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Farmer knowledge, attitudes and practices regarding agrochemical use in parts of Rivers Niger and Kaduna Catchments, North Central, Nigeria

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Abstract

Agrochemical use is increasing rapidly among smallholder farmers in the River Niger and Kaduna catchments of north-central Nigeria, yet the knowledge, attitudes, and practices governing their use remain poorly characterised. This study investigated the knowledge base, attitudes, and current practices of 350 farmers utilising pesticides and fertilisers in the study area using a structured questionnaire designed around a Knowledge, Attitudes, and Practices (KAP) framework. Findings revealed that farmers held very limited knowledge of agrochemical hazards, with a mean knowledge score of 2.3 out of 10. Only 35 per cent of respondents were aware of pesticide restrictions in Nigeria, and fewer than 9 per cent could correctly classify pesticide compounds. Attitudes were predominantly positive towards agrochemical necessity, with 89.7 per cent agreeing that synthetic inputs are essential for crop success. Unsafe practices were widespread, including non-compliance with label instructions (91.4 per cent), inadequate use of personal protective equipment (27.1 per cent), equipment washing in rivers (82.3 per cent), and improper disposal of empty containers in farm fields (58 per cent). These practices pose direct risks to water quality, biodiversity, and farmer health. The study recommends targeted farmer training, vendor licensing, subsidised protective equipment, and strengthened extension services to bridge identified knowledge and compliance gaps.

Keywords: Agrochemicals, Attitudes, Catchment management, Extension services, Farmer behaviour, Fertilizers, Knowledge, Pesticides, Practices.

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Contents

Contribution of this paper to the literature

This study provides the first systematic KAP assessment for agrochemical management across the Rivers Niger and Kaduna catchment communities, Nigeria. It identifies critical knowledge gaps (mean score 2.3/10), attitudinal barriers and compliance deficits in this under-researched riparian agricultural system, generating behavioural evidence not previously available for regulatory and extension programme design.

1. Introduction

Agrochemical use in sub-Saharan African agricultural systems has intensified considerably over recent decades in response to population growth, climate variability and government subsidy programmes [1]. Fertilizers and pesticides are central to crop production in these settings, but their adoption has frequently outpaced the regulatory capacity and extension infrastructure needed to ensure safe and sustainable use [2]. In Nigeria, the Rivers Niger and Kaduna catchments in the north-central region support extensive subsistence and semi-commercial agriculture, with an estimated 30,000 farming households practicing cultivation along the floodplains. Previous studies have documented high rates of pesticide and fertilizer application in the area and associated water quality degradation, including exceedance of regulatory limits for turbidity, biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

Knowledge, attitudes and practices (KAP) assessment is an established epidemiological and behavioural research tool for characterising the gap between what people know, how they feel and what they actually do in relation to a health or environmental risk [3]. In agrochemical management, KAP studies have consistently demonstrated that farmers in developing countries apply chemicals at rates, methods and frequencies that deviate substantially from recommendations, driven by limited access to extension support, economic pressures and inadequate knowledge of hazards [4]. Identification of specific knowledge gaps and misconceptions is essential for designing contextually appropriate interventions. Understanding whether unsafe practices reflect lack of knowledge, unfavourable attitudes or structural barriers such as cost and access shapes the nature of remedial programmes.

In the study area, systematic KAP assessment has not previously been conducted for agrochemical management despite documented environmental contamination. This represents a critical gap because the design of effective interventions, whether farmer training programmes, regulatory enforcement actions or public health warnings, requires understanding of the specific behavioural and knowledge determinants of unsafe practices. This study addresses this gap by conducting a comprehensive KAP assessment across 350 farming households in the study area, with findings intended to inform programme design by government, extension services and regulatory agencies including the National Environmental Standards and Regulations Enforcement Agency (NESREA) [5].

The Nigerian agricultural sector remains overwhelmingly dependent on smallholder producers, who account for the greater part of domestic food output and who cultivate under conditions of limited capital, restricted access to formal credit and minimal technical guidance [1]. Within this context, the adoption of synthetic fertilizers and pesticides has been actively encouraged through government subsidy schemes, agricultural intervention programmes and the informal distribution of inputs by political actors during electoral cycles. The effect of these arrangements has been a rapid substitution of traditional soil fertility and pest management methods with chemically intensive practices, unaccompanied by the training, supervision and enforcement structures that safe agrochemical use ordinarily requires [2]. Farmers therefore acquire and apply hazardous products without any structured exposure to the risks these products carry.

