Waste Management and Potential Environmental Impacts of Occupational Vat Dyeing Practices in Kano Metropolis, Nigeria

[1]*Abdullahi, S., [2]Adie, D. B., and [3]Salisu, A
[1]Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria
[2]Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria, Nigeria
[3]Division of Agricultural Colleges, Ahmadu Bello University, Zaria, Nigeria
*Corresponding author: abdullahis@abu.edu.ng, +2348020761942

Abstract
Industrial effluents in Nigeria are not treated in most cases but dumped into nearby open drainages and water bodies which is an exact situation in Kano metropolis. Vat dyes are the main causes of pollution in textile wastewaters and other industrial effluents. The aim of this paper is to investigate the waste management strategies of occupational dyers in Kano metropolis and determine the potential environmental impacts of the dyeing activity. A structured questionnaire was administered among 1387 dyers and further information was obtained via focus group discussion and observation. Data were analysed by descriptive statistics (frequency and percentage) using statistical package for the social sciences (SPSS) software. Results showed that environmental officers played a vital role in educating the dyers on the impacts of chemicals on the environment as well as waste management. Effluent from the dyehouses is not treated and the drainages are poor which could cause ground water contamination since the dyehouses are in close proximity to residential areas. The dyers are well aware of some of the potential impacts of their wastewaters. The study recommends that the dyehouses should be relocated to the industrial areas of the state and relevant agencies should enforce stringent environmental laws with regards to effluent discharge. The dyers should also be encouraged to revert to the use of natural dyes which are less polluting for sustainable development.

Key words: waste management, effluent, Kano metropolis, environmental impact, vat dye

INTRODUCTION

Waste management is one of the greatest challenges facing humanity in modern times and its principle is saddled with the mandate of protecting the environment by reducing, reusing, recycling, and proper disposal of waste (Yalcin-Enis *et al.,* 2019). Waste management is all the activities and actions required to manage waste from its inception to its final disposal which include collection, transport, treatment, disposal, as well as monitoring and regulation. The best practice available for waste management is zero waste which is an approach to eliminate waste rather than manage it (Shafiul and Islam, 2021). Currently, environmental legislation states that dyehouses have to ensure that the wastewater they release abide by the international dye industry wastewater discharge quality standards that were adopted from the Zero Discharge of Hazardous Chemicals Programme (ZDHC) (Rapo and Tonk, 2021).

Textile industries produce liquid waste containing dyes and finishing agents, a significant amount of solid waste, and greenhouse gases (Shafiul and Islam, 2021). Dye manufacturing industries and dyehouses constitute about 28 % of effluent generated worldwide (Rapo and Tonk, 2021). During colouration process, a large percentage of the dyes do not bind and is lost to the waste stream increasing their colour and toxicity (Arcanjo *et al.,* 2018). The composition of textile industry wastewater varies from mill to mill and from country to country, depending on the process, the equipment used in the factory, type of fabric produced, chemicals applied etc. (Yaseen and Scholz, 2019). Textile effluents are characterized by high values in terms of several physicochemical and biological parameters including colour, temperature, pH, salinity, biological oxygen demand (BOD), total dissolved solids (TDS), chemical oxygen demand (COD), total nitrogen, total phosphorous, and non-biodegradable organic compounds (Berradi *et al.,* 2019).

Effluent components can be classified in four ways of sustainability: coloured and colourless, dissolved or not dissolved, biodegradable or non-biodegradable, and toxic or non-toxic (Khatri *et al.,* 2015). As the quantity of wastewater increased and its characteristics become more complex, the carrying capacity of the receiving environment eventually decrease to a level where natural treatments are insufficient and environmental problems begin to arise (Amare *et al.,* 2018). Environmental pollution due to dyeing is mainly related to water pollution as emissions to air are generally not significant due to the low vapour pressure of the substances in the dyebath (Chavan, 2011). Contamination of aquatic systems is a universal phenomenon that greatly affects developing countries as a consequence of the dumping of untreated or partially treated wastewater (Barrios-Ziolo *et al.,* 2016). After their breakdown, dyes and auxiliary chemicals contaminate the nearby soil, sediment, and surface water becoming a major global environmental pollution challenge (Yaseen and Scholz, 2019).

Vat dyes in the non-soluble form do not represent an environmental risk as regards to their toxicity (Bozic and Kokol, 2008) but are the main causes of pollution in the wastewaters of textile and other industrial effluents (Rapo and Tonk, 2021) which some countries classify as the most toxic class of wastewaters (Bozic and Kokol, 2008). The anthraquinone based vat dyes require more synthetic steps than the acid, basic, direct, disperse and reactive dye classes (Baptista, 2009). The multiple chemical reactions increase the consumption of raw-materials, resulting in vat dyes having the highest ratio of raw-materials to finished dye. Synthesis of vat dyes involve the use of hazardous raw-materials, catalysts, and solvents. Common solvents used are nitrobenzene, naphthalene, 1,2-dichlorobenzene etc. and all of these are hazardous chemicals with the potential of severe environmental contamination (Baptista, 2009). Typically, released vat dyebath contains spent caustic soda, reducing agent, dispersing agents, auxiliaries such as levelling and sequestering agents (Bechtold and Turcanu, 2009) and heavy metals.

Several studies investigated waste management strategies and environmental impacts of effluent generated by small scale dyeing industries. Sulthonuddin and Herdiansyah (2021) suggested the strategies for sustainable batik wastewater management in Paoman village, Indonesia. Rahman et al. (2019) assessed public perception and the impact of loom-dye effluent contaminated irrigation water on the growth of rice in Belkuchi, Bangladesh. Selase et al. (2021) conducted a survey on waste management among batik and tie-dye workers in Ho Municipality, Ghana. Oguntade et al. (2018) investigated the impact of dye-laden effluent contaminated irrigation water on growth, yield, and metal uptake of plants produced in Abeokuta, Nigeria. Bioremediation of "Adire" tie-dye effluent in Ibadan, Nigeria (Okareh *et al.,* 2017), and Abeokuta, Nigeria (Balogun *et al.,* 2017) has been reported. Until now, very little work was done with regards to the effluent from occupational vat dyers in Kano metropolis. Previous studies were mainly on ecotoxicity of the dyes used (Abdullahi *et al*., 2016; Sani *et al*., 2018).

