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The Contribution of Pesticide Management Practices to Aquifer Vulnerability around Lake Naivasha, Kenya

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Abstract

Purpose: Numerous approaches have been used or proposed for assessing groundwater vulnerability occurring in the vadose zone and groundwater regime, to models that weight critical factors affecting vulnerability through either statistical methods or expert judgment.

Methodology: This study used responses from the personnel handling pesticides in farms around Lake Naivasha basin on pesticide management practices to calculate the value of aquifer vulnerability in the area. This paper did not include hydrogeological and hydrodynamic characteristics of the subsoil, which is the common method.

Findings: The results showed that the contribution of pesticide management practices to aquifer vulnerable in the area was 45.5%. It was concluded that this contribution is quite high, needing the intervention of farm owners, managers and policy makers in order to protect the quality of groundwater in this area.

Unique Contributions to Theory, Policy and Practice: This Study only used pesticide management practices in order to assess their independent contribution to aquifer vulnerability in the study area. This contribution has often been overlooked. It was clear from this study that pesticide management practices accounted for a higher magnitude of aquifer vulnerability.

Keywords: *Pesticide, Management practices, Aquifer, Vulnerability, Lake Naivasha*

1.0 Introduction

Agricultural products, especially the ones produced for export have to match a high quality standard[1, 2]. To achieve these quality standards, it is necessary to have a good program of weed control and pest management. The use of pesticides is one of the most used tools to achieve it[3-5]. But improper pesticide application results in high toxicity levels causing environmental risk[5, 6].

Environmental concerns have focused on protecting non-target species, such as the birds[7]. Increasing use of pesticides also threatens the quality of surface and ground waters by contamination. Once groundwater is contaminated, analyzing the problem and providing alternative water supplies can be quite expensive. In 1987, U.S. Environmental Protection Agency documented 19 pesticides occurring in groundwater from 24 states attributed to agricultural practices[8].

Most groundwater comes from infiltrated precipitation. Groundwater contamination occurs when water comes in contact with naturally occurring contaminants or with contaminants introduced into the environment by anthropogenic activities[9]. Contaminants associated with human activity most commonly include bacteria, petroleum products, natural and synthetic organic compounds, fertilizer, pesticides and metals[10].

Finding out how compatible a specific anthropogenic development is with environmental conservation by assessing its impact on natural resources is a key step towards understanding the interactions between territory and local activities[11]. Ecological risk assessment evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. In general terms, risk is defined as a combination of hazard and vulnerability[12].

Vulnerability indicates the degree of intrinsic weakness of the investigated natural system. In the context of groundwater contamination, 'vulnerability' represents the degree of intrinsic weakness of the aquifer analyzed[13].

Numerous approaches have been used or proposed for assessing groundwater vulnerability[11, 14, 15]. They range from sophisticated models of the physical, chemical, and biological processes occurring in the vadose zone and groundwater regime, to models that weight critical factors affecting vulnerability through either statistical methods or expert judgment. The models are used either under field conditions or in large–scale areas in order to evaluate the fate of pollutants at different levels of sophistication, in relation to processes and dimension.

Parametric models considering the intrinsic vulnerability of an aquifer take into account hydrogeological and hydrodynamic characteristics of the subsoil[11]. All parametric models are based on the same principle, i.e. different parameters describing a phenomenon (e.g. groundwater depth, water infiltration, type of soil coverage, hydrology of the aquifer, conductivity, slope etc.) are divided into classes and weighted according to the their importance [16, 17].

Experts dealing with a complex problem, do a qualitative pre-selection of the context, considering only the aspects of the problem that, according to their judgment, allow them to solve it[11, 18]. Experts have indicated some factors (Table 1) linked to the characteristics of the site that influence the intrinsic vulnerability[11].

Table 1: Factors influencing the vulnerability degree according to expert judgment

Factors linked to the site characteristics	**Factors linked to the cultural practices**
Exposition to sun	Pesticide mobility in subsoil
Presence of organic matter in the soil	Quantity of pesticides used
Soil structure	Type of crop
Slope of soil surface	Seasonality of treatment
Pedology	Type of tillage
Temperature and rain	Type of pruning
	Irrigation techniques
	Presence of draining systems

Source:[11]

The factors from table 1, which are available to the experts, are then assigned specific weights according to expert judgment. The weights are based on rules expressed by the experts in terms of linguistic statements according to the importance of the factors involved in the statement. Examples of linguistic statements are given in Table 2 below.