The consequences of this transition are not confined to the farm. In riparian agricultural systems such as those found along the Rivers Niger and Kaduna, agrochemical residues and nutrient loads migrate readily into surface water through runoff, leaching, spray drift and the direct washing of application equipment in streams and ponds. These pathways connect individual farmer behaviour to catchment-scale environmental outcomes, including eutrophication, loss of aquatic biodiversity and contamination of the very water sources upon which farming communities depend for drinking, domestic use and fishing. The behavioural determinants of unsafe agrochemical handling are consequently a matter of public and environmental health significance well beyond the individual holding.

A knowledge, attitudes and practices assessment is well suited to disentangling these determinants because it examines separately what farmers understand about agrochemical hazards, how they feel about the necessity and risk of chemical inputs, and what they actually do in the course of purchasing, storing, mixing, applying and disposing of these products [3]. The distinction matters for programme design. Where unsafe practices are driven principally by absence of knowledge, information and training, interventions may be sufficient. Where they persist despite adequate knowledge, the obstacles are more likely to be economic, structural or attitudinal, and the appropriate response must address cost, access and the incentives that govern farmer decision-making [4]. Without this diagnostic clarity, interventions risk being misdirected and ineffective.

The present study forms part of a wider doctoral investigation into pesticide and fertilizer use, water quality degradation and the socioeconomic and regulatory dimensions of agrochemical management in the Rivers Niger and Kaduna catchments. Earlier components of that investigation established the physical extent of contamination, documenting exceedances of regulatory limits for several physicochemical parameters and confirming the presence of organochlorine pesticide residues, including compounds that are banned or restricted in Nigeria, in both water and sediment across all sampled zones. The regulatory appraisal further demonstrated that extant environmental laws governing agrochemical use near sensitive and vulnerable areas were largely unenforced and poorly understood by the regulated communities. This paper contributes the behavioural evidence that explains, at the level of the individual farmer, how contamination of this kind arises and is sustained, and it identifies the specific knowledge and compliance gaps that any remediation programme must close [5].

2. Literature Review

The rapid intensification of agrochemical use in sub-Saharan African smallholder farming systems has been closely documented over the past two decades. Aktar, et al. [6] reviewed global pesticide use and found that

developing countries bear a disproportionately high share of pesticide-related health and environmental impacts relative to their agricultural output, a disparity driven by weak regulatory infrastructure, inadequate extension systems and widespread absence of protective equipment. In Nigeria specifically, Adeshina, et al. [7] confirmed the presence of organochlorine and organophosphorus pesticide residues in water and sediment from River Owena, demonstrating the same contamination pathways operating in the wider Niger Delta and north-central Nigerian catchments. Knowledge, attitudes and practices assessment is widely applied in public and environmental health research to characterise the behavioural determinants of exposure and to design contextually appropriate interventions. Karunamoorthi, et al. [3] conducted a landmark KAP study among farmers in Ethiopia and found that fewer than fifteen per cent of respondents could correctly interpret pesticide hazard labels, that knowledge of banned compounds was essentially absent, and that the primary information source was the pesticide vendor rather than any qualified advisory channel. Atreya, et al. [2] reported analogous patterns in Nepal, demonstrating that acetylcholinesterase inhibition consistent with organophosphate exposure was common among farmers who reported no awareness of pesticide toxicity.

Attitudinal barriers to safe agrochemical practice are particularly prominent in West African farming systems. Williamson, et al. [4] reviewed pesticide use trends in four African countries and found that positive attitudes towards chemical inputs persisted even where farmers acknowledged symptoms of exposure, driven by the perceived productivity necessity of agrochemicals and by the absence of demonstrated alternatives. Dasgupta, et al. [8] provided economic evidence from Vietnam that the hidden health costs of pesticide use substantially exceed farmer awareness of those costs, suggesting that attitudinal surveys underestimate the true harm being tolerated by farming communities. The non-use of personal protective equipment is a consistent and well-documented finding across occupational exposure studies in developing country agriculture. Sosan and Akingbohungbe [9] found that PPE use among cacao farmers in southwestern Nigeria was near-absent, with cost, thermal discomfort and the perception that chemicals were safe for traditional use cited as the principal barriers. Abubakar and Yusuf [10] assessed water quality along River Kaduna in Niger State and found exceedances of standard regulatory limits for multiple physicochemical parameters attributable to agricultural runoff, providing direct physical evidence for the contamination pathways that the behavioural findings of the present study explain. The role of agrochemical vendors as the dominant source of farmer information is a structural feature of West African pesticide markets with important implications for risk reproduction. Banerjee, et al. [11] demonstrated that farmers in rural West Bengal obtained virtually all their pesticide safety guidance from the point of sale, and that this channel consistently conveyed information biased towards increased application. Maumbe and Swinton [12] estimated the economic burden of pesticide-related illness among Zimbabwean smallholders and concluded that the costs imposed by unsafe practice substantially outweighed any productivity gain attributable to chemical use, creating a net economic loss that remained invisible because it was borne primarily in the form of unreported illness and lost labour capacity.