In this paper, we report the results obtained from an investigation of waste management strategies and potential environmental impacts of effluent generated by the occupational dyers in Kano metropolis. Kano metropolis was selected because there are many secondary dyeing units in the area that are engaged in non-industrial dyeing using synthetic vat dyes and chemicals consuming large amount of water for dyeing and rinsing, and generating large quantities of effluent. The study will contribute in addressing the fundamental questions: How is effluent discharged in the dyehouses? How close are the dyehouses to residential areas? What are the dyers' perceptions on the potential environmental impacts of the dye wastewater? The study will focus on dyers using synthetic vat dyes and chemicals.

MATERIALS AND METHODS

Study Area

Kano metropolis is boarded by Madobi and Tofa Local Government Areas to the South West, Gezawa to the East, Dawakin Kudu to the South East, and Minjibir on the North East. The metropolitan area comprises 6 core local governments (Dala, Fagge, Kano Municipal, Nassarawa, Gwale, and Tarauni) and 2 peri-urban local governments, Kumbotso and Ungogo (Balogun *et al*., 2020). It has an estimated population of 3, 507, 632 as at 2014 (Weber *et al*., 2017) with a population density of about 1000 inhabitants per km^2 compared to the national average of 267 per km^2. It lies between Lat. 10º and 12ºN and Long. 8º and 9ºE with an area of 600 km^2, an altitude of 488 m above sea level (Suleiman *et al*., 2020) and predominantly comprised of Hausa and Fulani ethnic groups who are mostly Muslims (Iliyas, 2000).

The climate of the area is the tropical wet and dry Aw by Koppen's classification and there is no large water body or shared border with an ocean (Shawai *et al.,* 2019). As at 2015, there were 270 factories in the 4 industrial estates where tanneries and textiles are dominant and generate more than 90 % of liquid and solid wastes mostly discharged into open drains and eventually onto land surfaces and into natural waters in the vicinity (Nabegu, 2016). Increased population in Kano metropolis results in the generation of high heaps of municipal waste which are dumped at the shoulders of major streets, available open spaces, and even in open water bodies where those refuse are good contaminants of streams and ground water especially shallow wells (Butu and Mshelia, 2014). For the purpose of this study, the respondents are called “dyers” and the non-industrial dyeing units are referred to as “dyehouses”.

Data Collection and Analysis

The study relied on data gathered through a structured questionnaire, focus group discussion (FGD), and observation. Responses and FGD were supported by observation to have a clear picture of the situation and better understanding of the processes. A structured questionnaire was developed according to standard protocol for questionnaire design and testing as described by Geer et al (2006) and questions were developed as a result of insight from UNESCO (1999). The validity of the coverage of questions included in the questionnaire (content validity) was gained through experts in the field, colleagues as well as members of the target population. Reconnaissance visits were made in June, 2020 to locate the dyers. The developed questionnaire was pretested among the dyers that did not participate in the study and during the reconnaissance visits. Variability in dyers response and the understanding of question content (face validity) were evaluated and this information was used to produce a revised final version of the questionnaire, specifically questions were added where content coverage was lacking and questions were rephrased where understanding was vague. The questionnaire was prepared in English but was communicated to the dyers in their local dialect (Hausa).

There were 5 questions in 1 section (e.g., whether an environmental officer visited the dyeing enterprise and why, ways in which wastewater is discharged, distance of the dyehouse to the next available residence etc.). The research population is the total number of occupational vat dyers in Kano metropolis and participating dyers were chosen as a purposive sample. A total of 1387 questionnaires were administered in 20 dyehouses (geographical locations of the dyehouses are shown in Abdullahi *et al.,* 2021a) where willingness to participate in the study was confirmed through completed consent form. Dyers who are at least 18 years of age and had worked for at least 5 years in the dyehouses were eligible to participate in the study. Data was collected from August to December, 2020, with the dyers working, through self-completed questionnaire by the researcher and 3 enumerators over a duration of 25-30 minutes with each dyer being asked the same question in the same order. A monetary incentive of ₦3000 ($7.75) was provided for participation due to initial reluctance to participate because according to the dyers, the Chinese used similar approach to learn their techniques. Before initial data screening all the completed questionnaires were coded and entered in Excel software after which the data were analysed by descriptive statistics (frequency and average) using SPSS version 26.

Other data sources included observations while the dyers are on the job. For a study such as this, observation approach is indispensable as certain information can best be obtained through direct observation hence, we adopted a participant observation method. Additional information was obtained from focus group discussion with the researcher, assistant researcher and 7 dyers, 1 from a dyehouse in each of 7 local government areas (Nassarawa was not represented) in December, 2020 selected by purposive sampling technique. Two key informants were used in the study. Focus group discussion with the dyers centred on a short list of 3 open-ended questions namely how they discharge their wastewaters, their encounter with environmental officer, and their perception on the potential environmental impacts of the dye effluent. Focus group discussions were audiotape-recorded so that reference could be made to the remarks of the participants in order to ascertain common themes. The discussion lasted for 2 hours and was recorded using paper and pencil.

RESULTS AND DISCUSSION

Waste Management

Figure 1 shows that most of the dyers (72 %) belong in a dyehouse where the liquid waste (dye effluent/mercerizing wastewater) is discharged into open drain. Effluent from tannery and dyeing industries in Kano metropolis are similarly discharged into open drains affecting the natural waters in the vicinity (Nabegu, 2016). It has been observed that the open drains (gutters) are shallow (Figure 2) and stagnate wastewater (Figure 3). The stagnation of wastewater could be due to the fact that littering of refuse in drainages is common along the streets of Kano metropolis (Balogun *et al.,* 2021). Some of the dyehouses do not even have drainage at all which was why certain proportions of the dyers either dump the effluent on the ground or into a sewage system. Recently, residents of Kano metropolis lamented on lack of drainage on the streets of the city (Murtala, 2018). Discharge of dye wastewater into poor drainage system by small scale dyeing industries has been reported previously (Selase *et al.,* 2021; Makinde *et al.,* 2010; Upadhyay and Panday, 2015; Howard *et al.,* 2019). Selase *et al.* (2021) reported that local batik/tie-dye workers in Ghana dispose of their wastewater into sewage system, onto the ground, into septic tank which is emptied from time to time, and by recycling.

