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Heavy metals and pathogens concentrations of soil and wastewater for irrigating vegetables in the Zagyuri community vegetable field in the Tamale Metropolis of Ghana

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Abstract
Vegetables irrigated with contaminated wastewater with high amounts of heavy metals and Pathogens could be a route to human exposure to toxicity and risk to life. An absorption Spectrophotometer analysis and pour plate count revealed a high concentration of heavy metals and Pathogens in the soil and wastewater. However, the heavy metals concentration in the soil was higher than those in the wastewater. The heavy metals ranged from 0.04 - 668.76 mg/kg from the soil and 0.01 - 2.05 mg /l from the wastewater. The order of heavy metals concentrations observed from the highest to the least in the soil is Fe $>$ Mn $>$ Cd/Pd $>$ Cr (668.76$>$ 74.09$>$ 0.04 $=$ 0.04 and $>$ 0.002) and Fe $>$ Mn $>$ Cd $>$ Cr $>$ Pd (2.05$>$ 0.71$>$0.144$>$0.011 and $>$ 0.001) for wastewater respectively. Except for Cr in the soil and wastewater Cr and Pb, all other heavy metals were above the World Health Organization (WHO) detection rates. Pathogens (total, *faecal coliforms*, *E. coli*, shigella, and salmonella) were high in soil and wastewater for cultivation. Total coliforms range from 51.0 X 10^{2+}- 53.0 X 10^3 and 41.4 X 10^4. Faecal coliforms (40.0x 10^4) were higher in the wastewater. Salmonella and *E. coli* had values as 50 X 10^0 to 42 X 10^4 and 51.0 x 10^4. Prolonged exposure of vegetables irrigated with contaminated water, could lead to chronic disorders such as kidney impairment, nervous systems disorders, systemic dysfunction of the human body, and a devastating effect on terrestrial and aquatic ecosystems.

Keywords
Wastewater, Heavy metals, Pathogens, Soil, Toxicity

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1. Introduction

As population increases and the demand for resources intensifies, competition for water for domestic and agricultural uses rises giving way to the use of wastewater in the cultivation of crops and rearing of animals. According to Ursula et al. (2000) and Vojdani (2006), the reuse of wastewater is one of the main options being considered as a new source of water in regions where water is scarce. Sharma et al. (2007) also stated that the use of municipal wastewater in the agricultural sector is frequently seen as a common practice in many parts of the world.

Globally, existing data suggest that approximately 350,000 ha in 75 cities are directly irrigated with wastewater, and 550,000 ha in 17 cities are irrigated indirectly (Van der Hoek, 2004). In America, a total of more than 500,000 ha of agricultural land is irrigated with wastewater (Chanduvi, 2000), of these 350,000 ha are in Mexico alone (Peasey et al., 2000). FAO Water Reports (2010) identified that in Saudi Arabia, Kuwait, Israel, Jordan, Tunisia, and Morocco about 70,100 ha are irrigated with wastewater (AQUASTAT, 1997). Similarly, about 170,000

– 200, 000 m^3/d of the treated effluence is used for agricultural activities in Riyadh (Al- Jasser, 2011), and by 2006, Kuwait had about 10,142 ha irrigated with treated wastewater (AQUASTAT, 2009).

According to Raschid-Sally et al. (2004), about 7000 ha of the wastewater-irrigated field were available within the metropolitan boundaries of Vietnam for cultivation and Pakistan has an estimated 30,600 ha of wastewater for irrigation (Ensink et al., 2004). Again, an estimated 9675 ha of agricultural land in the Musi River in India is irrigated by wastewater (Buechler, 2005). With about 58000 households in 16 villages using wastewater for irrigation (Mekala et al., 2008).

In Africa including Ghana, wastewater is used for irrigating vegetables in urban areas such as Accra, Kumasi, and Tamale (Osei et al., 2015). An estimate of actual renewable water resources is 53.20 km^3 per year with 30.30 km^3 per year being internally generated (Ghana National Water Policy, GNWP, 2007). About 17% of Ghana's arable land is irrigated with wastewater and produces approximately 34% of the crops consumed in urban areas in Ghana (Kaetzl et al., 2018). As the climate is fast changing, it is obvious the likelihood of increased demand for wastewater for irrigation in the near future. The irregular rainfall patterns, higher and fluctuating temperatures, indiscriminate floods, and frequent drought experiences in Ghana, more especially in Northern Ghana are likely evidence of high demand for wastewater in the near future.

Untreated wastewater is known to contain a significant amount of pollutants including heavy metals and Pathogens (de Oliveira et al., 2007; Kinuthia et al., 2020; Pescod, 1992; Singh et al., 2010;). The World Bank report (2020) indicated that inadequate water supply, sanitation, and hygiene (WASH) are important challenges in Ghana. The problem of waterborne diseases is particularly serious in rural areas, where only a small number of households benefit from safely managed WASH. These problems are aggravated when solid waste, industrial effluents, and toxic substances are discharged into the water system, leading to serious effects on health (World Bank, 2020).

