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Implication of Pesticide Use in Vegetable Farms to Surface Water Quality: A Case of Themi River in Arusha, Tanzania

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ABSTRACT

Surface water contamination by pesticides is intertwined to surface runoff and soil erosion from agricultural farms. This study determined the presence and levels of pesticide residue in water from Themi River which is a source of irrigation water at Fire vegetable farm located in Arusha, Tanzania. Using grabbing water sampling technique, three (3) composite samples of water were collected from three strategic locations along the Themi River. Applying liquid phase extraction method, the residual of three pesticides namely trichlorfon, dimethoate, and vamidothion were detected and quantified using Gas Chromatography Mass Spectrophotometer (GC-MS) Agilent 7890A with 2-20 ppm detection limit. Results shows that the concentration of trichlorfon in the water was averaged at 0.71±0.1 µg/l, dimethoate was at 1.64±0.31 µg/l while vamidothion was at 0.78±0.38 µg/l all exceeding the 0.1 µg/l International Union of Pure and Applied Chemistry (IUPAC) recommended limits for individual pesticides residual in irrigation water. Unsustainable application of pesticide in vegetable farms not only contaminates the river but also threatens environment, life below water and human health through trophic chain.

Keywords: Surface water, pesticide residue, maximum residue limit, agriculture.

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1. INTRODUCTION

Environmental pollution of natural surface waters by pesticide residues from agricultural activities is of great apprehension these days. Water pollution by pesticides can distress many biological systems it may take very long time to disappear and cause danger of bioaccumulation [1]. The prevalent use of synthetic pesticides over the past half-century has led to their detection in many hydrologic systems of many countries [2]. Even though pesticides are also used in other sectors but then in Agriculture there is no reservation that it is the most important source of contamination in environmental components. Pesticide residues/remains from agricultural areas reach the marine environment through direct runoff, containers and equipment washings [3].

Definitely, existences of pests and diseases have led to an increased, indiscriminate use of pesticide and other agricultural synthetic chemicals. The problem is severe in areas where irrigated farming is practiced because of multiple cropping and increased frequency of pesticide application per growth season. High levels of pesticides application in smallholder vegetable farmers in Northern Tanzania have been reported [4]. From 2000 to 2003 the imports of pesticides increased from 500 to 2500 tons, and by 2006, a total of 682 different types of pesticides were registered [5] the amount and intensity of pesticide use varies across the country. Majority of communities in Tanzania depend on surface water from rivers and lakes for potable uses, such as washing, drinking, and domestic animals also drink from these sources. Reports from studies done in Northern Tanzania have indicated the presence of significant levels of pesticides, phosphates, and nitrates in surface and groundwater [6].

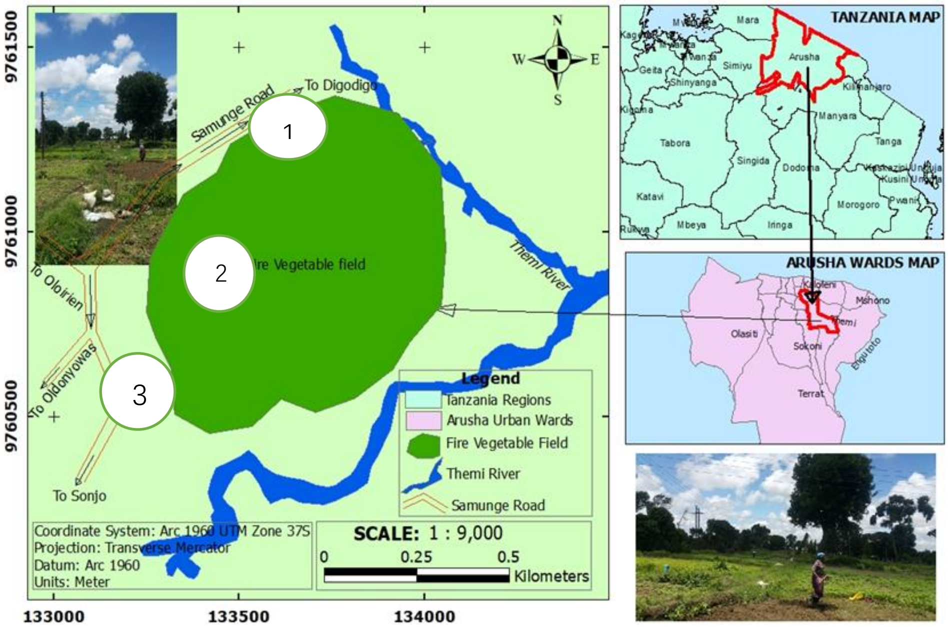
Arusha is the prominent region in pesticide trading and utilization in Tanzania because of its favorable climate for agriculture [5]. Both small- and large-scale farms are reported to indiscriminately use large quantities of different pesticides. Furthermore, vegetable farming is highly practiced by small scale farmers in the region, who frequently use pesticides without the knowledge on the effect of these pesticides on human and the environment [4].