Palis, et al. [13] demonstrated that farmer field school programmes designed to address the knowledge and practice deficits documented in KAP studies are effective in changing both attitudes and behaviour, but only where training is sustained beyond a single season and where trained farmers are supported by peer networks and accessible extension agents. Fashola, et al. [14] found comparable patterns in Oyo State, Nigeria, where farmers who had participated in extension training showed significantly higher rates of safe practice across all domains assessed. Hassan and Hussain [15] specifically documented the consequences of synthetic fertilizer over-application in the Sudano-Sahelian zone, finding nitrate loading and soil acidification consistent with the application rates and water quality impacts documented in the present study area, and confirming that the Rivers Niger and Kaduna catchments are part of a broader regional pattern of agrochemical intensification without adequate management infrastructure.

3. The Study Area

The study area encompasses communities in parts of Rivers Niger and Kaduna catchments in Niger State, lying between Longitude 3°30¹E and 7°20¹E and Latitude 8°22¹N and 11°30¹N, within the Guinea Savannah vegetation zone. Along River Niger, three zones were delineated: the upper zone from Rabba village in Mokwa Local Government Area (LGA), the middle zone at Muregi and the lower zone extending from Muregi to Baro village in Agaie LGA. Along River Kaduna, two zones were defined: the upper zone from Wuya village in Lavun LGA and the lower zone towards Muregi. The major livelihood activities in the communities are agriculture and fishing, which are the leading sectors in employment and household income. Crops grown in the area include rice, maize, beans, groundnut, millet and melon. The distribution of sampling locations and delineated zones within the catchment is shown in Figure 1.

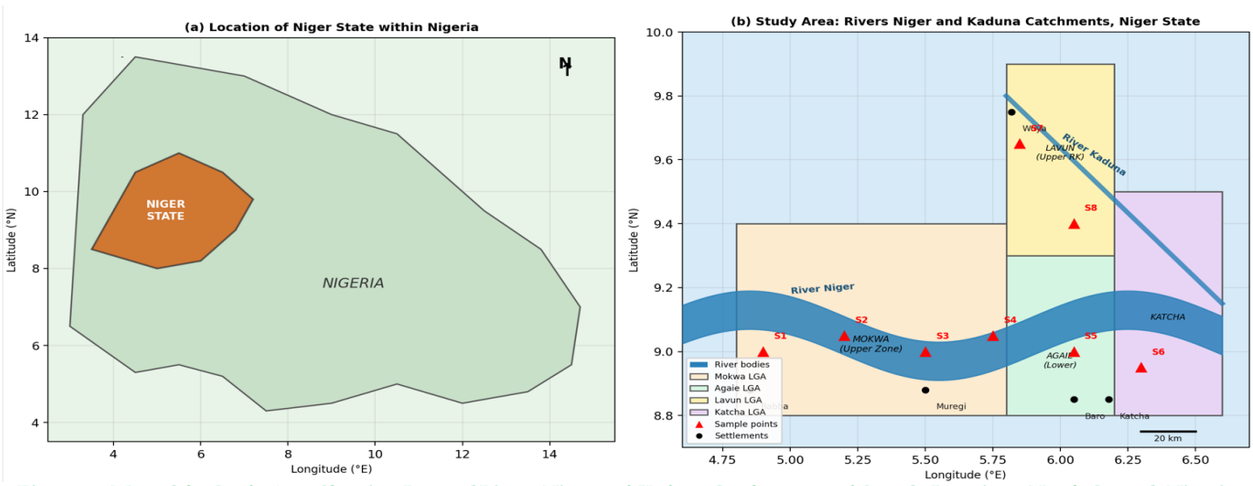

Figure 1. Map of the Study Area Showing Parts of Rivers Niger and Kaduna Catchments and Sample Locations, North Central, Nigeria.

Agriculture in the five delineated zones is predominantly subsistence and semi-commercial in character. Field enumeration established that the greater part of the study population cultivated holdings of between two and ten hectares, a size range consistent with smallholder subsistence production, while a smaller proportion worked holdings of up to fifteen hectares. Many of the farmlands surveyed had been under continuous cultivation for more than thirty years, a history that has itself contributed to declining soil fertility and to the escalating reliance on synthetic inputs observed across the area. The principal crops cultivated are rice, maize, beans, groundnut, millet and melon, with vegetables and sugarcane also grown in the wetter locations.