Prolonged consumption of vegetables irrigated with contaminated water, could lead to chronic accumulation of the metals in the kidney and liver. This can disrupt numerous biochemical processes, leading to various fatal illnesses such as kidney failure and diseases of the bone and the nervous system (Jarup, 2003; Prakongkep et al., 2013; Trichopoulos, 2001). Tamale has no perennial stream but rather, a few seasonal ones which are replenished during the rainy season and dry up in the prolonged dry season (Obuobie, 2006). Farmers are, however, compelled to use wastewater despite that between half to one million Ghanaian city dwellers are at risk of infections from consuming vegetables that are irrigated with polluted water (Amponsah et al., 2015). At the study site (Tamale), there are varied reports regarding the concentration of heavy metals and pathogens in wastewater for irrigation. Anim-Gyampo et al. (2012) identified that manganese (Mn), cadmium (Cd), and iron (Fe) were above the WHO-recommended minimum ratings. Abagale (2014) also identified manganese (Mn) and iron (Fe) to be above the WHO ratings. A study conducted in 2018 by Abdanlla and Khaldoon (2021) at the study site also revealed a significant level of Fe, Pd, and Cd in the wastewater.

There were equally varied and higher levels of pathogens observed at the study site. Abagale (2014), Kaetzl et al. (2018) and Abdalla and Khaldoon (2021) studies indicated very high faecal and total coliforms above the recommended limits. *Escherichia coli* (E. coli) and *Enterococci* values obtained by Korbinia et al. (2018) in the irrigated water (wastewater) are 6.4 x 10^6 and 2.3 x 10^6 mL-1 respectively, which is far above the WHO standard limits of 100 mL-1. The total and *faecal coliforms* recorded by Abagale (2014) at the Zagyuri irrigated field area were 56,930 MPN/l and 24,444 MPN/l respectively for the rainy season, with the dry seasons recording 41, 113 MPN/l for total coliforms and 13,780 MPN/l *faecal coliforms.* As against the recommended limits of less than 1000 /100 ml (WHO, 2006). Abdanlla and Khaldoon (2021) recorded 4.0 x 10^3 and 1 x 10^2 for *E. coli* and *Faecal coliforms* respectively at the Zagyuri irrigation field.

Many studies have been documented on the pathogen and heavy metals loads in the Zagyuri irrigated field, however not all Enteric pathogens have been investigated. Also, there is a paucity of data on a comparative study in terms of pathogen load for both rainy and dry seasons, hence the gap this study tried to address. This study, therefore, seeks to unfold the diversity in the current state of heavy metals and pathogens in the soil and wastewater for both rainy and dry used for irrigation at the Zagyuli irrigation field. Taking into account the total and faecal coliforms, *E. coli*, Salmonella, and Shigella content in the Zagyuri irrigated water (wastewater) for vegetable cultivation. This study was conducted based on the hypothesis that irrigated soil has a high potential in retaining heavy metals and pathogens from wastewater, with variations in heavy metals and pathogens composition in soil and wastewater for the rainy and dry seasons. The main objectives of this study are to ascertain heavy metals and pathogens concentration in the cultivated soil and wastewater and to determine the differences in heavy metals and pathogens concentration in soil and wastewater for irrigation in both rainy and dry seasons in the Zagyuli irrigation field.

2. Materials and methods

2.1 Experimental site

Zagyuri is one of the major vegetable growing sites in the urban Tamale Metropolis. Tamale is the Regional Capital of the Northern Region of Ghana and the third largest city in Ghana. It is made up of 197 communities of which 33 are within the urban, and the remaining are peri-urban and rural (Anim-Gyampo et al., 2012). The Metropolis is located in the central part of the northern region. It is approximately 930 km^2 and lies within latitude 9º 16'N and 9º 34'W 0º 57'W respectively. It is bounded to the north by Savelugu Nantong District, to the east by Yandi Municipality, to the west by Tolon-Kumbugu District, south by Central Gonja and East Gonja districts (Agodzo et al., 2003). Figure 1 depicts a graphical representation of the study site.

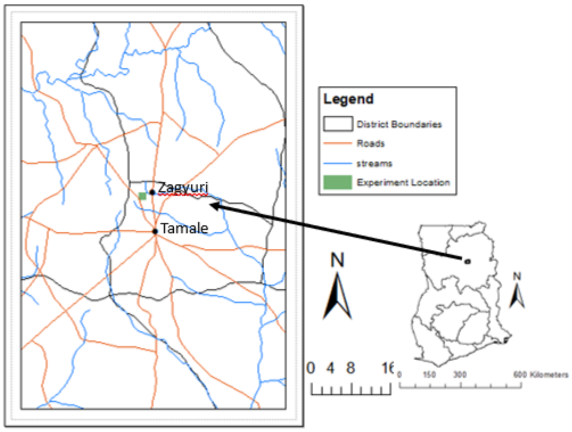

Figure 1. A map of Ghana indicating Tamale and the study site

2.2 Experimental design

Random Complete Block Design (RCBD) design was used for the study. Three different samples for soil and water were selected and analysed separately and the average was taken. The experiments were conducted at Zagyuri, near Kamina Military Barracks in Tamale Metropolis, Ghana, from April to November 2020; and January to March 2021 (rainy and dry seasons respectively). Heavy metals such as lead (Pd), chromium (Cr), cadmium (Cd), iron (Fe), and manganese (Mn); as well as pathogens: (*faecal coliforms*), *Escherichia coli* (*E. coli*), shigella, helminth eggs, and salmonella -were sampled and determined in the soil and wastewater at both rainy and dry season as discussed below. The physical-chemical properties of soil and wastewater such as EC, pH, organic carbon (OC) and chemical oxidation demand (COD), temperature, and turbidity were determined. Nitrogen (N), Phosphorus (P), and potassium (K) were determined in soil and wastewater during the rainy and dry seasons. Systematic procedures for the preparation of each parameter are discussed below.