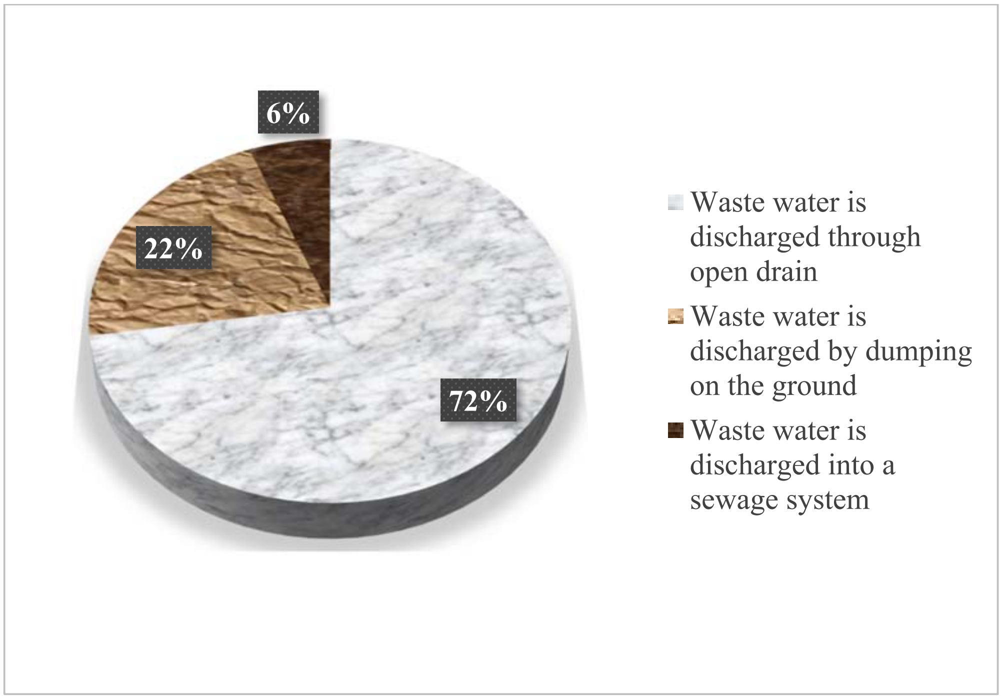

Figure 1: Ways of discharging dye effluent

Figure 2: Shallow drainage

Figure 3: Stagnant effluent in a drainage

The effluent discharged by the dyers is not recycled or treated to remove toxic substances. Similarly, companies producing readymade clothing in Bangladesh (Shafiul and Islam, 2021) and small-scale batik industries in Indonesia (Sulthonuddin and Herdiansyah, 2021) do not have wastewater treatment plants. Even in textile industries, it is difficult to properly dispose of wastewater which is one of the major challenges that affects the global world (Al-Tohamy, 2022) where this problem is more serious in developing countries (Rosa *et al.,* 2017) like Nigeria. Generally, poor working conditions and low economic status associated with small scale industries do not allow an efficient wastewater treatment before disposal (Bazin *et al.,* 2012) and as such local dyeing industries in Nigeria do not operate any treatment process for their wastewater (Okareh *et al.,*2017; Adedeji and Ako, 2009). Adopting conventional treatment methods to treat huge volumes of wastewater in developing countries would be expensive in terms of initial installation cost and subsequent operational and maintenance costs (Manu, 2007).

The recent treatment approaches for dye wastewater include membrane separation, adsorption, advanced oxidation processes, bio-electrochemical treatment, photocatalytic degradation etc. (Shindhal *et al.,* 2020) where adsorption was found to be more suitable due to its ease of use, cost effectiveness, and high efficiency (Rapo and Tonk, 2021). Vat dye effluent has been treated using bioremediation (Gurav *et al.,* 2011; Olaganathan and Patterson, 2009; Sirianuntapiboon *et al.,* 2006), adsorption (Golob and Ojstrsek, 2005), coagulation/flocculation (Manu, 2007), ultrafiltration (Golob and Ojstrsek, 2005), and electrochemical methods (Kariyajjanavar *et al.,* 2013). Membrane filtration preceded by physicochemical treatment was proposed for the reclamation of dye wastewater from a denim manufacturing textile mill in Turkey (Yukseler *et al.,* 2017). The dyers mostly mercerize the fabric before dyeing (see Abdullahi *et al.,* 2021b) and this also constitutes a lot of liquid waste. It is possible to reuse mercerization wastewater because high amount of caustic soda can be recovered and reused (Yukseler *et al.,* 2017). Merkel et al. (2017) has recovered significant amount of caustic soda using electrodialysis.

Discussion with the dyers revealed that some of them have tried the use of septic tanks for wastewater discharge but that did not work because the tank could not be emptied after accumulation. According to them, there was little or no environmental problem when they were using natural indigo dye. Some of the dyers suggested that provision of adequate and appropriate drainage will solve the effluent problem while others opined that wastewater treatment plant will suffice. It was observed that the best option is to relocate the dyeing units to any of the 4 industrial estates. Tie-dye workers in Ghana suggested the use of incinerator (27.5 %), sewer system (16.2 %), and wastewater treatment plant (48.8 %) as waste management strategies (Selase *et al.,* 2021). Sulthonuddin and Herdiansyah (2021) have suggested preventive measures for small scale batik industry in Indonesia which include educating communities on industrial waste management, provision of waste management facilities, monitoring activities for environmental quality, and educating the dyers on eco-friendly processes such as the use of natural dyes.

