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An Analysis of Agricultural Pesticide Practices and Anthropogenic Footprints in Himalayan Freshwaters of Nepal

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Abstract

The growing number of agro-vets in Nepal reflects an increasing demand for pesticides, highlighting the need to investigate the types, toxicity, and public awareness of associated hazards. This study collected data from the oldest agro-vet in Kathmandu Valley, documenting the specific pesticides used. Although the data on pesticide volume is limited, the study is significant as it was carried out with limited research resources, both using synthesis data and primary data over a decade ago. The data was systematically organized in MS-Excel to provide a detailed overview of each pesticide. Additionally, the study examined the anthropogenic footprint, focusing on human activities such as population density and agricultural practices. The population size was plotted by calculating the overall population of districts touched by the river basins, extracted from the census. The percentage of gross national product was presented graphically to illustrate the anthropogenic features in each basin from high mountain terrain to lowlands. The lower sections of Nepal's Himalayan rivers and the middle segments of the Bagmati River face significant human and agricultural pressures, exacerbated by the widespread use of hazardous pesticides in Kathmandu, necessitating stringent regulatory actions, regular monitoring programs, and enhanced research efforts to assess and mitigate associated risks. These findings shed light on the historical background of the introduction of pesticides in Nepal and the most common types of pesticide in the Kathmandu valley, while the analysis of anthropogenic footprints offer a framework for evaluating human-induced impacts on the Himalayan freshwater systems of Nepal.

Keywords: toxicity, pesticides, anthropogenic footprint, features, Himalayan freshwater

1. Introduction

Pesticides are chemicals designed to prevent, destroy, repel, or mitigate pests, encompassing insecticides, herbicides, fungicides, rodenticides, and other pest control substances. They are broadly classified into narrow-spectrum, which targets specific pests, and broad-spectrum pesticides, which affect both pests and beneficial organisms. In Nepal, the majority of pesticides used are broad-spectrum, with an average national use of 396g a.i./ha with the highest use (1.604 a.i.kg/ha) reported in vegetables (Ghimire et al., 2018). While pesticides play a crucial role in protecting crops from pest infestations, the choice of pesticide type and appropriate dosage remains a significant challenge for many farmers, highlighting the need for increased awareness and better practices.

Nepal's introduction to pesticides began in the 1950s with the import of DDT for malaria eradication (Sharma et al., 2013). Over the following decades, additional class of pesticides, including organochlorines, organophosphates, and carbamates, were progressively introduced, with fungicides becoming the most widely used type (Sarker et al., 2021). Agricultural intensification in Nepal has also altered water chemistry and microbiology, with rural watersheds showing elevated levels of chemical fertilizers such as NH_3 and NO_3 (Dahal et al., 2007). While limited studies have focused on large rivers, the growing use of pesticides and fertilizers raises concerns about their broader environmental impacts, particularly in Himalayan catchments and watersheds. The pesticides and fertilizers registered in Nepal to date are summarized in **Table 1**.

Table 1. The list of chemical fertilizers and pesticides recorded in Nepal from the references

Types of Chemical fertilizers	1. Urea 2. Diammonium Phosphate (DAP) 3. Murate of Potash (MOP) 4. Ammonium Sulphate (AS) 5. Single Super Phosphate (SSP) 6. Ammonium Phosphate Sulphate (APS) 7. NPK	(Diwakar et al., 2008; Panta et al., 2018)
Types of pesticides	1. Organochlorine (Endosulfan) 2. Organophosphates (Acephate, Chlorpyriphos, Quinalphos, Dichlorovos, Phorate etc.) 3. Carbamates 4. Synthetic Pyrethroids (Alphametrin, Cypermethrin, Fenvalerate, Deltamethrin, etc.) 5. Mixed insecticides (Chlorpyriphos + Cypermethrin, Alphamethrin+Chlopyriphos, Quinalphos+Cypermethrin, etc. 6. Others (Aluminium phosphide, Cartaphydrochloride, Imidacloprid, Propagite, Ethofenox, Fenpropathrin, Fipronil etc.)	(Diwakar et al., 2008)

The extensive use of pesticides in agriculture and related sectors has led to an accumulation of pesticide residues in food chains and commodities, becoming a significant global concern. Exposure to hazardous chemicals and waste throughout their supply chains and life cycles threatens human health and disproportionately impacts vulnerable and at-risk groups (UNEP, Global Framework on Chemicals). Ensuring food safety is paramount, as consumers must be protected from exposure to harmful level of pesticide residues. In Nepal, intensive agricultural practices have driven the widespread use of pesticides, including prohibited chemicals like dichlorodiphenyltrichloroethane (DDT), endosulfan, and Hexachlorocyclohexane (HCH), also unapproved substances such as alachlor, diuron, and pyrimethanil. These pesticides have been detected in the catchments of the Nepal Himalayas, signaling a decline in freshwater quality. This contamination not only threatens aquatic ecosystems but also poses serious health risks to humans, particularly through the consumption of fish (Acharya et al., 2023). Also, the regular misuse of pesticide causes pests to adapt and become resistant to the pesticide (Giri, 2010). This results in the requirement higher dose of pesticides for future use.