The climate is characterized by a single rainy season from April / May to September / October, under the influence of moist south-west (monsoon) winds originating from the Atlantic Ocean with a mean annual rainfall of 1100 mm followed by a prolonged dry season which is under the influence of the dry north-east (Harmattan) trade winds originating from the Sahara Desert and is laden with sandstorm from November -March, and sunshine from March-May.

2.3 Data collection

2.3.1 Soil sampling, preparation and analysis

Soil samples were taken along the two diagonals of one hector-demarcated area of the field. Five (5) cores were picked along each diagonal at regular intervals at a depth of 15 cm and mixed thoroughly. A composite soil sample was then taken with a sterile auger into sterile plastic bags (Stomacher (R) lab system) sealed and put into cooling boxes with ice blocks for cooling and transported to the microbiology laboratory CSRI- Water Research, Accra for analysis heavy metals and pathogens.

2.3.2 Water sampling, preparation, and analysis

Zagyuri irrigation field was purposefully selected because of its accessibility of water all year round, farming activities around the site and yearly availability of vegetables to consumers. Wastewater was collected from the reservoir and the up-flow near the production source (homes from which the wastewater is a channel). These areas were selected because there are places where vegetable cultivation is practised all year round. Farmers' activities at the Zagyuri irrigation field (Plate 1-6).

Figure 2. Plate 1 and 2: Source of water for irrigation Plates 3-6: Harvesting and packaging vegetables to the market

The wastewater was sampled during rainy and dry seasons, three samples were taken for analysis on the same day for each season. Wastewater for irrigation was sampled into pre-labelled 500 ml plastic bottles. The samples were kept in the ice chest with ice blocks and transported to the microbiology laboratory CSRI- Water Research, Accra for analysis of heavy metals and pathogens. Each sampled wastewater was used for the analysis of all the parameters (EC, pH, COD, temperature, turbidity, heavy metals, pathogens, and NPK).

2.4 Laboratory analysis of wastewater and soil

2.4.1 pH

The pH of wastewater was determined using a pH meter (Basic 20) of the Crison model in a 10 ml container. The pH was then identified by inserting the electrode of the pH meter into it and the value was recorded.

2.4.2 Electrical conductivity of wastewater (EC)

A Crison Basic EC meter (CM39P model) was used to determine the EC of wastewater. Samples were determined by inserting the electrode of the EC meter into the wastewater in the container as described by (Rowell, 1994).

2.4.3 The concentration of NPK in wastewater

The NPK concentration in wastewater was done using Jenway 6405 UV/VIS Spectrophotometer at the microbiology laboratory CSRI- Water Research, Accra. The N was identified using the Hydrazine Reduction method described by APHA-AWASTEWATERA-WEF, (2001). P was determined using the Stannous Chloride Method. And the potassium (K) portion of the wastewater was identified using the Flame Photometer (Jenway PFP7) method.

2.4.4 pH of soil

Ten (10) g of air-dried soil sampled was weighed into a 50 ml beaker. Twenty-five (25) ml of distilled water was added. The suspension was vigorously stirred for 20 minutes to allow homogeneity. The mixture was allowed to stand for about 30 minutes. The pH meter (Crison (Basic 20) of the Crison model was calibrated with blanks respectively. The electrode of the pH meter was inserted into the partly settled suspension then the values of the pH were taken.

2.4.5 Electrical conductivity of soil (EC)

A Crison Basic EC meter (CM39P model) was used to determine the EC of soil samples. Samples were determined as in wastewater.

2.4.6 Organic carbon of soil

Organic carbon was determined using the dichromate oxidation method (Walkley-Black wet oxidation procedure, Schumacher, 2002).

2.4.7 Procedure

Two grams (2.0 g) of soil sample was weighed into a 500 ml Erlenmeyer flask. Ten (10 ml) of 1.0 N Potassium dichromate ($K_2Cr_2O_7$) solution was then added, followed by 20 ml of concentrated H_2SO_4. The mixture was swirled to ensure that the solution is in contact with all the particles of the soil. The flask and content are allowed to cool on an asbestos sheet for 30 minutes. Two hundred (200 ml) of distilled water is added, and 10 ml of Orthophosphoric acid. Two (2.0 ml) (of 10 ml) of diphenylamine indicator are then added to the mixture. The mixture is titrated with 10 N ferrous sulfate solution until the colour changes to blue and then to a green end–point. The titre values are recorded and correct for the blank solution (> 10.5)

2.4.8 Concentration of NPK in soil

The N was identified using the micro Kheldahl method. Three processes were involved in identifying crude protein which includes digestion, distillation, and titration. The digestion portion of the crude protein was done by grindings the oven-dry matter samples into powder and one gram each was weighed into filter papers.