It has been observed that the solid waste generated range from polyethene bags containing caustic soda, hydros, and dyes, candle wax used for batik work, and polyester yarn used for creating patterns during tie-dye, as well as sludge accumulated where liquid waste is continuously dumped on the ground. The dyers usually burn solid waste or allow it to litter in the environment. Similarly, a large proportion of tie-dye workers in Ghana dispose of their solid waste by burning (Selase *et al.,* 2021). Conventionally, landfill and incineration are the 2 main strategies that are used for solid waste management where the former produces leachate which may result in soil and ground water contamination while the latter produces hazardous gases such as dioxin and nitrogen oxides which are discharged into the atmosphere (Shafiul and Islam, 2021). Industries within residential areas in Kano metropolis generate only 2.9 % of municipal solid waste (MSW) but those wastes are left on the street and clogs drainages (Nabegu, 2016) where it is very common to find the drainage lines being filled up with refuse after rainfall (Butu and Mshelia, 2014).

A little more than half of the dyers (53.1 %) have been visited/monitored by an environmental officer (EO) in their place of work. The 737 (53.1 %) of the dyers visited were enlightened on waste management while 731 (52.7 %) of them were educated on the environmental impacts of dye effluent as shown in Table 1. Some of the dyers (19.5 %) have been penalized previously due to improper discharge of effluent. Discussion with the dyers revealed that representatives of Kano State Ministry of Environment (KSME) occasionally pay them a visit to inspect their activities particularly the manner in which wastewater is discharged. The areas not visited by those officials are mostly in Kumbotso and Fagge Local Government Areas where the dyehouses are difficult to locate with most of them working in the house of owner (see Abdullahi *et al.,* 2021a).

Table 1: Legislation on waste management

Reasons for EO's visit	Yes N=1387 (%)	No N=1387 (%)	Missing N=1387 (%)	Total N=1387 (%)
Ensure dye effluent is properly discharged	731 (52.7)	6 (0.4)	650 (46.9)	1387 (100)
Explain the impact of effluent on the environment	737 (53.1)	0 (0)	106 (46.9)	1387 (100)
Penalize those that discharge wastewater indiscriminately	270 (19.5)	467 (33.6)	650 (46.9)	1387 (100)

Many guidelines, recommendations, and propositions have been developed to ensure the protection of water which may soon become a scarce commodity. Countries such as the United States, Canada, Australia, France etc. have national environmental legislation which establishes dyehouse effluent limit values to comply while in some countries the emission limits are mainly recommended but not mandatory (Hessel *et al.,* 2007). In Nigeria, the Federal Ministry of Environment through the National Environmental Standards and Regulations Enforcement Agency (NESREA), KSME as well as local governments in the affected area are responsible for ensuring the safe use and disposal of toxic chemicals (Nabegu, 2016). Regulations and guidelines are set by NESRIEA even though the legislation of the agency is limited because proof of causation is a requirement which is often difficult to establish especially with regards to water pollution originating from industrial operations (Adedeji and Ako, 2009). Recently, the agency warned manufacturers in Kano to desist from degrading the environment and also urged them to treat effluent at least to primary levels before discharge into the public drain (Essen, 2017).

Potential Environmental Impacts

It is estimated that the World's population will reach 8.2 billion in 2025 with the current annual growth rate of 1 % (Yalcin-Enis *et al.,* 2019) and nearly 1.8 billion people all over the world may face absolute water scarcity by 2025 (Hasan *et al.,* 2019). The World's annual waste generation amounts to 7-10 billion tonnes out of which approximately 2 billion tonnes is MSW (Yalcin-Enis *et al.,* 2019). In developing countries such as Nigeria, the sitting of industries is determined by various criteria some of which are environmentally unacceptable like the establishment of industrial estates in most state capitals and large urban centres in the country (WHO/UNEP, 1997). Toxicity of chemicals used by industries in Kano metropolis are not generally tested where most of those chemicals can be harmful to the environment. Tannery and dye effluent from factories (Nabegu, 2016) as well as high rate of MSW in Kano (Butu and Mshelia, 2014) largely contribute to environmental pollution.

During the dyeing process, 100-200 l of water/kg of fabric is used and 85-95 % of that water is discharged as waste (Olaganathan and Patterson, 2009). Additionally, in batch dyeing, as carried out by the dyers investigated, the fabric remains in a single piece of equipment which is filled with water and then drained after both the actual dyeing and rinsing. Each time the fabric is exposed to a separate bath, it uses water about 5-10 times its weight (Chequer *et al.,* 2013). Dumping of such huge wastewater into the poor drainages or on the ground means that, ultimately, the large volume of dye effluent will seep into the ground and also affect the surrounding soil. Similarly, Oyedele et al. (2014) suggested that dye effluent from "Adire" dye workers in Abeokuta, Nigeria seep into the wells of residents in the production area. Wastewaters that flow in drainages corrodes the sewage pipes, affects drinking water quality and can be a breeding ground for bacteria and viruses. When effluent is allowed to flow in the fields it clogs the pores of the soil resulting in loss of soil productivity, hardening of soil texture, and impeding penetration of roots (Kant, 2012). The wastewaters can have serious effect on groundwater sources since 65 % of the dyehouses are not more than 91 m away from residential buildings as shown in Figure 4.