Cultivation follows a bimodal seasonal pattern. The majority of farming activity occurs in the rainy season, favoured for its abundant moisture and the lower cost of farming inputs at that time, while a smaller proportion of farmers cultivate in the dry season, when pest infestations other than bird attack are generally reduced. A significant number of farmers plant certain crops, including maize, rice, sugarcane and vegetables, up to three times within a single year across the two seasons. This intensive cropping calendar sustains a continuous demand for agrochemical inputs and provides repeated opportunities for the contamination pathways described above to operate throughout the year. Fishing constitutes the second principal livelihood in the catchment communities, which heightens the socioeconomic stake these communities hold in the ecological integrity of the rivers.

4. Materials and Methods

4.1. Study Design and Sampling

A prospective cross-sectional household survey was conducted between March and August 2019 across the three zones of Rivers Niger and Kaduna catchments. Sample size was determined using Yamane's formula at 95 per cent confidence level and 5 per cent tolerance error [16], yielding a minimum sample of 390 respondents from the estimated population of 30,229 farming households. In practice, 395 questionnaires were distributed and 350 returned (response rate 88.6 per cent). Respondents were selected by simple random sampling from farmer registration lists held by local government extension offices.

The sampling frame was stratified across the five agroecological zones so that each zone contributed a share of respondents broadly proportional to its farming population, ensuring that the upper, middle and lower reaches of both rivers were adequately represented. Field enumeration was conducted by locally recruited assistants fluent in Hausa and Nupe, the two dominant languages of the study communities, which allowed questions to be posed and clarified in the respondent's own language and reduced the measurement error that arises when survey instruments are administered in an unfamiliar language. Enumerators were briefed on the objectives of the study, on the neutral posing of questions and on the ethical obligation to obtain informed consent and to preserve respondent confidentiality.

4.2. Data Collection

A structured questionnaire was administered by trained enumerators following pre-testing with 30 farmers and subsequent revision. The instrument comprised three modules: (a) a knowledge module with 10 factual questions on hazard symbols, pesticide classes, health effects and banned compounds; (b) an attitude module with 10 statements rated on a five-point Likert scale measuring perceived necessity and risk of agrochemicals; and (c) a practices module documenting application methods, rates, protective equipment use, storage arrangements and disposal practices. Twelve key informant interviews were conducted with extension agents, agrochemical vendors and community leaders to triangulate questionnaire findings [11].

In addition to the structured survey instrument, the study drew on participatory rural appraisal techniques, including village-level group discussions and direct field observation of storage arrangements, mixing procedures and disposal behaviour. Key informants were purposively selected to include experienced district officers, agricultural extension agents, agrochemical vendors, senior members of the farming community and community health workers, each chosen for their capacity to provide reliable information on local farming problems and on the pattern of agrochemical acquisition and use. This triangulation of self-reported questionnaire data against observed behaviour and against the testimony of knowledgeable community actors strengthened the validity of the findings and guarded against the social desirability bias to which self-reported practice data are ordinarily prone [11].

4.3. Statistical Analysis

Knowledge scores (maximum 10 points) and attitude scores (maximum 50 points) were computed for each respondent. Data were analysed using Statistical Package for the Social Sciences (SPSS) version 23, with descriptive statistics and frequency distributions presented by zone. Chi-square tests examined associations between farmer characteristics and adoption of safe practices, with statistical significance set at $p<0.05$ [17].

5. Results and Discussion

5.1. Respondent Characteristics

Of the 350 respondents, 73 per cent were male, with a mean age of 48.2 years. Primary education was the highest level of schooling for 61 per cent of respondents, and 14 per cent had no formal education. Mean farming experience was 21.3 years and household size averaged 7.2 persons. These characteristics are summarised in Table 1 and are consistent with sociodemographic profiles documented for smallholder farmers throughout north-central Nigeria [15].

Table 1. Sociodemographic Characteristics of Respondents by Zone, Rivers Niger and Kaduna Catchments.