The content of the filter paper was placed into a graduated cylinder and 15 ml of concentrated sulphuric acid was added into the cylinder with 2 kheldehl tablets, a catalyst to speed up the reaction. The mixture in the cylinder was placed in a digester to heat overnight. Distillation was done to separate the ammonia which is the nitrogen from the digestion mixture. 50 ml of deoxidized water and sodium hydroxide were added to the digested solution. The solution was distilled and condensed and passed through 25 ml of boric acid (H_3BO_3) to trap N and allowed to settle in a container. The N levels were identified by titrating with dilute hydrochloric acids.

2.4.9 Analysis of heavy metals from soil and wastewater

Measurement of heavy metals was conducted by Absorption Spectrophotometer (Model 2380, Perkin Elmer, Inc. Norwalk, CT, and USA) at the microbiology laboratory of CSRI- Water research Legon, Accra.

2.4.10 Reference standards

Blanks and duplications were used as a positive control to analyse heavy metals. The same approach used to analyse the metals was adopted for the blanks and duplication analysis. The equipment was calibrated to zero (blank). This allows for effective monitoring of contaminations throughout sample preparation and the efficacy of all the equipment used for the study.

2.5 Pathogens determination

2.5.1 Pathogens: *(Faecal coliforms)*, *Escherichia coli* (E. coli), Shigella sp, salmonella, and Total coliforms using the pour plate method

The pathogens determined were *faecal coliforms* (E. coli, Shigella sp, salmonella, *faecal* and the total coliforms.

2.5.2 Media preparation for *E. coli*, and Salmonella using the pour plate method

Four hundred (400 ml) of distilled water was added to 25.2 grams of SS agar powder in a 500 ml flat bottom flask and placed in a magnetic bar in the solution, heated to stir on an electric heating mantel (Agimatic N model) for uniform homogeneity. The media was allowed to cool to about 50^oC. Ninety (90 ml) of SS Agar solution was added to 10g of soil, wastewater and all the filtrate separately in a sterilized test tube for dilution.

2.5.3 The procedure

One millilitre(1ml) of the wastewater and all filtrates were poured into a 90ml test tube each of distilled water using a micropipette. The 1ml samples in the test tube was then diluted in 90 ml of agar solution and shaken thoroughly with an Agimatic N model to obtain homogeneity. The mixture was then autoclaved for 15 minutes and allowed to cool after that 10 ml of wastewater and each filtrate was mixed with 100g of MacConkey media and evenly mixed to obtain homogeneity. Using a macro pipette, 1 ml of the diluted sample was then poured into arranged Petri dishes under a laminal cohood. The Petri dish is shaken mechanically for homogeneity (uniform mixing). The sample was then inverted into the incubator. Whilst E. coli and coliforms are incubated at 44 ^{o}C. The petri dish is finally placed under the colony counter (Digital S) to count coliform using the Coliform Forming Unit (CFU) per 100 ml. Inspection is done within 18-24 hours after incubation at 37^{o}C for salmonella and shigella.

NOTE: The final result was multiplied by the dilution factor of 100 to determine the actual number of the total and faecal coliform.

The total coliform is determined by a pink colour whilst faecal coliform by a cream colour. Shigella sp under McConkey are colourless due to lack of lactose fermentation, a quality that differentiates Shigella sp from other bacteria present.

Bacteria (Total and Faecal) Coliform Growth observed on McConkey Agar.

Seven point five grams (7.5g) of buffer peptone powder is dissolved in 500 ml of water. The media was prepared using the manufacturing protocols.

2.5.4 Performing serial dilution

This was done to reduce the percentage concentration in the actual diluted solution.

To decrease bacterial concentration to a required concentration, in the laboratory, serial dilution was done to give an estimated concentration in the sample. In performing serial dilution, ten grams (10g) of each sample were separately weighed in sterile bags, diluted in 90 ml of ionized water, and shaken by hand vigorously to homogenize and uniformly mixed.

2.5.5 Data analysis

The data gathered on physico- chemical properties, and heavy metals concentrations in both soil and WW for both seasons were presented on tables and Microsoft Excel was used to analyse and compare the data obtained and results.

3. Results and Discussion

3.1 Physicochemical properties of soil

The physicochemical properties of the soil sample are summarised in Table 1.

Table 1. Physico-chemical properties of soil / initial soil analysis

Soil parameters	Unit	Wet season
pH (1:2.5 H2O)		6.52
Temperature	OC	27.3
EC	Us/cm	23.8
Organic carbon	%	1.2768
Porosity	%	43
Sand	%	44.2
Clay	%	24.56
Silt	%	31.25
Texture		Loam
Nitrogen	mg/kg	0.49
Phosphorus	mg/kg	2.4
Calcium	mg/kg	0.89
Potassium	mg/kg	4.9

The Laboratory analysis conducted on the irrigated soil indicates that the Zagyuri irrigation field contains mean values of 1.28 organic carbon (OC), 23.8 ppm EC, and slightly acidic soil with a pH of 6.52. The soil has a particle size distribution of sand 44.2 %, clay 24.56 %, and silt 31.25%, with a porosity of 43 %. The soil property is the best for plant absorption of nutrients since the characteristics of the soil ensure easy root penetration and water retention, an effective quality for nutrient adsorption. According to FAO (2020), crops need aerated soils for the uptake and utilization of nutrients. The irrigated soil has nutritional composition: of 0.49 mg/kg of N, and the available P is 2.4 mg/kg whiles K has 47 mg/kg. The levels of nutrients in the soil could be a result of the bioaccumulation of ions from wastewater irrigation in the soil compared to previous studies that observed very low concentrations 0.04 N, and 38.9 K at the site (Asirifi et al., 2021). According to Qadir et al. (2008), wastewater used for irrigation can contribute a significant amount of NPK to the irrigated soil. Okalebo et al. (2002) noted that CEC reflects the capacity of soil to retain nutrients against leaching.