The Central Himalayan region of Nepal has been increasingly impacted by human-induced factors such as urbanization, rising population density, agricultural expansion, and growing pesticide usage, driven by rapid population growth (Dahal et al., 2007; Jha et al., 2018; Pant et al., 2018; Pant et al., 2020; Regmi, 2022). To better understand these impacts, we introduced the concept of anthropogenic footprints in Nepal's Himalayan rivers to identify human-induced interferences affecting water quality in the basins. In this study, we evaluated these footprints along the river basins, by classifying the basins with significant anthropogenic influences, including population density and agricultural activities (NPHC, 2021, USDA Foreign Agriculture Service). The population size is plotted by calculating the population from overall districts touched by the selected rivers of the basins as extracted from the National Population and Housing Census 2021 (**Appendix 1**).

River basins in the fertile alluvial plains, particularly in less geologically challenging lower regions, are characterized by high population densities. Urban areas, in turn, exhibit more significant anthropogenic impacts compared to the environmentally sensitive source regions of the Himalayan rivers (Paudyal et al., 2016a; Paudyal et al., 2016b). This study evaluated these footprints across various river basins, identifying key areas of human influence, including population density and agriculture. **Figure 1** illustrates these findings and highlights the study site, Kathmandu, Nepal, where the top ten pesticides are used.

2. Methodology

The primary objective of this study was to identify the top pesticides used in the Kathmandu Valley and examine the anthropogenic footprints in the Himalayan rivers associated with agricultural practices and pesticide usage in Nepal. Initially, the District Agriculture Development Office (DADO), governed by the Ministry of Agriculture and Livestock Development, was considered the primary source for pesticide data. However, DADO did not maintain records specific to individual districts, only providing nationwide pesticide data.

Consequently, data were collected from Khanal Agrovet, located in Mahankal, Kathmandu in the year 2016 targeting the pesticide usage for any one year. This agrovet, operational for over 70 years, is recognized as one of the oldest and most prominent in Nepal. Relevant information was obtained through direct inquiries with personnel and by examining pesticide bottles and packaging materials. The collected data were systematically tabulated and supplemented with insights from scientific research papers and online sources, as presented in the results section.