Table 2: Linguistic statements used in assigning weights

Very Important Important Moderately important Not important	Very high High Medium Low Very low

Source: [11]

The contribution of this study aims at estimating aquifer vulnerability using pesticide management activities that were considered as contributing to groundwater pollution in the farms surrounding Lake Naivasha, Kenya.

2.0 Materials and Method

Lake Naivasha is located in Naivasha Subcounty, Nakuru County in the Eastern Rift Valley, about 100km Northwest of Nairobi, Kenya's capital. It is bounded by latitude 0°49′ S and 0°52′ S and longitude36°18′ E and 36°21′ E. The study area is located in the central portion of the Rift floor at a mean altitude of 1885m above mean sea level.

All the farms among the 20 major horticulture farms located around Lake Naivasha, which agreed to participate in the study, were asked to choose the personnel handling pesticides to fill the questionnaires. Major farms were selected purposively as they grew wide varieties of crops and therefore used a wide range of pesticides. Interviewer administered questionnaires and researcher observation were used to collect data on pesticide management. The pesticide management practices that contributed to groundwater contamination studied were pesticide selection, storage, handling, application, pesticide and container disposal and other methods of controlling plant diseases and pests. Consent to conduct the study was sought from Moi University's School of Environmental Studies and Lake Naivasha Riparian owner's Association (LNROA)[19].

The vulnerability of the aquifer to pollution was determined from pesticide management practices in the farms surrounding Lake Naivasha. The management practices considered were those that exposed the aquifer to contamination by pesticides. The practises in pesticide management that were considered to be poor management activities were quantified and then weighted according to their importance[16].

3.0 Results and Discussion

The responses from the personnel involved in pesticides application in the farms and the weights assigned to each activity in pesticide management are given in Table 3.

Table 3: Pesticide management activities weights

Management Factors Contributing to Groundwater Contamination	Pesticide Management responses	Relation to Groundwater	Level of Importance	Weight	Weighted Management

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	(In decimal)	**Contamination**			**Activities**
Education level	1.000	inversely proportional	Very important	1.00	0.250
Lowest location of cap is 5cm	0.167	directly proportional	Moderately important	0.50	0.084
Lowest pesticide storage location and distance to mixing/water source (10m)	0.250	directly proportional	Important	0.75	0.188
Unused pesticide disposal on damp site	0.286	directly proportional	very important	1.00	0.286
Underground pesticide container disposal	0.111	directly proportional	Important	0.75	0.083
Disposal of excess spray by pouring on soil	0.143	directly proportional	Important	0.75	0.107
Spillage during transportation	0.143	directly proportional	Important	0.75	0.107
Total					**1.105**

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Aquifer vulnerability, $V_{aq} = f(M)$ *Eqn. 1*

Where, *M* is the sum of pesticide management activities,

Aquifer vulnerability α poor pesticide management practices *Eqn. 2*

From equation 2, aquifer vulnerability is proportional to poor pesticide management activities i.e.:

$V_{aqm} \alpha M$ *Eqn. 3*

Thus $V_{aqm} = kM$ *Eqn. 4*

V_{aqm} *is the aquifer vulnerability considering poor management activities,*

Where, *k* is a constant associated with pesticide management activities.

The value of *k* was determined by plotting the weighted pesticide management activities values determined from questionnaires administered in the farms versus the respective weights assigned to each activity (Figure 1).