The irrigated soil has a pH within the FAO limit (6.5) (Ayers & Westcot,1994; Boeckmann, 2019, Liu et al., 2018) which is suitable for the cultivation of vegetables. However, some vegetables perform normally at lower pH as long as larger amounts of micronutrients are not present in the soil (Liu et al., 2018).

The level of OC in the soil is a key factor in the determination of the productivity of the soil. Lal et al. (2013) stated that OC in the soil is key to production where the soil has low fertility. This can increase food production by 17.6 Mt in a year thereby ensuring food security worldwide (Sá et al., 2017). An additional oneton increase in the OC in the soil can increase wheat yield by 20 - 40 kg /ha, maize by 10 -20 kg/ha, and cowpea by 0.5 kg/ha. Additionally, soil with optimal OC can absorb and store rainwater which in turn releases for crop use under drought. Such soil provides proper aeration and an efficient supply of oxygen which can impede carbon emission as a result of methanogenesis (FAO and IIPS, 2015). Also, soil irrigated with wastewater can increase the physico – chemical properties of the soil (Mojiri and Jalalian, 2011; Najafi and Nasr, 2009 Kiziloglu et al., 2007).

3.2 Physico-chemical properties of wastewater for rainy and dry seasons

The physico- chemical properties conducted on wastewater revealed that the EC, pH, chemical oxidation demand (COD), temperature, and turbidity were 517 µS/cm, 7.43, 108 mg/l, 29.4 OC, and 45.9 NTU during the rainy season and 1250 µS/cm, 7.0, 168 mg/l, 36.1 OC and 7.11 NTU for the dry season respectively (Table 2). The EC obtained for the wastewater during the dry season doubled the wet season data. In both seasons the EC obtained exceeded the WHO recommended limits of 100 µS/cm^3 (WHO, 2010) and a range limit of < 0.7 µS/m. The high EC in both seasons could be a result of dissolved salts, substances, chemicals and mineral particles in the wastewater which indicates higher risks of salinity in the irrigated water (Ayers and Westco, 1994; SENSOREX, 2019) which is not suitable to be discharged in the water bodies (Kandiah, 1990). Anim-Gyampo et al. (2012), also identified high EC in the irrigated wastewater at the study site.

The pH in wastewater for both seasons as shown in Table 2 ranges from neutral to alkaline and falls within the WHO recommended limits (WHO, 2010). Hydrogen-ion concentration (pH) is an important quality parameter for both natural and wastewater (Abagale et al., 2014). The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids. It can, however, be concluded that the pH of wastewater is said to be inversely proportional to H^+ ion since a higher ion concentration leads to less in a concentration of pH.

Nitrate nitrogen ($NO3^-$), phosphorus (P), and potassium (K) concentration in the wastewater ranged from (19.14 – 4. 10 N, 6.7 - 3.1 P, and 31.1-10.0 mg/l K) for the rainy season and 0.14- 6.31 N, 0.14 - 0.21 P and 1.30 - 30.2 K for the dry season respectively. The data in Table 2 depicts the chemical oxidation demand (COD) in the wastewater used for irrigation during the dry (168 mg /l) and rainy (108 mg /l) seasons. COD of the wastewater in the dry season was higher than in the rainy season, which attests to the findings of Venkatesharaju et al. (2010), who equally experienced high COD in the dry season than in the rainy season. These results of COD of wastewater are consistent with the findings of Abagale (2014) who identified a higher COD in the dry (132.78 mg/l) season as compared to the rainy (102.5 mg /l) season. Again, the findings of Korbinain et al. (2018) recorded a higher COD value of (202 mg/l) at the study site during the dry season. Knowing the constituents of COD in the wastewater helps to identify the organic pollution in wastewater and how much oxygen is required to oxidize all organic and inorganic matter in the wastewater (Siyu et al., 2016 and Sasse, 1998). The differences in COD in the wastewater could be a result of the nutritional composition of the wastewater and the anthropogenic activities as well as the variation in wastewater flow during the dry and wet seasons could be the reasons for variations in irrigation water (Saiful et al., 2015)