Characteristic	Upper Zone	Middle Zone	Lower Zone
Sex	n=123	n=86	n=141
Male (%)	74.0	71.0	73.1
Female (%)	26.0	29.0	26.9
Mean age (years)	47.8	48.5	48.3
Education	n=123	n=86	n=141

Characteristic	Upper Zone	Middle Zone	Lower Zone
No formal education (%)	16.3	12.8	13.5
Primary education (%)	59.3	62.8	61.0
Secondary and above (%)	24.4	24.4	25.5
Mean farming experience (years)	22.1	20.4	21.5
Mean household size	7.4	6.8	7.3

5.2. Knowledge of Agrochemical Hazards

Knowledge assessment revealed substantial gaps across all domains measured. Mean knowledge score across all respondents was 2.3 out of 10 (standard deviation 1.1), indicating very limited comprehension of agrochemical hazards. Only 18.9 per cent of respondents correctly identified the meaning of hazard symbols on pesticide containers, a fundamental safety competency [13]. Awareness of banned and restricted pesticides was reported by 35 per cent of respondents; however, none was able to correctly name the restricted compounds. Fewer than 9 per cent of respondents could classify common pesticides as organochlorine, organophosphorus or synthetic pyrethroid compounds, and 22 per cent were unable to name any active nutrient in NPK fertilizers. Knowledge regarding health effects of pesticide exposure was extremely limited, with 92.9 per cent unable to identify specific health hazards. These patterns are illustrated in Figure 2a and are consistent with findings from analogous studies in West African smallholder systems [7].

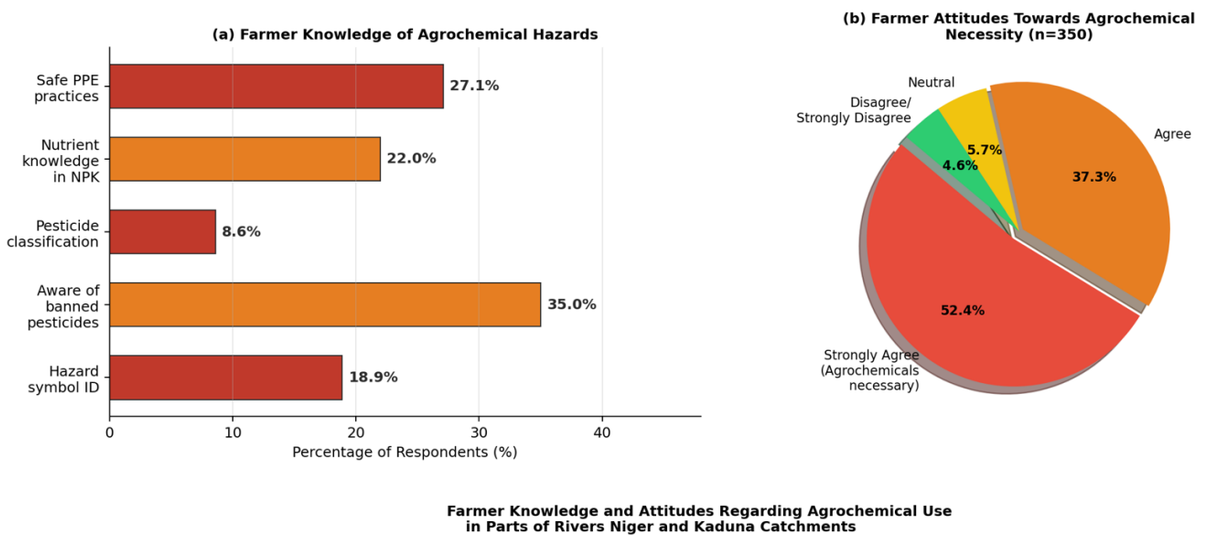

Figure 2. Farmer Knowledge and Attitudes Regarding Agrochemical Hazards and Necessity (n=350): (a) Percentage of respondents with correct knowledge by domain; (b) Attitude distribution regarding agrochemical necessity.