Fire vegetable farm is one of the farms in Arusha region. In this farm, farmers spray synthetic pesticides on the growing vegetables in order to protect them from various pests and tap surface water from Themi River by directing the water flowing into small water channels for irrigation. This study aimed at determining the level of pesticide residue in water from Themi River used as a source of irrigation at the farm. This study envisages deterioration in quality and safety of surface water as a result of usage of pesticides and, thus, pose danger of exposure of people using these water sources to pesticides from agricultural practices.

2. MATERIALS AND METHOD

2.1. Description of the Study Area

Fire vegetable growing farm, as shown in Figure 1 is found near Arusha Fire Fighting Brigade, well known as Zima moto in Kiswahili language. The farm is located at 9761000 Northings and 133500 Eastings is bordered by Themi River, which is located at 9761000 Northings and 134000 Eastings. Vegetable growing farmers depend on this river as source of water for irrigation year around.



Key: Sampling point 1= main Themi River**,** sampling point 2 = irrigation stream, and sampling point 3 = outlet.

Figure 1. Fire vegetable farm and Themi River in Arusha .

The vegetables farms cover 13,000 m^2 and is in operation since 2002. The ownership belongs to the public, and by the time of conducting this study about 30 farmers were reported to use it for growing various vegetables which feed Tengeru market and other customers who buy directly, as per their demand. The farm not only produce employment but also livelihood to at least 30 households through income generated by selling the vegetables.

2.2. Materials

2.2.1. Water Samples Collection and Analysis for Physicochemical Parameters

Three (3) water samples were collected from Themi River bordering the vegetable farm. To facilitate irrigation, farmers have diverged small streams into the farm from the river, as indicated in Figure 2.

Figure 2. Irrigating streams from Themi River into Fire vegetable farm.

Using grabbing method, the water samples were filled into 1.5-liter bottles and transported to the Pesticide Residue Laboratory at Tanzania Plant Health and Pesticides Authority (TPHPA) in Arusha for physicochemical analysis, which involved three parameters namely pH, salinity, and electrical conductivity. Standard test method for water analysis described in PHA 2005 were used in which Inolab-720 pH meter, pre-calibrated by using standard buffer solutions of pH 4.0, 7.0 and 9.0 and WTW, Inolab conductivity meter respectively were used.

2.2.2. Chemicals and Reagents Used

In the analysis of the level of pesticide residues in water samples collected, a liquid phase extraction method was used, while detection and quantifying levels of pesticide residues was done using Gas Chromatography-Mass Spectrophotometer (GC-MS). Laboratory In-house developed method for extraction of pesticides residue was used. In this method a number of proposed extracting chemicals, including Dichloromethane, Acetonitrile solvent, Potassium hydrogen phthalate, Magnesium and sodium sulphate, Internal standard solution was used. On the other hand, buffer solutions including pH= 4.0, Potassium dihydrogen phosphate, disodium hydrogen phosphate pH= 7.0 and Sodium borate decarbonate pH=10 was used.

2.2.3. Standard Solutions

Stock solutions (100 mg/mL) of pesticide standards were prepared applying the laboratory in-house developed method in which an appropriate aliquot or weight of the pesticides was dispensed into 25 mL volumetric flasks, and then dissolving, homogenized with the aid of a vortex mixer and/or diluted to the marks using ethyl acetate. Working solutions of standards for fortification standards in the procedural recovery process and as calibration standards in the instrument calibration were freshly prepared through dilution of an appropriate aliquot of the stock solutions with ethyl acetate. Distilled water was used to prepare all aqueous solutions. All solutions prepared for Gas Chromatography (GC) were filtered through a 0.45µm nylon filter.