The NPK level in the wastewater exceeded the WHO recommended rate of nutrient discharge into water bodies (N 10 mg/l, P 0.005 mg/l, and K 4.9 mg/l). Tables 1 and 2 show the physicochemical properties of soil and wastewater at the Zagyuri irrigation field. These findings support (Anim-gyampo et al., 2012) Maxwell et al. (2012) and Korbinian et al. (2018) study that indicates that wastewater at the Zanyuri irrigated field contains more nitrate (about 4.10- 19.14 mg/l and 0.14-6.31mg/l) for both rainy and dry season respectively. With the rainy season exceeding the WHO rate. Abagale (2014) however identified very low N levels in the wastewater during both rainy and dry seasons with the respective values of 0.433 mg/l and 4.84 mg/l for the dry and wet seasons at the same study site. Much research confirms that when nitrogen exceeds its critical limits in wastewater could result in toxicity to aquatic and terrestrial organisms including man (Martinez-Dalmau et al., 2021, Mensing et al., 2003, Cheg et al., 2014). When nitrate gets in contact with blood and interferes with iron, it affects how oxygen is transported which can cause methemoglobinemia (blue baby syndrome, FAO/WHO, 2007). Haiyan and Stuanes (2003) and Speijers (1996) mentioned that consumption of nitrate-contaminated food could results in gastric cancer when it is converted to highly carcinogenic nitrosamines. Excessive nitrate in water leads to foul odor in the water which causes the overgrowth of algae that impede sunshine from reaching beneficial aquatic vegetation (Aczel, 2019). It is estimated that 1000m^3 of municipal wastewater used for irrigating vegetables can contribute 16-62 kg nitrogen, 4-24 kg phosphorus, 2-69 kg potassium, 18-208 kg calcium, 9-100kg magnesium and 27-182 kg sodium (Aczel, 2019). Tables 1 and 2 depict the physico- chemical properties of soil and wastewater at the Zagyuri irrigation field. (2019).

3.3 Heavy Metal concentration in cultivated soil and wastewater at Zagyuri (Tamale, Ghana)

The initial analysis to determine the level of heavy metals before the cultivation of crops revealed a higher concentration of heavy metals in the soils and wastewater. Except for chromium, all other metals in the soils were above the environmental protection agency (EPA) Ghana and WHO recommended detection rates for soil whilst in the wastewater, Pd, and Mn for dry and rainy seasons were below the detectable limits. The results indicated that the concentration of heavy metals in the soil was higher than those in the wastewater. The metal concentration ranged from 0.04 - 668.76 Mg/Kg in the soil and 0.01 - 2.05 Mg /L in the wastewater. Higher and greater concentrations were observed from the soil Fe (668.76), Cd (0.04), Mn (74.09), Pd (0.04) and Fe (2.05) Cd (0.14) and Mn (0.71) in wastewater respectively with a relatively low level of Cr (0.002), below the WHO detectable limits. This finding is in line with Maxwell et al. (2012) study which indicated higher heavy metals in the irrigated soil than in wastewater. According to Alexander et al. (2006), Toze (2004), Angelova et al. (2004), and WHO / FAO, (2007), long-term usage of wastewater for irrigation can lead to heavy metals accumulation in the soil which in turn cause degradation of soil productivity and plant toxicity. Aydinalp and Marinova (2003) and Khaled and Muhammed (2016) also added that physic-chemical properties in the soil can build metal accumulation in groundwater.

Silveira et al. (2003), Pescod (1992), and Willett et al. (1984) identified that heavy metals are significantly retained in moist soils but a high pH favours the immobilization process. The study of Xiongs et al, (2001) also demonstrated the capacity for metals to accumulate over time in the soil with long time wastewater irrigation. Again, a high heavy metal load in the soils reduces the effectiveness of soil biota resulting in reduced microbial activities (Kandeler et al., 1999). Zagyuri irrigated field is said to be highly contaminated with heavy metals, as evidenced by the study results and those obtained by Maxwell et al. (2012) at the study site.

Contrary to Maxwell et al. (2012) findings, 100 % of wastewater used for irrigation had very high heavy metals above the WHO standard limits (2006) in both rainy and dry seasons except Mn in the dry season and Pd in the rainy season (Table 4). This study is consistent with the finding of Abagale (2014) who stated that Fe and Mn recorded higher concentrations in the wet season than in the dry season. Among all the heavy metals, Fe had a higher concentration in both the rainy and dry seasons at the study site (Abagale, 2014). According to Stevens and McLaughlin (2006), Cd has been identified as the major heavy metal of health concern in sewage. Lou et al. (2012) and Zhang et al. (2012) are of the view that Cd has a greater exchangeable capacity, thus easily becoming accessible and soluble in soils that become bio-available and accumulating in the edible parts of the plants. According to Akan et al. (2008), Pd increase in solubility of metals such as Fe, Cd, and Mn is said to be the most toxic metals found in the aquatic ecosystem (Abagale 2014). Pd causes lipid membrane damage that ultimately leads to damage to chlorophyll and photosynthetic processes and suppresses plant growth (Najeeb et al., 2014; Yongsheng et al., 2011). Even though chromium exists in different states (Zhitkovich, 2005) and can be found in protected metal coatings, metal alloys, magnetic tapes paint pigments, rubber, cement, paper, wood preservatives, leather

Table 2. Physico-chemical properties of soil / initial soil analysis

Parameter wastewater	**pH**	**EC**	**TURB**	**COD**	**Nitrate (NO3)**	**Phosphate (PO4)**	**Potassium (K2O)**
Rainy season	7.43	517	45.9	108	4.10-19.14	3.1-6.7	0.10- 0.45
Dry season	7.0	1250	7.11	168	0.14-6.31	0.14- 0.21	1.31-30.2
UNITS	9-Jun	µS/cm	NTU	Mg/L	Mg/L	Mg/L	Mg/L
W.H.O Limits	6.5-8	100	5	-	10	0.005	-
EPA Ghana	6.5-8	100	5	-	50.0	2.0	2.0