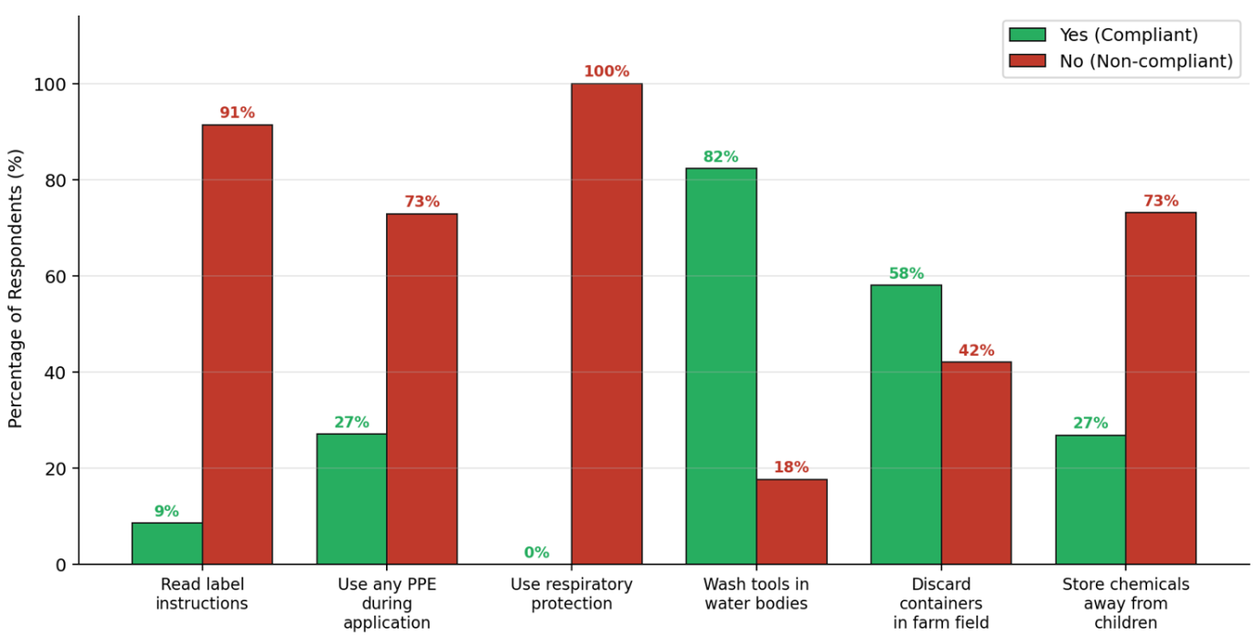

Figure 3. Current Agrochemical Handling and Disposal Practices Among Farmers in the Study Area (n=350).

5.3. Farmer Attitudes

Attitudes towards agrochemicals were predominantly positive. Eighty-nine point seven per cent of respondents agreed or strongly agreed that pesticides are necessary for successful farming, with 86.3 per cent attributing yield benefits as the primary motivation [8]. Despite documented water contamination, only 38.6 per cent agreed that fertilizer runoff damages water quality, and 71.4 per cent disagreed that agrochemicals pose personal health risks. Agrochemical vendors were trusted as information sources by 81.7 per cent of respondents, a finding consistent with the documented influence of commercial actors in technology adoption in sub-Saharan Africa [12]. Mean attitude score was 34.2 out of 50 points. The attitude distribution is shown in Figure 2b.

5.4. Agrochemical Practices and Compliance

Observed practices were characterised by widespread non-compliance with safe handling standards (Table 2). Ninety-one point four per cent of respondents did not follow container label instructions, instead applying agrochemicals at rates determined by personal judgement. This resulted in fertilizer applications of 50 to 170 kg per hectare and pesticide applications of 5 to 10 or more litres per hectare, substantially exceeding recommended rates. Only 27.1 per cent used any form of personal protective equipment (PPE), with cost (1,200 to 2,400 naira per protective set) and discomfort cited as primary barriers [9]. Eighty-two point three per cent of farmers washed application equipment in nearby streams and river channels. Regarding container disposal, 58 per cent discarded empty containers in farm fields and a further 20 per cent disposed of them in nearby bushes. Only 14.3 per cent used designated waste pits. Fifty-four point three per cent stored chemicals in accessible household spaces, and 18.6 per cent reported household members experiencing symptoms consistent with acute pesticide poisoning.

The rates of application documented in the survey substantially exceed agronomic recommendations. Fertilizer was applied at between fifty and one hundred and seventy kilogrammes per hectare, with the largest share of respondents applying in the highest band of one hundred and twenty-one to one hundred and seventy kilogrammes per hectare. Pesticide application ranged from five to more than ten litres per hectare, with the greatest proportion of farmers applying ten litres or more. These elevated rates were most pronounced in the lower zones of both rivers, a pattern of concern because contaminants applied upstream accumulate downstream, so that the heaviest chemical loading coincides with the reaches most exposed to the cumulative burden of the entire catchment. All application was carried out manually, fertilizer by direct broadcasting or hand spreading and pesticide by knapsack sprayer, with no consideration given to wind direction, timing relative to rainfall or proximity to watercourses and other vulnerable areas.

The disposal of empty pesticide containers followed equally hazardous patterns. The largest proportion of respondents discarded empty containers directly on their farmland, a further share disposed of them in nearby bushes and roadsides, and only a minority made use of designated disposal pits. A small number disposed of containers in latrines. Beyond the containers themselves, the study established that most farmers washed their application equipment in the rivers, streams and ponds after spraying, and that leftover spray mixture was frequently emptied directly into or near water bodies. Taken together, these disposal and equipment washing practices constitute a direct and continuous conduit for agrochemical residues into surface water, and they explain in behavioural terms the contamination that the analytical components of the wider investigation confirmed in both water and sediment across all zones.