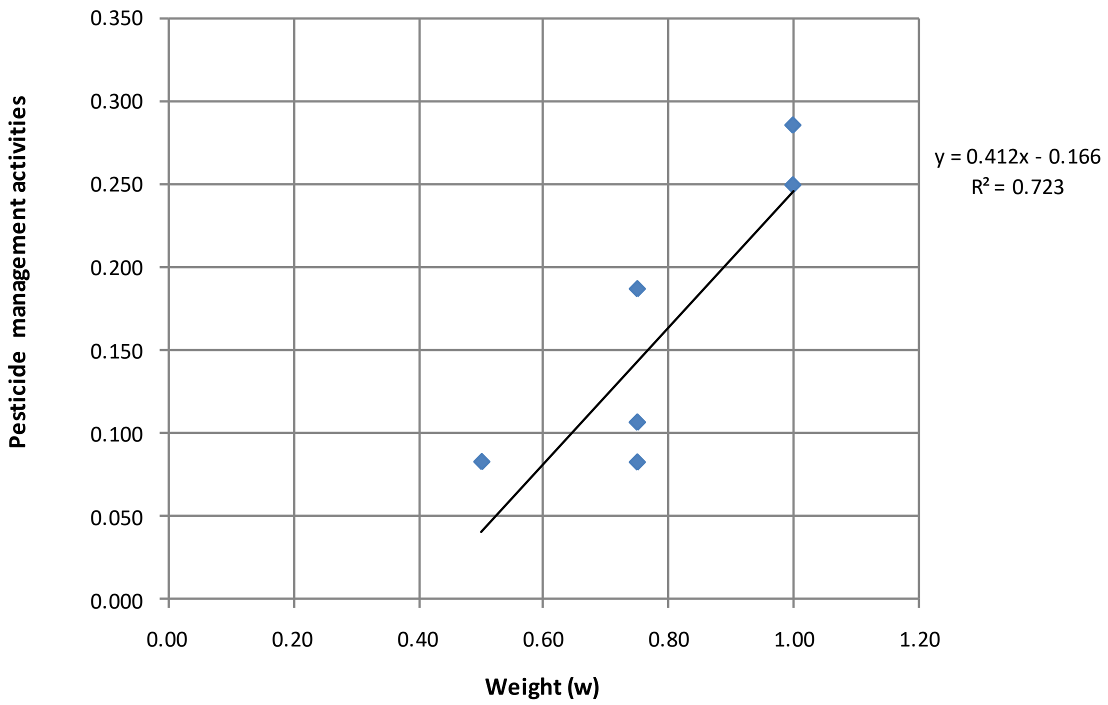

Figure 1: Plot of weighted pesticide management activities versus assigned weights

The total effect (contribution) of pesticide management practices to aquifer vulnerability to groundwater pollution by pesticides was arrived at by summing the weighted management activities shown in Table 3.

i.e. $M_v = \sum_{i=1}^{n} m_i w_i$ *Eqn. 5*

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where, M_v = Total effects (contribution) of pesticide management activities to aquifer vulnerability,

m_i = individual activity on pesticide management.

w_i = weight assigned to each individual management activity contributing to groundwater contamination by pesticides.

From Table 3, $M_Y = 1.105$

From equation 4:

Aquifer vulnerability due to poor management activities, $V_{aqm} = kM_v$ *Eqn. 6*

Where *k and* V_{aqm} are as defined in equation 4.

From Figure 1, k = 0.412

$V_{aqm} = 0.412 \times 1.105$ *Eqn. 7*

$\mathbf{V_{aqm} = 0.455}$ *Eqn. 8*

That is the aquifer vulnerability around Lake Naivasha from pesticide management practices was 0.455 (or 45.5%).

This means that the aquifer is 45.5% vulnerable to groundwater contamination by pesticides considering pesticide management activities alone. It should be noted that this paper did not include hydrogeological and hydrodynamic characteristics of the subsoil[11, 17, 20], which is the common method, but simply management practices by the personnel working in the farms. A study to determine aquifer vulnerability using DRASTIC and human activity impact within the Dead Sea groundwater basin, Jordan, found that human activity was affecting the groundwater quality and increasing its pollution risk [21]. A study by Shah *at al.*[22] showed high vulnerability region of their study area was mainly located in the groundwater recharge areas. Such groundwater recharge areas around Lake Naivasha can have an even much higher groundwater contamination potential when poor pesticide management practices are used.

4.0 Conclusion

The aquifer vulnerability from pesticide management practices around Lake Naivasha was determined to be 45.5%. This study therefore, quantified the human activities and came up with an aquifer vulnerability index for the study area. It was concluded that this aquifer vulnerability from pesticide management was high and therefore, exposed groundwater in the area to the risk of contamination by pesticides. This vulnerability should be a concern to stakeholders in the area, needing the intervention of farm owners, managers and policy makers in order to protect the quality of groundwater around Lake Naivasha.

5.0 Recommendations

The farms management using pesticides for plant diseases and weeds control around Lake Naivasha therefore, needs to put more emphasis on pesticide management practices highlighted in this study. The personnel handling pesticides should be trained and encouraged to adopt good and sound management practices in order to reduce this aquifer vulnerability.