2.3. Methods

2.3.1. Extraction, Clean-Up and Pesticide Residue Analysis of Water Samples

The extraction method used for the water samples in this work was as described in [7] and [8]. Briefly, in this method about 500 mls of water sample was put into a separating funnel, followed by addition of 60 mls of dichloromethane and 1ml of Triphenyl phosphate (TPP). TPP was used as an internal standard (ISTD) for monitoring extraction efficiency and correct for instrument drift. The function of dichloromethane was to capture all of the organic materials that are present in the water sample and thus forming two separable layers. Using an electric shaker, the mixture was shaken vigorously at 4200 rpm for 5 minutes, and the separating funnel was placed on the retort stand to allow settling and separation of the liquids. The layer containing the organic materials was allowed to flow into a 500 ml flask that contained a glass wool, filter paper, anhydrous sodium sulphate and sodium chloride for water removal. To ensure maximum recovery of the pesticide residues from water sample, the separation exercise was repeated three folds. The extract in the flask was transferred into a round bottomed flask and was concentrated under nitrogen gas stand with water bath operated at 35 °C to about 1 to 2 ml concentrate. The concentrate was then transferred into vials for detection and quantification.

Similar procedures were followed for preparation of lab control sample and blank sample, whereby distilled water was used but the difference was that in lab control sample different standards were added before addition of dichloromethane, and the mixture was shaken for 5 minutes in an electric shaker at 4200 rpm. Thereafter, 2 ml of ISTD (TPP) was added, followed by 60 ml of dichloromethane, and then followed similar procedures as used in extracting the water samples. For blank sample, laboratory distilled water was used but applying the same extraction procedures and treatment similarly to the water sample.

2.3.2. Determination of Pesticide Residues in Water

The samples of water collected were analyzed for pesticide residuals at Tanzania Plant Health and Pesticides Authority (TPHPA) using the Gas Chromatography- Mass Spectrophotometer (GC-MS) Agilent 7890 A which was programmed with multi-residue detection method (MSD). The GC-MS used was a single quadruple MS detector with capillary column of dimensions 25 m× 320 µm × 0.25 µm. Helium gas was used as both a carrier and make up gas in the GC-MS at a flow rate of 1.2178 ml/min. The temperature program was 50 °C held for 1 minute, 30 °C/min to 180 °C, 5 °C/min to 300 °C held for 5 minutes. The injector and detector temperatures were set at 250 °C and 300 °C (respectively). Identification of residues was detected by running samples, and external reference standards in GC-MS were used for comparing the chromatograms.

2.4. Data Analysis

One-way analysis of variance (ANOVA) was used to test for the significance in differences and similarities between the determined physicochemical properties and the concentrations of pesticide residues. So, the significant means obtained, these were further separated by applying least significant difference at 5 % significant level. A Pearson correlation analysis was carried out to establish the correlation between the physicochemical parameters and the concentrations of pesticides residues detected. The statistical significance difference tests were carried at 95 % confidence level and declared significant at $p < 0.05$.

2.5. Quality Assurance and Quality Control During Sample Analysis

Proper quality assurance procedures and precautions were taken to ensure the validity and reliability of the obtained results. The samples were carefully handled to avoid any external influences that could interfere with the sample and cause contamination. All glassware's were thoroughly washed with detergent, followed by three -times rinsing in distilled water. Thereafter, the glassware was thoroughly rinsed in acetone of analytical grade and dried overnight in an oven at a temperature of 150 °C. In the following day, the glassware was removed from the oven and allowed to cool before being stored in a dust-free cabinets. Double distilled water was used throughout the study. For the spectrophotometric analysis, reagent blank determinations were used to correct the instrument readings. For validation of the analytical procedure, analysis of the samples in comparison with the internationally certified reference material were performed. The quality of pesticide residues was assured through the analysis of solvent blanks, procedural matrix blanks and duplicate samples. All reagents used during the analysis were exposed to the same extraction procedures and subsequently run to check for interfering substances. In the blank sample for each extraction procedure, no pesticide was detected. A sample of each series was analyzed in duplicates. All extracts were kept frozen until quantification was done. Calibration curves were run with each batch of samples to check that the correlation coefficient (r^2) was kept not below 0.99. A fortification level of 0.02 mg/l for water was chosen before the analysis to evaluate the recovery of the water sample.