The origins of the products in use are also relevant to the compliance picture. Farmers reported obtaining their fertilizers and pesticides principally from local agrochemical vendors, from government subsidy and intervention programmes and from gifts distributed by politicians. This diversity of supply channels, several of which lie outside any regulatory oversight, complicates efforts to control the quality of products entering the catchment and to ensure that banned or restricted compounds do not reach farmers. It further explains why so many respondents were using organochlorine formulations of which they had no regulatory knowledge, since the informal and politically mediated supply routes carry no accompanying guidance on product status or safe handling.

Table 2. Summary of Farmer Knowledge, Attitude and Practice Scores by Domain.

KAP Domain	Indicator	Score / % Respondents
Knowledge (max=10)	Mean knowledge score	2.3 ± 1.1
	Correctly identified hazard symbols	18.9%
	Aware of banned pesticides	35.0%
	Could classify pesticide compounds	8.6%
Attitudes (max=50)	Mean attitude score	34.2 ± 5.8
	Agrochemicals necessary for farming	89.7%
	Disagree that pesticides pose health risks	71.4%
Practices	Follow label instructions	8.6%
	Use personal protective equipment (PPE)	27.1%
	Wash tools in nearby water bodies	82.3%
	Discard containers in farm field	58.0%

5.5. Socioeconomic Implications of Unsafe Practices

The unsafe practices documented above carry socioeconomic consequences that the study communities themselves recognise and articulate. An overwhelming majority of respondents affirmed the presence of environmental concerns attributable to agrochemical use in their zones, identifying the killing of aquatic organisms, water pollution and soil quality degradation as the most salient effects. When asked to rate the severity of these effects, most respondents judged agrochemical use to be moderately or very harmful to the environment, with surface water and soil identified as the media most at risk. The extinction of fish, upon which the communities depend heavily for both nutrition and income, was a recurring theme in the group discussions and represents a direct erosion of the natural resource base that sustains local livelihoods.

The human health burden was equally prominent in community testimony. A large majority of respondents affirmed the existence of health problems associated with fertilizer and pesticide use, and community health records for a single calendar year documented substantial numbers of skin, eye, stomach and respiratory complaints of the kind consistent with agrochemical exposure. Community health workers and other stakeholders further reported an apparent increase in more serious conditions since agrochemical use became widespread, including cancers, neurological disorders and reproductive complications, conditions that the broader scientific literature associates with chronic exposure to persistent organochlorine compounds and to nitrate contamination of drinking water. While the survey cannot establish causation for these severe conditions, the convergence of community testimony, documented residue contamination and the known toxicology of the compounds in use gives the reported health burden considerable plausibility.

These environmental and health effects translate directly into economic hardship. The great majority of respondents affirmed that agrochemical-related environmental and health problems had reduced household incomes, principally because earnings from farming were being diverted to meet the cost of treating illness, and because sickness reduced the labour capacity available for farming itself. Stakeholder interviews corroborated these accounts and additionally revealed farmer indebtedness to financial institutions arising from this compression of income. The socioeconomic evidence therefore closes a self-reinforcing loop in which unsafe agrochemical practice degrades the environment and community health, and the resulting costs deplete the very resources that farmers would need in order to invest in safer inputs and methods.

The pattern of knowledge deficit was consistent across the three zones and did not vary meaningfully with location along either river. Of particular concern was the finding that although thirty-five per cent of respondents were aware in general terms that certain pesticides are banned or restricted in Nigeria, none was able to name a single restricted compound or to identify the regulatory category to which any product belonged. This is a critical gap, because several of the pesticide formulations found in active use in the study area are organochlorine compounds of exactly the kind that national and international instruments seek to phase out. Among these was dichlorodiphenyltrichloroethane, which is banned in Nigeria, together with aldrin, chlordane, dieldrin and endosulfan, which are variously banned or restricted for local use and export in other jurisdictions. Farmers were applying these hazardous products with no awareness of their regulatory status and no comprehension of the persistence and toxicity that underlie their restriction.

The knowledge gap also extended to the health consequences of exposure. The overwhelming majority of respondents were unable to identify any specific health hazard associated with pesticide contact, notwithstanding that the study communities reported a substantial burden of skin complaints, eye irritation, stomach pain and respiratory symptoms consistent with acute pesticide exposure. This dissociation between the experience of symptoms and the attribution of those symptoms to agrochemical handling is itself a manifestation of the knowledge deficit, and it materially reduces the likelihood that farmers will adopt protective measures voluntarily. The finding that farmers acquire their limited understanding of application chiefly from agrochemical vendors, who are themselves without formal training, indicates that the prevailing informational channel actively reproduces unsafe practice rather than correcting it [13].