WHO; (2007) and FAO limit (Ayers and Westcot, 1994) TURB-Turbidity tannings, metal plating; Martin and Griswold, (2009) as found in cigarettes (Schroeder, 1984) its toxicity in plants depends on its valence state. Cr (VI) is very mobile and very toxic while Cr (III) is less mobile and less toxic. The low levels of Cr identified in the studies site confirm the facts that the wastewater source is domestic and not industrial (Avudainayagam et al., 2003) and that the soil and wastewater source is safe in cultivating vegetables as far as chromium is concerned. Fe was identified to be the most abundant metal in both soil and wastewater in the studies. It is so probably because Fe itself is the most abundant transition metal in the earth's crust and is said to be the most important nutrient for living organisms. Also, the application of fertilizers and pesticides as well as weedicides might have contributed to the higher amount of heavy metals in the soil (Sankhla et al., 2016 (Siddiqui et al., 2019).

Generally, Fe and Mn concentrations in the soil are not emphasized when discussing heavy metals as it is seen as essential crop nutrients however excessive amounts of these metals translocate in food can have detrimental effects on the human system (Attah and Regasa, 2013). Excess Fe can easily lead to the formation of radicals which can damage biomolecules, cells, tissues and the holistic development of an organism. Albretsen (2006) declares that children are more susceptible to Fe poisoning which can lead to gastrointestinal bleeding, vomiting, and diarrhoea (Osweiler et al., 1985). Pescod (1992) proposed that Mn does not have any health-related risk to humans but could be toxic to plants. Contrary to Pescod's (1992) submission, recent studies indicate that Mn in the human system can be transported through the blood to the liver, the kidneys, the pancreas, and the endocrine glands (Lenntech, 2021). It mostly affects the respiratory tract and brain functioning leading to hallucinations, forgetfulness, and nerve damage. It can also cause Parkinson's disease, lung embolism and bronchitis as well as impotency in men. Also, Mn effects cause symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia (Lenntech, 2021). The deficiency of Mn can however lead to fatness, Glucose intolerance, blood clotting, skin problem, and birth defects, among others (Lenntech, 2021).

This study observed a higher rate of Fe as compared to all other studies conducted in the irrigated field (Table 3). The higher levels of Fe in the study sites indicate higher risks involved in consuming vegetables cultivated in the study area either during the rainy season or the dry season. More so the higher level of heavy metals in the soil is a result of long buildup effects due to prolong wastewater irrigation on the field. This implies that vegetable consumption at the study site can have serious consequences for consumers. It can however be predicted that based on the high amount of Fe and Mn in both cultivated soil and wastewater, the translocation of Fe and Mn into food consumed in the study site and other related sites in the world would be higher with a larger population of the consumers more especially children being at risk of Fe and Mn toxicity and its related complications. heavy metals concentration in irrigated soil and water is represented in Tables 3 and 4.

Table 3. Concentration of heavy metals in Zagyuri irrigated field

Parameter (Mg/Kg)	Ghana EPA (Mg/Kg)	WHO (Mg/Kg)	Soil (Mg/Kg)
Manganese	<= 0.025	<= 0.02	0.06 - 74.09
Lead	<= 0.1	<= 0.03	0.63 - 0.95
Iron	-	<= 425.00	489.01 - 668.76
Chromium	<= 0.1	<= 0.023	0.001 - 0.002
Cadmium	<= 0.02	<= 0.02	0.023 - 0.043

Source field data (2020-2021); EPA Ghana (2003) Latif et al., (2018) and WHO (2007)

Table 4. The Concentration of heavy metals in wastewater at Zagyuri Irrigation Field for Both Rainy and Dry Season

Parameter wastewater	Fe (Mg/L)	Mn (Mg/L)	Cd (Mg/L)	Cr (Mg/L)	Pd (Mg/L)
Rainy season	2.045	0.71	0.144	0.011	0.001
Dry Season	0.747	0.12	0.23	0.016	0.026
W.H.O (2007)	0.3	0.5	0.003	0.005	0.001

Source field data (2020-2021); WHO (2007)

4. PATHOGENS

The concentration of Pathogens in wastewater and soil at the Zagyuri irrigated field

The analysis of wastewater and soil in the field of the study revealed a high concentration of pathogens in the study area. The results in Table 5 indicate too many to count (TMTC) for total coliforms at the initial analysis of wastewater. The serial dilution, however, indicates total coliforms of $5.1 \times 10^6 - 5.3 \times 10^7$ for the rainy season and $4.14 \times 10^8 - 4.5 \times 10^8$ for the dry season respectively. Faecal coliforms were recorded 4.0×10^7 and 3.7×10^8 for the rainy and dry seasons. The pathogen load is higher than what Abagale (2014) and Korbinian et al. (2018) obtained at the study site. This finding is consistent with Abagale (2014) and Korbinian et al. (2018) studies that indicate higher levels of Total and faecal coliform in both rainy and dry seasons with the rainy season observing a higher level of total and faecal coliforms than the dry season but lower than what this study recorded. The studies of Obuobie et al. (2006) and Faruqui (2004) support these findings of high concentrations of Total and Faecal coliform in the rainy season. Salmonella and E. coli present in the wastewater had their respective values of 5.0 x 10^4 to 4.2 x 10^8 and 5.1 x 10.8^8 to 5.1 x 10^6 for the rainy and dry seasons. The soil for cultivation, however, indicates a very high concentration of all the pathogens – *total coliforms*, *faecal coliforms*, *E. coli*, Shigella and salmonella than in the wastewater (Table 5). Shigella, a major gastrointestinal infection that causes dysentery (Grant et al., 1996) was also identified to be high in the irrigated soil than in the wastewater. The higher levels of Shigella on the soil could be linked to the settler's activities which include open defecation, indiscriminate refuse disposal, domestic animal droppings coupled with continued wastewater irrigation.