The efficiency of the analytical methods (the extraction and clean-up methods) was determined by recoveries of an internal standard. In all experiments performed, the recoveries of internal standards ranged between 70 % to beyond 100 % for all the pesticide residues analyzed. These recovery values show that the method used was robust, rugged, and reproducible.

2.6. Results and Discussion

2.6.1. Physicochemical Properties of Water Samples Collected from Themi-River

Table 1 summarizes the selected physicochemical properties of water samples taken from Themi River. The collected water samples were analyzed for pH, electrical conductivity, and salinity. The measured pH from the three water samples collected from the small streams within the farm had a mean pH value ranging from 6.6 to 7.2. This mean pH value falls within the acceptable limits as recommended in Tanzania Standards TZS 789:2018 which describe specification for surface water ranging from 6.5-8.5. There was however no significant difference in pH ($p=0.15$) among the water samples collected from the small irrigation streams within the Fire vegetable growing farm.

The electrical conductivity in all water samples collected from the three sampling points were above the recommended standards, which recommend a typical range EC of maximum of 1500 µS/cm. The range in electrical conductivity of the water samples was found to be 1398.7 to µS/cm. There was however no significant difference ($p<0.05$) among E/C of the water samples collected from the streams within the vegetable farm.

Also, the salinity of the collected water samples was measured to have a mean value of 0.21±0.01 ppt. There was no significant difference, since $p=0.3$ which implies that $p>0.05$.

Table 1. Summary of physicochemical characteristics of water at three sampling points (n=3)

Sampling points	**1**	**2**	**3**	**Standard TZS 789:2018**
pH	6.6±0.1	7.0±0.2	7.0±0.2	6.5-8.5
Electrical conductivity (µS/cm)	1536.8 ±34.0	1398.6 7±5.2	1420.8 ±79.0	1500 µS/cm
Salinity(ppt)	0.20 ±0.01	0.22 ±0.01	0.20 ±0.01	NS

Key: Results given as confidence interval (mean ± uncertainty) for 95% confidence limit, NS = value not specified in the standard.

2.6.2. Pesticide Residue in Water Samples

Figure 3 summarizes the concentration of pesticide residue detected in water samples collected from Themi River. The pesticides detected in all water samples were dimethoate, trichlorfon, and vamidothion, which were found to be at concentrations above the recommended IUPAC Regulatory limits for pesticides of 2003.

For trichlorfon, concentration was found to be 0.71µg/l in water sample from the first selected sampling point, 0.72 and 0.70 µg/l in the second and third water samples respectively which exceeded the recommended IUPAC Regulatory limits for individual pesticide in water which is 0.1 µg/l. Concerning effects on environmental organisms, the report cites evidence that trichlorfon is moderately toxic for fish and birds and moderately to highly toxic for aquatic arthropods, supporting the conclusion that this insecticide should never be sprayed over water bodies or streams [9]

Dimethoate was detected to be at 1.93, 1.69 and 1.31 µg/l concentrations in the consecutive water samples which also exceeded the recommended acceptable concentration of 0.1 µg/l for individual pesticides in water. According to [10], the dimethoate residues found in the Themi River are indicative of threat that the natural water bodies Arusha Region have started getting contaminated with pesticides residues used in farms found in this region and therefore It is important to have an eye on distribution pattern of these pesticides in the environment because they do not remain at their target site but often enter aquatic environment via soil percolation, air drift or surface runoff affecting abundance and diversity of non-target species producing complex effect on the ecosystems and altering tropics interactions [11], [12].

Also, for all the three water samples, the concentration for vamidothion was found to be 1.22 µg/l, 0.56 µg/l and 0.57 µg/l which were all above the recommended maximum acceptable limit for individual pesticides according to IUPAC, which is 0.1 µg/l.