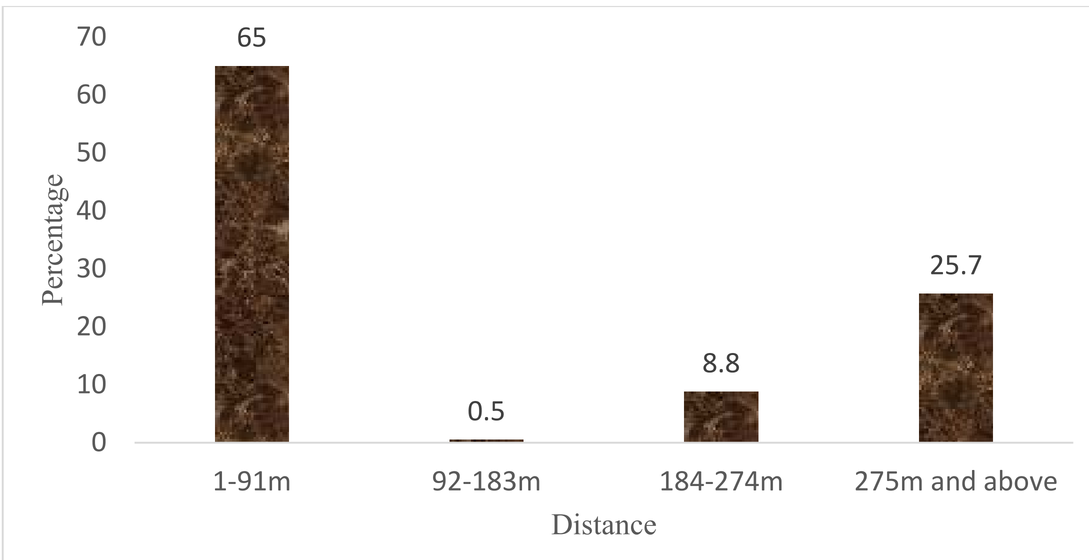

Figure 4: Distance from dyehouse to a residential building

Table 2 shows the perception of the dyers on the potential environmental impacts of dye effluent. Most of them (68.2 %) strongly agreed with the perception that dye effluent seep into the ground. More than half disagreed with the possibility of dye effluent going to treatment plant. A little above half (53.3 %) are in agreement that the dye effluent is highly coloured. Almost half (49.6 %) strongly agreed that the dye effluent can kill plants and aquatic organisms. About two third of the dyers are strongly in disagreement with the assertion that the dye effluent does not smell. Discussion revealed that most of the dyers are aware that dye effluent should not be disposed of directly onto soil surfaces or into water bodies. Similarly, dye workers in Bangladesh agreed (48.3 %) with the perception that fish culture and cattle rearing is hampered due to pollution caused by loom-dye effluent, agreed (48.33 %) that loom-dye effluent should not be disposed directly in cropland, and also agreed (66.67 %) that the loom-dye effluent should not be disposed directly in water bodies (Rahman *et al.,* 2020).

Table 2: Perception of dyers on environmental impacts of dye effluent

Perception	Strongly disagree N=1387 (%)	Disagree N=1387 (%)	Agree N=1387 (%)	Strongly agree N=1387 (%)	Total N=1387 (%)
Wastewater discharged seep into the ground	6 (0.4)	6 (0.4)	430 (31)	945 (68.2)	1387 (100)
Wastewater discharged goes straight to a treatment plant	423 (30.5)	841 (60.6)	80 (5.8)	43 (3.1)	1387 (100)
Wastewater disposal unit is highly coloured	12 (0.9)	0 (0)	767 (55.3)	608 (43.8)	1387 (100)
Vat dye effluent can kill plants and aquatic animals	25 (1.8)	6 (0.4)	669 (48.2)	687 (49.6)	1387 (100)
Waste water discharged does not smell	884 (63.7)	448 (32.3)	18 (1.3)	37 (2.7)	1387 (100)

Dyebath prepared by the dyers contains the dye, caustic soda, hydros, and to a very little extent sodium sulphate and sodium chloride (Abdullahi *et al.,* 2021c). The sizing bath contains cassava starch which is used to stiffen the dyed materials in preparation for calandering. Typically, released vat dyebath contains spent caustic soda, reducing agent, dispersing agents, auxiliaries such as levelling and sequestering agents (Bechtold and Turcanu, 2009), and heavy metal impurities due to their production processes (Baptista, 2009; Rapo and Tonk, 2021). Vat dyes are highly eliminable due to their high degree of fixation and for the fact that they are water insoluble. They are not bioavailable due to their insolubility and the amount of unfixed dye is small because of their high exhaustion levels (Lacasse and Baumann, 2004). As most vat dyes are exhausted up to 95 %, a little of the dye is left in the bath and consequently the effluent load resulting from this unused dye is minimal (Chakraborty, 1992). Vat dye effluent is considered as a highly polluting wastewater (Bozic and Kokol, 2008; Rapo and Tonk, 2021).

Croce et al. (2017) assessed the ecotoxicity of several dye formulations including 3 vat dyes and classified all the dyes as "toxic" by the algal assay. De Luna et al. (2014) investigated acute and chronic ecotoxicity of vat, reactive, acid and food dyes and showed that among the textile dyes used, vat dye was the most toxic where after 30 mins. of treatment the generated products were more toxic than the original dyes. De Oliveira et al. (2016) assessed the toxicity of direct, reactive, and vat dyes to the embryonic and larval development of zebra fish and suggested that all the dyes exhibited developmental toxicity to the fish embryo which could decrease survival and that Vat Green 3 have sublethal effects on the embryo at a concentration of 100 mg/l. Fish and other aquatic organisms, which are the major source of protein, can cause symptoms such as cramps, fever, and hypertension if they are consumed by humans whilst retaining dyes (Al-Tohamy, 2022). Sani et al. (2018) investigated the ecotoxicity of vat dyes used in Kano metropolis and suggested that the dyes may pose serious environmental risk especially with the presence of heavy metals.

The amounts of auxiliaries consumed in wet dyeing processes is much higher than dyes and those chemicals are generally non-reactive and are not absorbed by the substrate being dyed ending up in wastewater which may cause problems in the aquatic environment (Wang *et al.,* 2002). Dyers in Kano metropolis use an average of 21.36±3.36 g/l caustic soda and 18.93±1.98 g/l hydros for just 0.5 g/l of dye powder for dyeing (Abdullahi, 2023). It has been reported that stream containing 25 mg/l caustic soda caused the death of fish and highly concentrated solution kills crops and destroys vegetation (Bhupinder Kaur and Chanchal, 2016). Caustic soda spills on soil causes groundwater pollution if precipitation occurs before clean-up and the greatest negative impact from the release of caustic soda solution into the environment is the resulting pH change (Gad, 2014). Presence of excess concentration of soluble salts such as caustic soda, sodium sulphate, sodium chloride etc. even in small quantities are found to be toxic to aquatic life (Ghaly *et al.,* 2014) and in arid and semi-arid regions increase in salinity of water increases the osmotic pressure of mammalian and aquatic species (Hessel *et al.,* 2007).

