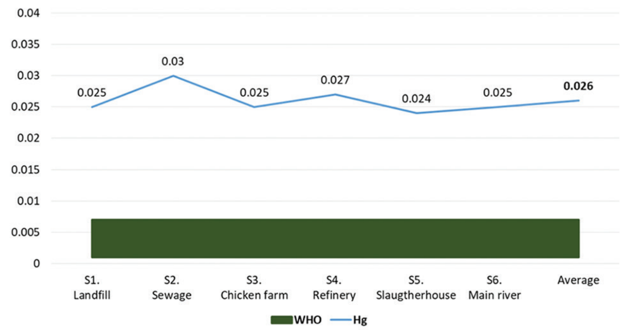


Fig. 8. Mercury values compared with the World Health Organization guideline.

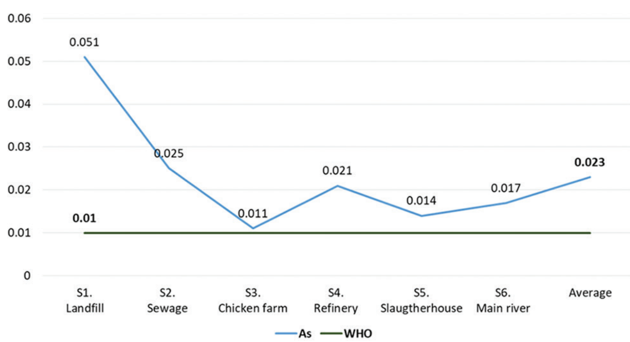


Fig. 9. Manganese values compared with the World Health Organization guideline.

43.173 ppm and 184.369 ppm, respectively (Table III). The same interpretation can apply to manganese, as location number 1 has recorded the peak and location number 2 the lowest, 1.43 ppm and 0.007 ppm, respectively. Average and the other sample value are within the WHO 2017 standard (Fig. 9).

*Arsenic*

Arsenic can found in any water, but high level of arsenic may result in serious health risks, even fatality. In this current study, all samples exceed the WHO guideline; the highest one is sample number 1 and lowest is sample number 3 which are very close to the standard 0.051 ppm and 0.011 ppm, respectively. These two locations illustrate that human intervention has played its role to increase arsenic value, because sample number 1 highly affected by unsupervised landfill leachate, whereas sample number 3 is low because natural spring reduces human intervention impacts. The arsenic average is 0.023 ppm, whereas the WHO standard is 0.01 ppm (Fig. 10).

## IV. Conclusion

The study confirms that Koya River water is not safe to use directly. The river is no longer acceptable for use in domestic consumption, irrigation, and recreation. All the pollutant sources are playing their roles to reduce the water quality, especially landfill leachate through introducing very high heavy metal values, such as iron, barium, mercury, arsenic, sodium, and calcium. Some other physical and chemical properties of the river also altered, for example, conductivity,

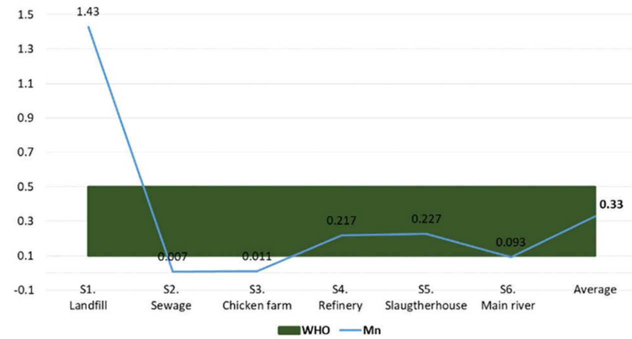


Fig. 10. Arsenic values compared with the World Health Organization guideline.

turbidity, OIW, and bacterial activities. To reduce pollution and conserve the natural resources and environment, it is recommended to have governmental intervention for achieving zero direct discharge of refineries, slaughterhouse, and chicken farms to the nature. Sewage water should treat and pass all the national or international parameters before releasing to the river. Furthermore, the municipal solid waste should be landfilled in an appropriately designed facility. In conclusion, this kind of research should be ongoing to gather more data about the river and contamination impacts of the living organism's health and ecosystem services.

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