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References

1. Martinez, M.G. and N. Poole, *The development of private fresh produce safety standards: implications for developing Mediterranean exporting countries.* Food Policy, 2004. **29**(3): p. 229-255.
2. Asfaw, S., D. Mithöfer, and H. Waibel, *What impact are EU supermarket standards having on developing countries' export of high-value horticultural products? Evidence from Kenya.* Journal of International Food & Agribusiness Marketing, 2010. **22**(3-4): p. 252-276.
3. Chen, C., J. Yang, and C. Findlay, *Measuring the effect of food safety standards on China's agricultural exports.* Review of World Economics, 2008. **144**(1): p. 83-106.
4. Wilson, J.S. and T. Otsuki, *To spray or not to spray: pesticides, banana exports, and food safety.* Food policy, 2004. **29**(2): p. 131-146.
5. Khan, M.J., M.S. Zia, and M. Qasim, *Use of pesticides and their role in environmental pollution.* World Acad Sci Eng Technol, 2010. **72**: p. 122-128.
6. Ma, J., et al., *Sources of water pollution and evolution of water quality in the Wuwei basin of Shiyang river, Northwest China.* Journal of environmental management, 2009. **90**(2): p. 1168-1177.
7. Trautmann, N.M., K.S. Porter, and R.J. Wegenet, *Pesticides and Groundwater: A Guide for the Pesticide User*. 2005, Cornell University, Ithaca, New York: Natural Resources Cornell Cooperative Extension.
8. US-EPA, *Agricultural chemicals in groundwater: proposed pesticide strategy, USEPA office of pesticides and toxic substances*. 1987, U.S. Environmental Protection Agency
9. Babiker, I.S., et al., *Assessment of groundwater contamination by nitrate leaching from intensive vegetable cultivation using geographical information system.* Environment International, 2004. **29**(8): p. 1009-1017.

10. Mor, S., et al., *Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site.* Environmental monitoring and assessment, 2006. **118**(1-3): p. 435-456.

11. Uricchio, V.F., R. Giordano, and N. Lopez, *A fuzzy knowledge-based decision support system for groundwater pollution risk evaluation.* Journal of environmental management, 2004. **73**(3): p. 189-197.

12. Varnes, D.J., *Landslide hazard zonation: a review of principles and practice*. 1984.

13. Civita, M., *Le carte di vulnerabilita degli acquiferi all'inquinamento: teoria e pratica.* Quaderni di tecniche di protezione ambientale, Pitagora ed, 1994.

14. Stempvoort, D.V., L. Ewert, and L. Wassenaar, *Aquifer vulnerability index: a GIS-compatible method for groundwater vulnerability mapping.* Canadian Water Resources Journal, 1993. **18**(1): p. 25-37.

15. Ouedraogo, I., *Mapping groundwater vulnerability at the pan-African scale*. 2017, UCL-Université Catholique de Louvain.

16. Zaghi, C. and S. Lucci, *Identification of vulnerable areas to pesticides. Methodological aspects.* QUADERNI-ISTITUTO DI RICERCA SULLE ACQUE, 2000: p. 265-282.

17. Aller, L., et al., *DRASTIC: a standardized system to evaluate groundwater pollution potential using hydrogeologic settings.* National Water Well Association, Worthington, Ohio, United States of America, 1987.

18. Maciocco, G., et al., *The Relationship between Individual Subjects and the "Community of Practice".* People and Space: New Forms of Interaction in the City Project, 2009: p. 93-98.

19. Abiya, I.O., *Towards sustainable utilization of Lake Naivasha, Kenya.* Lakes & Reservoirs: Research & Management, 1996. **2**(3-4): p. 231-242.

20. Jang, W.S., et al., *Aquifer vulnerability assessment for sustainable groundwater management using DRASTIC.* Water, 2017. **9**(10): p. 792.

21. Al-Hanbali, A. and A. Kondoh, *Groundwater vulnerability assessment and evaluation of human activity impact (HAI) within the Dead Sea groundwater basin, Jordan.* Hydrogeology Journal, 2008. **16**(3): p. 499-510.

22. Shah, S.H.I.A., et al., *Classification of aquifer vulnerability by using the drastic index and geo-electrical techniques.* Water, 2021. **13**(16): p. 2144.