Salts of sulphur in the form of sulphates and sulphites contaminate sewage, lower its pH and show corrosive action where sewage comes in contact with concrete works, iron structures etc. (Kulandainathan *et al.,* 2007). They also affect the environment detrimentally by noxious odours, toxicity, and high chemical oxygen demand of the wastewater (Bozic and Kokol, 2008). When hydros is exposed to water, it liberates sulphur dioxide gasses which are corrosive to equipment and buildings (Bajpai, 2018). Dispersing agents in vat dye formulations (mostly formaldehyde condensation products) are water insoluble and poorly degradable and therefore remain in the wastewater (Lacasse and Baumann, 2004). Heavy metal and dyes remain in water and soil for long periods reducing soil fertility as well as the photosynthetic activity of aquatic plants resulting in the development of anoxic conditions for aquatic fauna and flora (Al-Tohamy, 2022). Fossil fuels used by the dyers as a source of power can pollute the environment as their use causes climate change (Yalsin-Enis *et al.,* 2021).

CONCLUSION

Results showed that environmental officers played a vital role in educating the dyers on the impacts of chemicals on the environment as well as how to manage wastewaters. Effluent from the dyehouses is not treated and is normally discharged into drainages that are poor and also on the ground and into sewer systems. The discharged effluent may seep into the ground and cause ground water contamination since the dyehouses are not more than 91 m away from residential areas. The effluent can also affect soil fertility thereby retarding the growth of plants. The dyers are well aware of the potential impacts of their wastewaters and believe that provision of adequate and functional drainages will solve the effluent problems. The study recommends that the dyehouses should be relocated to industrial areas of the state where their activities can be closely monitored. Stringent environmental laws should be enforced with regards to waste management and the dyers should be encouraged to revert to the use of natural indigo dyes which are usually grown in the state and most of the dyers already have the technical know-how being formally traditional indigo dye workers. The natural dyes could be less polluting for sustainable development.

FUNDING

This research was supported by the Federal Government of Nigeria under TETFUND supervised by National Research Fund (TETFund/DR&D/CE/NRF/CC/03/Vol.1).

REFERENCES

Abdullahi, L. I., Yakasai, M. A., Bello, B., and Khan, A. R (2016). Determination of heavy metals and acute toxicity studies of vat dyes on earthworm (*Lumbricusterrestis*) as ecological risk indicators. *Journal of Pharmacy*, 6(2): 31-36.

Abdullahi, S (2023). Survey on occupational vat dyeing in Kano metropolis, its environmental impacts, and improvement on the dyeing processes using design of experiments (Unpublished PhD Thesis). Ahmadu Bello University, Zaria, Nigeria.

Abdullahi, S., Nkeonye, P. O., Yakubu, M. K., and Gumel, M. S., Iliya, E. B., and Arigbede, O. O (2021a). Occupational vat dyeing practices in the Kano Metropolis of Nigeria-part 1: demographic/socio-economic characteristics of the dyers and composition of the dyeing enterprises. *Nigerian Journal of Textiles*, 7: 25-36.

Abdullahi, S., Nkeonye, P. O., Yakubu, M. K., Gumel, M. S., and Iliya, E. B (2021b). Occupational vat dyeing practices in the Kano Metropolis of Nigeria-part 3: step-by-step dyeing processes in relation to industrial practices. *Nigerian Journal of Textiles*, 7: 50-62.

Abdullahi, S., Nkeonye, P. O., Yakubu, M. K., Gumel, M. S., and Iliya, E. B (2021c). Occupational vat dyeing practices in the Kano Metropolis of Nigeria-part 2: Operations of the dyers/dyeing enterprises in relation to industrial practices. *Nigerian Journal of Textiles*, 7: 37-49.

Adedeji, A. A., and Ako, R. T (2009). Towards achieving the United Nation's Millennium Development Goals: the imperative of reforming water pollution control and waste management laws in Nigeria. Desalination, 24: 642-649.

Al-Tohamy, R., Ali, S. S., Li, F., Okasha, K. M., Mahmoud, Y. A. G., Elsamahy, T., Jiao, H., Fu, Y., and Sun, J (2022). A critical review on the treatment of dye-containing wastewater: ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety. *Ecotoxicity and Environmental Safety*, 231: https://doi.org/10.1016/j.ecoenv.2021.113160

Amare. E., Kebede. F and Mulat. W (2018). Wastewater treatment by Lemna minor and Azolla filiculoides in tropical semi-arid of Ethiopia. Ecological Engineering, 120: 465-473.

Arcanjo G. S., Mounteer A. H., Bellato C. R., Marçal da Silva L. M., Dias S. H. B and Romana da Silva. P (2018). Heterogeneous photocatalysis using TiO2 modified with hydrotalcite and iron oxide under UV-visible irradiation for color and toxicity reduction in secondary textile mill effluent. Journal of environmental Management, 211: 154-163.

Bajpai, P (2018). Fibre from recycled paper and utilization. In Bajpai, P (Ed.). *Biermann's Handbook of pulp and paper*. Vol. 1. RawmaterialRawmaterials and pulp making. 3rd Edition.

Balogun, D. O., Abe, G. O., Ibrahim, A., Ibrahim, B. K., Auta, U. S., and Adgidzi, J. A. (2020). Spatial distribution of groundwater quality using GIS in Kano Metropolis, Kano State, Nigeria. *Worldwide Journal of Multidisciplinary Research and Development*, 6(5), 51-58.

Balogun, D. O., Ibrahim, A., Mshelia, A. N., Okewu, A. A., Adgidzi, J. A., and Boyi, S (2020). Municipal solid waste management practices and impact on the environment in Nassarawa local government area, Kano state. World Wide Journal of Multidisciplinary Research and Development, 6 (9): 15-22.