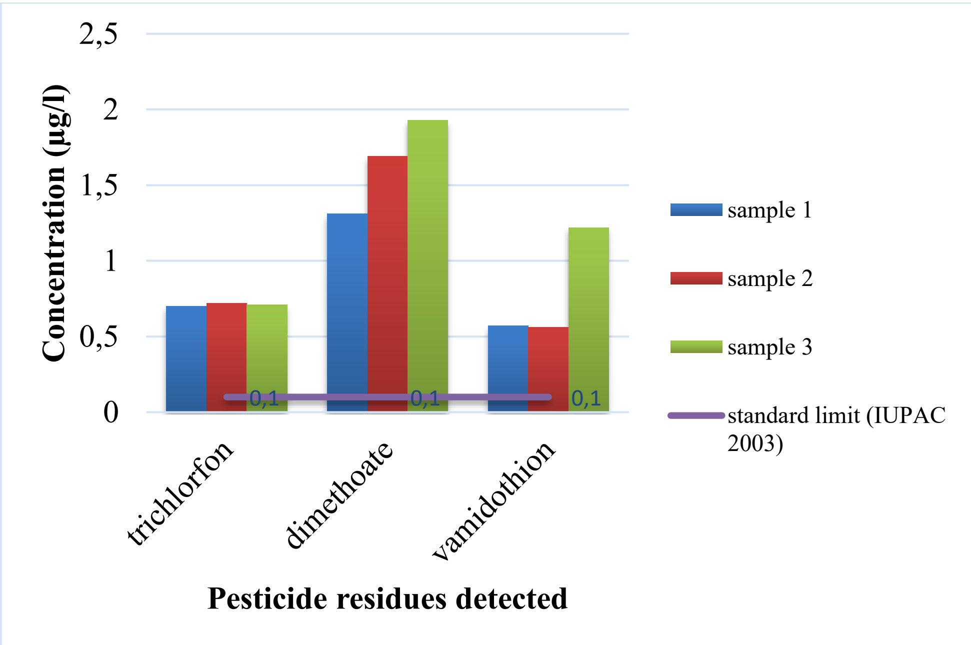


Figure 3. Concetration of pesticide residues in water samples from Themi River.

2.6.3. Relationship Between Water Physicochemical Parameters and Pesticide Residues Detected

For correlation significance, the criteria value of probabilities ($p < 0.05$) was used. A positive insignificant correlation was observed between pH and (Trichlorfon and Dimethoate), E/C and Dimethoate, and salinity and Trichlorfon, whereas a positive significant correlation was observed between E/C and Vamidothion as indicated in Table 2.

The positive correlation between pH and (Trichlorfon and Dimethoate), E/C and (Dimethoate and Vamidothion) and salinity and Trichlorfon indicates that pH, E/C and salinity could have enhanced the adsorption of these pesticide compounds [13], [14]

Table 2. Pearson correlation values between water physicochemical properties and pesticide residues detected.

Physicochemical properties / Pesticides	pH	EC	Salinity
Trichlorfon	0.87	<, LOQ*	0.87
Dimethoate	0.92	0.79	0.13
Vamidothion	0.49	1.00	-0.5

*LOQ is the Limit of Quantification

3. CONCLUSIONS AND RECOMMENDATION

3.1. Conclusion

Pesticide usage in agricultural practices in Fire vegetable growing farm is still going on and this results to pollution of Themi River. Water samples from the selected sampling points were found to be contaminated with trichlorfon, dimethoate, and vamidothion pesticides at concentrations that exceed the recommended IUPAC standard limits of pesticide residue concentration for individual pesticides in surface water.

3.2. Recommendation

Vegetable farmers should adhere to Tanzania national set regulation which prohibit human activities (such as farming) to be done at a distance below 60 meters from water sources.

The National Environmental Management Council (NEMC) should enforce adherence to the set regulations so as to eliminate agricultural practices along water bodies and also provide education to farming community so as they can be aware of risks related to farming activities to water bodies to ensure sustainability.

Routine monitoring of pesticide residues is necessary for the prevention, control, and reduction of environmental pollution, so as to minimize health risks to humans. Alternative option is switching to compounds or pesticides that have higher sorption or faster degradation. This implies that instead of using synthetic pesticides, farmers could also use natural pesticides, also known as reduced risk pesticides, with low toxicity to non-target organisms and break down quickly in sunlight. For instance, pyrethrins, neem, and also home-made organic pesticides made out of lemon peels, ash and water (natural insecticide).

Furthermore, further studies should be done to check on the extent of ground water contamination from pesticides used in local vegetable farms located close to ground water sources (i.e. wells), in vegetables and soil so as to establish environmental health risk to avoid incorporation of pesticide into trophic chain.

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