Figure 3 illustrates the distribution of agrochemical handling and disposal practices among the 350 respondents, showing the proportions engaging in equipment washing in watercourses, inadequate use of personal protective equipment, improper container disposal and other unsafe behaviours that collectively constitute the principal pathways through which agrochemical residues enter the Rivers Niger and Kaduna catchments.

5.6. Discussion

The critically low knowledge scores and pervasive unsafe practices documented in this study reflect the combined and mutually reinforcing effects of inadequate extension support, economic constraints and the near-absence of regulatory enforcement. The finding that 81.7 per cent of farmers rely on agrochemical vendors as their primary source of advice, whilst those vendors themselves lack formal training, represents a critical institutional gap that multiplies risk at scale [4]. The positive attitudes towards agrochemical use, even in communities where some family members report poisoning symptoms, indicate that perceived yield benefits override concern about health and environmental risks [2]. This suggests that simply providing risk information is unlikely to change behaviour; rather, interventions should demonstrate safer alternatives that maintain or improve productivity. The finding that farmers with secondary education and prior extension programme experience show significantly higher adoption intentions (chi-square test, $p<0.05$) indicates that investing in education and extension access would yield measurable attitude and behaviour change [3].

The regulatory dimension compounds these behavioural findings. The wider investigation established that the environmental laws and extant regulations governing agrochemical use near sensitive and vulnerable areas were rated as weak or very weak across almost every dimension of the compliance framework applied, from the clarity and comprehensibility of the rules to the probability of inspection and the strength of both formal and informal sanctions. Farmers and vendors reported little knowledge of the legal requirements, saw compliance as a burden that yielded no benefit, and operated in an environment where the objective chance of being inspected was negligible. In such conditions, voluntary safe practice cannot be expected to emerge from regulation alone, and the burden of behaviour change falls almost entirely on education, extension and the demonstration of viable alternatives.

The convergence of very low knowledge, favourable attitudes towards chemical inputs, pervasively unsafe practice, a supply system that operates partly outside regulatory control and an enforcement architecture that is effectively dormant produces a situation in which contamination is not an aberration but the predictable outcome of the prevailing incentive structure. Interventions that address only one of these elements are unlikely to succeed. A durable improvement requires simultaneous action on farmer knowledge through participatory training delivered in local languages, on the competence and accountability of the vendor network through licensing and mandatory training, on the affordability and availability of protective equipment, and on the credibility of enforcement, so that the incentives facing farmers begin to reward rather than penalise safe practice.

6. Conclusions

Farmer knowledge regarding agrochemical hazards is critically limited in the study area, with mean scores of 2.3 out of 10 points. Attitudes are broadly supportive of agrochemical use, and practices are widely unsafe. These findings confirm the need for targeted, participatory farmer training programmes delivered in local languages, agrochemical vendor licensing and training, subsidised protective equipment distribution, and strengthened extension services. Without these measures, current practices will continue to degrade water quality in the Rivers Niger and Kaduna catchments and expose farming communities to preventable health risks [5].

The evidence assembled here indicates that the knowledge, attitudes and practices of farmers in the Rivers Niger and Kaduna catchments together constitute a coherent behavioural system that generates and sustains agrochemical contamination of the catchment environment. Knowledge of hazards is critically deficient, attitudes strongly favour

continued chemical use, and practices across acquisition, application, storage and disposal depart systematically from safe standards. These behavioural findings are consistent with, and provide the human explanation for, the physical contamination and socioeconomic hardship documented in the companion components of this research. They also demonstrate that risk information alone is unlikely to alter behaviour, since farmers already tolerate observable harm to health and environment in exchange for perceived yield security.

Effective response therefore demands a coordinated programme rather than isolated measures. Participatory farmer training delivered in Hausa and Nupe should be prioritised and structured around the demonstration of safer methods that preserve or improve productivity, since attitudinal evidence shows that farmers will consider change only where productivity is protected. The agrochemical vendor network, which currently functions as the principal and unqualified source of technical advice, should be brought within a licensing and training regime so that the dominant informational channel ceases to reproduce unsafe practice. Subsidised distribution of protective equipment should address the cost barrier that most respondents identified, and extension services, presently understaffed to the point of near absence, require substantial reinvestment if any of these measures is to reach farmers at scale. In the absence of such coordinated action, the practices described will continue to degrade water quality across the catchment and to expose farming communities to preventable environmental, health and economic harm [5].

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