Bankole, P. O., Adekunle, A. A., Obidi, O. F., Olukanni, O. D., and Govindwar, S. P (2017). Degradation of indigo dye by a newly isolated yeast Diutina rugose from dye waste water polluted soil. Journal of Environment Chemical Engineering, 5:4639-4648.

Baptista, R. J (2009). The chemistry and manufacture of vat dyes.

Barrios-Ziolo, L. F., Gaviria-Restrepo, L. F., Agudelo, E. A., and Cardona-Gallo, S. A (2016). Study of toxicity associated to dumping of wastewater containing dyes and pigments in the Aburra Valley metropolitan area. Revista EIA, 13(26): 61-74.

Bazin, I., Hassine, A. I. H., Hamouda, Y. H., Mnif, W., Bartegi, A., Lopez-Ferber, M., de Waard, M., and Gonzalez, C (2012). Ecotoxicity and Environmental Safety, 85: 131-136.

Bechtold, T., and Turcanu, A (2009). Electrochemical reduction of vat dyeing: greener chemistry replaces traditional processes. *Journal of Cleaner Production*, 17:1669-1679.

Berradi, M., Hsissou, R., Khudhair, M., Assouag, M., Cherkaoui, O., El-Bachiri, A., El-Harfi, A (2019). Textile finishing dyes and their impact on aquatic environments. *Heliyon*, 5: e02711: 1-12.

Bhupinder Kaur and Chanchal (2016). Environmental and health concerns of the textile industry. International Journal of Civil, Structural, Environmental, Infrastructural Engineering Research and Development, 6 (6): 13-26.

Bozic, M and Kokol, V (2008). Ecological alternatives to the reduction and oxidation processes in dyeing with vat and sulphur dyes. *Dyes and Pigments*, 76:299-309.

Butu. A. W and Mshelia S. S (2014). Municipal solid waste disposal and environmental issues in Kano Metropolis, Nigeria. British Journal of Environmental Sciences, 2(1): 1-16.

Chakraborty, J. N. (1992). Sodium hydrosulphite in vat dyeing. *The Indian Textile Journal*, 103 (10), 24-31.

Chavan, R. B (2011). Environmentally friendly dyes. Chapter 16. Clark, M (Ed.). handbook of textile and industrial dyeing. Woodhead Publishing Ltd. https://doi.org/10.1533/9780857093974.2.5.15 .

Chequer, F. M. D., de-Oliveira, G. A. R., Cardoso, J. C., Zanoni, M. V. B., and de-Oliveira, D. P (2013). Textile dyes: dyeing process and environmental impact. Chapter 6. http://dx.doi.org/10.5772/53659

Croce, R., Cina, F., Lombardo, A., Crispeyn, G., Cappelli, C. I., Vian, M., Maiorana, S., Benfenati, E., and Baderna, G (2017). Aquatic toxicity of several textile dye formulations: acute and chronic assays with Daphnia magna and Raphidocelis subcapitata. Ecotoxicity and Environmental Safety, 14: 79-87.

De Luna, L. A. V., da Silva, T. H. G., Nogueira, R. F. P., Kummrow, F., and Umbuzeiro, G. A (2014). Aquatic toxicity of dyes before and after photo-Fenton treatment. *Journal of Hazardous Materials*, 276: 332-338.

De Oliveira, G. A. R., de Lapuente, J., Teixido, E., Porredon, C., Borras, M., and de Oliveira, D. P (2016). Textile dyes induce toxicity on Zebrafish early life stages. *Environmental Toxicology and Chemistry*, 35 (2): 429-434.

Essen, C (2017). NESREA warns Kano tannery operators against pollution. The Guardian, 13th November, 2017.

Gad, S. E (2014). Lye. *Encyclopaedia of Toxicology*, Vol. 3. https://doi.org/10.1016/8978-0-12-3864-54-3.00871-8 .

Garba, S. B. (1997). Public land ownership and urban land management effectiveness in the metropolitan Kano, Nigeria. *Habitat International*, 21(3), 305-317.

Geer, L. A., Curbow, B. A., Anna, D. H., Lees, P. S. J., and Buckley, T. J. (2006). Development of a questionnaire to assess worker knowledge, attitudes and perceptions underlying dermal exposure. Scandinavian *Journal of Work and Environmental Health*, 32(3), 209-218.

Ghaly, A. E., Ananthashankar, R., Alhattab, M., and Ramakrishnan, V. V (2014). Production, characterization and treatment of textile effluents: a critical review. *Chemical Engineering and Process Technology*, 5 (1): 1-18.

Golob, V., and Ojstrsek, A (2005). Removal of vat and disperse dyes from residual pad liquors. Dyes and Pigments, 64: 57-61.

Gurav, A. A., Ghosh, J. S., and Kulkarni, G. S (2011). Decolorization of anthraquinone based dye Vat Red 10 by pseudomonas desmolyticum NCIM 2112 and Galactomyces geotrichum MTCC 1360.

International Journal of Biotechnology and Molecular Biology Research, 2 (6): 93-97.

Hasan, M. K., Shahriar, A., and Jim, K. U (2019). Water pollution in Bangladesh and its impact on public health. Heliyon, 5: 1-23.

Hessel, C., Maisseu, A. M., Charbit, F., and Moulin, P (2007). Guidelines and legislation for dye house effluents. Journal of Environmental Management, 83: 171-180.

Howard, E. K., Frimpong, C., and Seidu, R. K (2019). Risk assessment of attitudes and practices of students and practitioners toward studio dyeing in Ghana. *Research Journal of Textile and Apparel*, 23 (3): 189-200.

Iliyas, M. H. (2000). Strengthening the capacity of water utilities to deliver water and sanitation services, environmental health and hygiene to low incomelow-income communities. Case study of Kano (town), Nigeria. context and practices. Water utility project.

Islam, M. S., and Islam, J. M. M (2021). Sources and fates of textile solid wastes and their sustainable management. Baskar et al. (Eds.). Handbook of solid waste management. Springer Nature, Singapore Pte Ltd. https://doi.org/10.1007/978-981-15-7525-9_199-1 .