Again, the difference in pathogens in the irrigated soil and wastewater in both dry and rainy seasons could be associated with the environmental/climatic conditions (Benedek et al., 2014; Nasser et al., 1995; Rajkowski et al., 1996; Xiang et al., 2019) as well as the presence of oxygen and frequency of domestic water flow from the wastewater source (Abagale, 2014; Jansons et al., 1989; Lindström, 2000; Weyhenmeyer et al., 2012). Again, runoff during the rainy season might have washed pathogens from the surrounding area into the wastewater; as the inhabitants practice open defecation and indiscriminate dumping of refuse. The level of physico - chemical contaminant present in the soil and wastewater can also influence the pathogen activities as well as the ability of the bacterial to adhere to surfaces of soil due to their nutritional content (Capuano et al., 1995; Metge et al., 1995). According to Chauret et al., (2001), pH is an important determinant of water quality because it has a high influence on the chemical, biological and geological processes that occurs in the environment. COD, EC and other factors greatly influence the presence of pathogens in soil and wastewater (Toze, 2004). Studies indicate that variations of COD in wastewater indicate the presence of organic matter and the amount of contaminations in the water therefore the higher the COD, the more likely it is to have more organic matter and vice vase (Faith, 2006; King et al, 2003). Hence, the more likely to have varied pathogens / microbial composition in the water (Dumestre et.al, 2001; Lindström, 2000; Ruiz-González et al., 2013). Which is critical for the accurate modelling of biotransformation in the wastewater treatment process (Hu and Grasso, 2005). The higher concentration of pathogens in both soil and wastewater could also be associated with the variation in the climatic conditions of the study area. The length of the dry weather period preceding the runoff event impacts the amount of constituents accumulated in the catchment before being washed off by surface flows (Arheimer and Lidén, 2000; Lecce et al., 2006; Stutter et al., 2008).

Table 5. The Concentration of pathogens in wastewater and Soil at Zagyuri Irrigated Field

Sample	Total Coliforms CFC 100 M/L	Faecal Coliforms CFC 100 M/L	Salmonella CFC 100 M/L	Shigella CFC 100 M/L	E. coli CFC 100 M/L
Wastewater	TMTC	TMTC	5.1 x 10^4	30.3 x 10^6	100-TMTC
Rainy season	5.1 x 10^6 - 5.3 x 10^7 41.4 x 10^7	4.1 x 109	4.2 x 10^8	32.1 x 10^6	51.0 x 10^7
Dry season	41.4 x 10^7 – 4.5 x 10.8^8	3.7 x 10^9	1.3 x 10^3 - 92 x 10^3	31.5 x 10^3	41.5 x 10^6
SOIL	TMTC	TMTC	2.5 X 10^4	12.5 x 10^4	TMTC

Source field data (2020-2021); WHO (2007); TMTC-Too many to count

5. Conclusion

The bioaccumulation effects of heavy metals on the Zagyuri irrigation field are very high as a result of continuous irrigation with wastewater which has resulted in a higher concentration of heavy metals and pathogenic loads in the soil. The study revealed very high levels of Fe and Mn in both soils and wastewater. The soil retains a higher concentration level of Fe and Mn; about 200 % above the WHO maximum recommended limits. The results are very alarming concerning the levels of heavy metals (Fe, Mn and Cd) and NPK in the soil and the wastewater. However, Pd was below the WHO rate in the wastewater but higher in the soil. Additionally, there was a lower rate of Cr in the soil and slightly higher Cr in the wastewater. There is also a high pathogenic load in the wastewater and irrigated fields. Shigella, the major gastrointestinal infection that causes dysentery was higher in the soil than in the wastewater. The values of NPK in the soil are indicated as 0.49 mg/kg for N, 2.4 mg/kg for P, and 47 mg/kg for K. while the wastewater had NPK concentration ranges from (19.14 – 4.10 N (nitrate), 6.7 - 3.1 P and 0.10 – 0.45 K, mg/l) for the rainy season and 6.3 - 0.14 N (nitrate), 0.21- 0.14 P and 30.2 - 1.31 K for the dry season respectively. Based on the findings, this study recommends that simplified and low-cost (affordable) and more effective remediation techniques should be introduced to the farmers to help reduce the risks of heavy metals and pathogen infection on farmers more particularly women and children as well as consumers. Again, further study should be conducted to investigate the concentration of other enteric pathogens and other higher toxic heavy metals in the Zagyuri irrigated field for awareness creation and corresponding remediation development.

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