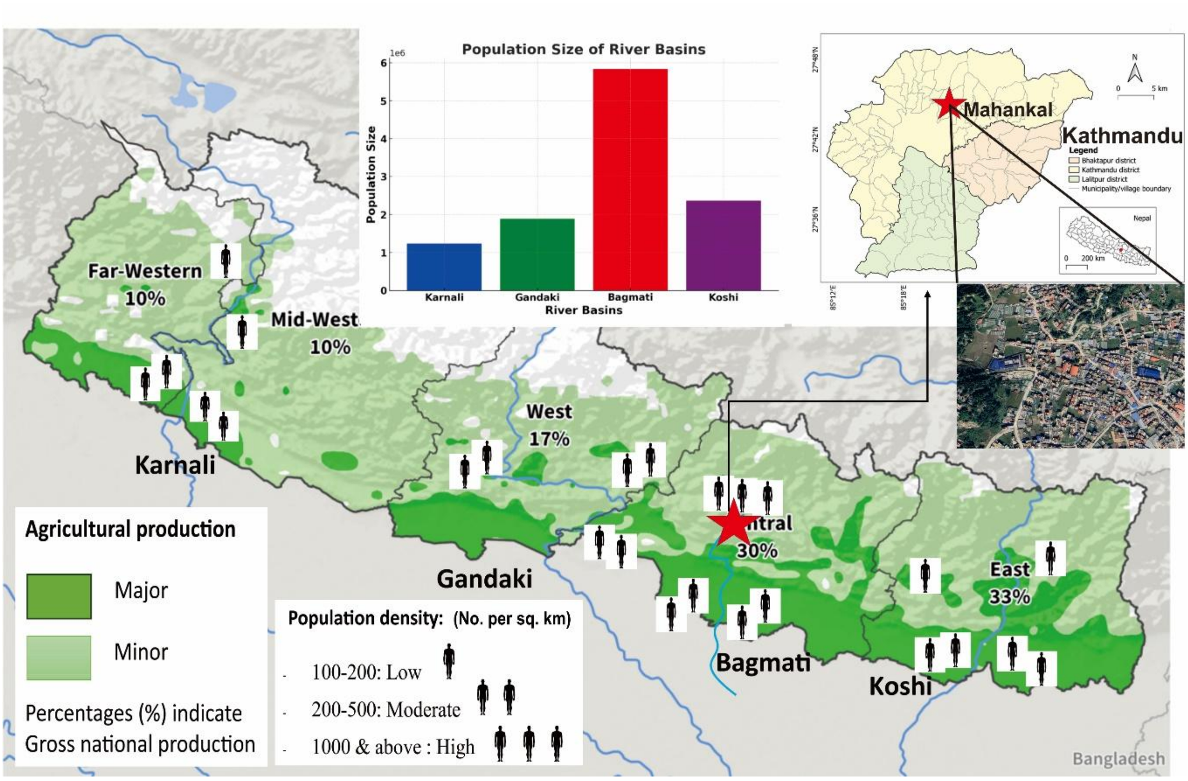

Figure 1. Anthropogenic footprints in the Nepal Himalayan Rivers as a result of anthropogenic features and the study site of top ten pesticides used, i.e. Mahankal, Kathmandu, Nepal (adopted and edited from Kandel et al. 2024)

Additionally, data on anthropogenic footprints, including population density and agricultural activities, were integrated (Kandel et al., 2024) and represented graphically in **Figure 1**. This figure highlights the areas of significant human influence, offering a comprehensive overview of the study's findings.

3. Results and Discussion

The top 10 pesticides used in Kathmandu Valley in the year 2016 along with the common name and trade name are presented in **Table 2**. The information includes common name, trade name, chemical name, WHO class, type, label, and the hierarchy of the most commonly used pesticides, marked with ^{ah}, ^{mh}, and ^{nh}, abbreviated to acute, moderate, and negligible hazard, respectively as per (WHO, 2004) guidelines. This is represented in **Figure 2**, use as of types (Insecticide>Rodenticide>Fungicide) and hazardous level (Rodenticide>Insecticide>Fungicide).

Table 2. The list of top 10 pesticides used in Kathmandu Valley with types, classes, and label

S.N.	Trade name	Common name	Type (target pest)	WHO class (Ia, Ib)	Label (red, yellow, etc.)
1	Synfume	aluminum phosphide	Rodenticide[mh]	FM	Red
2	Dhanuka M- 45	mancozeb	Fungicide[nh]	U	Green
3	Bloom	dichlorvos	Insecticide[ah]	Ib	Red
4	Anumite	cypermethrin	Insecticide[mh]	II	Yellow
5	Anugor	dimethoate	Insecticide[mh]	II	Yellow
6	Bavisthin	carbendazim	Fungicide[nh]	U	Green
7	Krinoxyl	metalaxyl8% + mancozeb 64%	Fungicide[nh]	U	Blue
8	Roban	bromadiolone	Rodenticide[mh]	Ia	Red
9	Kaardon	cartap hydrochloride	Insecticide[ah]	II	Yellow
10	Ratil	zinc phosphide	Rodenticide[mh]	Ib	Red

Insecticides are the most commonly used pesticides in Nepal, with dichlorvos, an organophosphate, categorized as highly hazardous. Rodenticides rank second in usage, and most are marked with a red hazard symbol, indicating high toxicity, except for bromadiolone, which is classified as extremely hazardous (WHO Class Ia). In contrast, fungicides are categorized under WHO Class U, signifying they are unlikely to pose an acute hazard under normal use, making them relatively safer among the pesticides studied.

Pesticide prices fluctuate daily due to market competition, complicating the ability to provide consistent pricing. One notable pesticide is Synfume, or aluminum phosphide, a highly hazardous metal phosphide. Although banned in India and many other countries, it is manufactured in India and sold exclusively in Nepal. Despite clear labeling stating "not to be used in India," aluminum phosphide remains unregulated in Nepal and sustains to be the top-selling pesticide throughout the year.

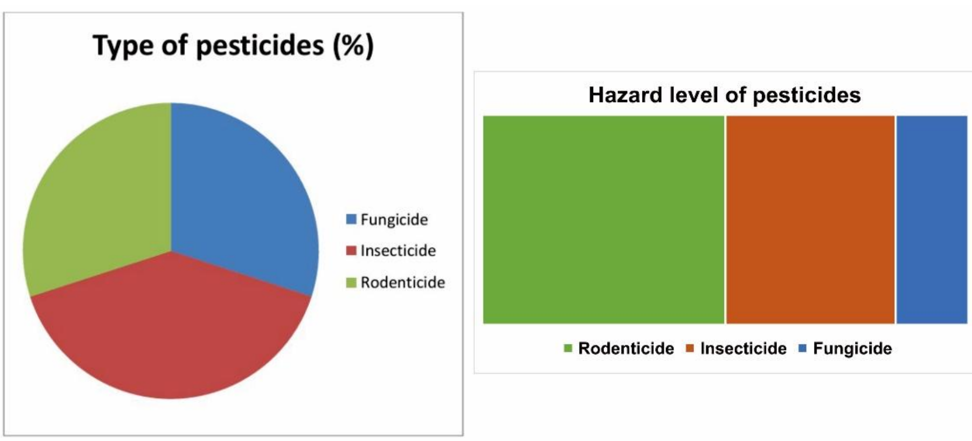

Figure 2. Pie chart showing types of pesticides used in Kathmandu valley according to target pest, and their hazard levels respectively

The Pie chart (Figure 2) represents the highest types of pesticides used Insecticide, followed by Rodenticide and Fungicide. Likewise, based on the level of hazardness, Rodenticide posed the greatest hazard, Insecticide posed the moderate hazard whereas Fungicide posed the least risk. Briefing on the footprint, the lower sections of Nepal's Himalayan rivers show a significant human footprint, marked by dense populations and intensive agricultural activities (**Figure 1**). Notably, the middle segment of the Bagmati River stands out with a greater density, coupled with moderate farming output. Downstream, the impacts become even more pronounced, reflecting greater human and agronomic pressures on the river system.

4. Conclusion, Recommendation, and Future Perspectives

The widespread use of hazardous pesticides in Kathmandu highlights the urgent need for regulatory action. The government must implement regular monitoring programs to evaluate the types of pesticides in use and their associated risks. Large-scale public awareness campaigns are necessary to encourage the responsible use of pesticides in alignment with labeling guidelines. Additionally, increased research efforts are crucial for identifying and mitigating the risks displayed by hazardous pesticides.

To address these challenges, the government should ban extremely hazardous substances, such as aluminum phosphide, and actively promote safer alternatives. On an individual level, consumers must take responsibility for their safety by thoroughly understanding the pesticides they purchase. This includes carefully reading labels, adhering to recommended dosages, and being aware of potential risks to ensure proper safety measures during use.

With a focus on scientific insight and future perspectives, this study introduces the concept of anthropogenic footprints to evaluate general human-induced interferences in the Himalayan waters of Nepal. Analysis of these footprints highlights the middle segment of the Bagmati River, characterized by a high population density of 5,169 people per square kilometer (a total population of 2,041,587) and moderate agricultural activity, as a notable area of impact. Downstream regions, however, exhibit even greater anthropogenic pressures.

As a pioneering effort, this review underscores the importance of integrated monitoring and assessment of river water quality throughout the Himalayan region, from the high mountains to the lowlands. Such a comprehensive approach is critical to understanding and mitigating the impacts of human activities on these vital freshwater systems.

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Authors contribution

Kshitiz Kandel: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Conceptualization. Bed Mani Dahal: Writing – review & editing, Resources. Chhatra Mani Sharma: Writing – review & editing, Resources. Manish Devkota: Investigation and review. Bakhat Rawat: Investigation. Prabesh Kandel: Data curation and review.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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Peoples; and the elderly

Appendix

Appendix 1. Population size of the river basins calculated from the population of districts touched by the basins, population size extracted from National Population and Housing Census 2021

River basins	Districts touched	Population Size
1.KARNALI	Humla	55,394
	Bajura	138,523
	Kalikot	145,292
	Dailekh	252,313
	Achaam	228,852
	Surkhet	415,126
Total		**1,235,500**
2.GANDAKI		
Marsyangdi*	Manang	5,658
	Lamjung	155,852
	Tanahaun	
Trishuli*	Rasuwa	46,689
	Dhading	325,710
	Chitwan	
Kaligandaki*	Tanahaun	321,153
	Chitwan	
Narayani*	Chitwan	654,471
	Nawalparasi, Bardaghat Susta (East)	378,079
Total		**1,887,612**
3.BAGMATI	Kathmandu	2,041,587
	Bhaktapur	432,132
	Lalitpur	551,667
	Makawanpur	466,073
	Kavrepalanchowk	364,039
	Sindhuli	300,026
	Sarlahi	862,470
	Rautahat	813,573
Total		**5,831,567**
4. KOSHI		
Dudhkoshi*	Solukhumbu	104,851
Indrawati*	Sindhupalchowk	262,624
	Kavrepalanchowk	364,039
Saptakoshi*	Saptari	706,255
	Sunsari	926,962
Total		**2,364,731**