Kant, R (2012). Textile dyeing industry an environmental hazard. Natural Science, 4 (1): 22-26.

Kariyajjanavar, P., Narayana, J., and Nayaka, Y. A (2013). Degradation of textile dye C. I. Vat Black 27 by electrochemical method by using carbon electrodes. *Journal of Environmental Chemical Engineering*, http://dx.doi.org/10.1016/j.jece.2013.08.002 .

Khatri, A., Peezada, M. H., Mohsin, M., and White, M (2015). A review on developments in dyeing cotton fabrics with reactive dyes for reducing effluent pollution. Journal of cleaner production, 87: 50-57.

Kulandainathan, M. A., Patil, K., Muthukumaran, A., and Chavan, R. B (2007). Review of the process development aspects of electrochemical dyeing: its impacts and commercial applications. Society of Dyers and Colourists, Colouration Technology, 123: 143-151.

Lacasse, K., and Baumann, W (2004). Textile chemicals. Environmental data and facts. Springer-Verlag Berlin, Heidelberg GmbH.

Liman, M. A. (2015). A spatial analysis of industrial growth and decline in kano metropolis, Nigeria. Unpublished PhD Thesis. Ahmadu Bello University, Zaria, Nigeria. p29.

Makinde, D. O, Ijisakin, E. T., and Ijisakin, Y. O (2010). Indoor and outdoor pollution in cloth dyeing: examples from textile students in Nigeria tertiary institutions. Air Pollution, 136 (18): 313-320.

Manu, B (2007). Physico-chemical treatment of indigo dye waste water. Society of Dyers and Colourists, Colouration Technology, 123: 197-202.

Merkel, A., Ashrafi, A. M., and Ondrusek, M (2017). The use of electrodialysis for recovery of sodium hydroxide from the high alkaline solution as a model of mercerization wastewater. *Journal of Water Process Engineering*, 20:123-129.

Murtala, A. (2018). Kano residents lament lack of drainage system. Vanguard, December 24.

Nabegu, A. B (2016). Report of a study on industrial effluent situation in Kano. Kano State ministry of environment, green house, Kano. Prepra Nig. Ltd.

Oguntade, O. A., Adetunji, M. T., Salako, F. K., Arowolo, T. A., and Azeez, J. O (2018). Growth, dry matter and heavy metal uptake of potted Amaranthus cruentus L. as influenced by dye-laden wastewater. Tropical Agriculture (Trinidad), 95 (2): 132-145.

Okareh, O. T., Ademodi, T. F., and Igbinosa, E. O (2017). Biotreatment of effluent from “adire” textile factories in Ibadan, Nigeria. Environmental Monitoring and Assessment. https://doi.org/10.1007/s10661-017-6357-9 .

Olaganathan, R., and Patterson, J (2009). Decolorization of anthraquinone Vat Blue 4 by the free cells of an autochthonous bacterium, Bacillus subtilis. Water Science and Technology, 60 (12): 3225-3232.

Oloyede, A. M., Ogunlaja, O., and Ogunlaja, A. (2014). Sub-chronic toxicity assessment of local textile ‘Adire and Kampala’ (Tie and Dye) effluents on Mica (Musmusculus). *Research Journal of Environmental Sciences*, 8(3), 142-148.

Rahman, M. K., Saha, B. K., Chowdhury, M. A. H., and Mohiuddin, K. M (2020). Public perception and health implication of loom-dye effluent irrigation on growth of rice (*Oryza sativa* L) and red amaranth (*Amaranthus tricolor* L) seedlings. Environmental Science and Pollution Research. https://10.1007/s11356-020-08377-0 .

Rapo, E., and Tonk, S (2021). Factors affecting synthetic dye adsorption; desorption studies: a review of results from the last five years (2017-2021). Molecules, 26, 5419. https://doi.org/10.3390/molecules.26175419 .

Rosa, J. M., Borrely, S. I., and Araujo, M. D. C (2017). Assessment of toxicity of raw textile wastewater and after its reuse. 17th World Textile Conference AUTEX 2017-Shaping the future. IOP Conference Series: Materials Science and

Engineering, 254: 192015. http://doi.org/10.1088/1757-1088X/254/19/192015

Sani, Z. M., Abdullahi, I. L., and Sani, A (2018). Toxicity evaluation of selected dyes commonly used for clothing materials in Urban Kano, Nigeria. *European Journal of Experimental Biology*, 8 (4): 1-4.

Selase, G. B., Divine, V., Mawuli, Q., and Edem, B (2021). Waste management by small scale textile industries in Ghana. Journal of Chemical, Environmental, and Biological Engineering, 5 (2): 43-48.

Shawai, S. A. A., Abubakar, B. B., Nahannu, M. S., and Gaya, H. S (2019). Status of water used for drinking and irrigation in Kano. A critical review on physiochemical and heavy metals concentration. American Journal of Biomedical Science and Research, 5 (3): 235-242.

Shindhal, T., Rakholiya, P., Varjani, S., Pandey, A., Ngo, H. H., Guo, W., Ng, H. Y., and Taherzadeh, M. J (2020). A critical review on advances in the practices and perspectives for the treatment of dye industry wastewater. Bioengineered, 12 (1): 70-87.

Sirianuntapiboon, S., Chairattanawan, K., and Jungphungsukpanich, S (2006). Some properties of a sequencing batch reactor system for removal of vat dyes. Bioresource Technology, 97: 1243-1252.

Suleiman, A. A., Ibrahim, A., and Abdullahi, U. A. (2020). Statistical explanatory assessment of groundwater quality in Gwale, Kano State, Northwest Nigeria. Hydrospatial Analysis, 4(1), 1-13.

Sulthonuddin, I., and Herdiansyah, H (2021). Sustainability of batik wastewater quality management strategies: analytical hierarchy process. Applied Water Science, 11:31. https://doi.org/10.1007/s13201-021-01360-1 .

Umar, G. K., Yusuf, D. A., and Mustapha, A. (2019). Urban land use, planning and historical theories: an overview of Kano metropolis. *World Scientific News*, 118, 257-264.

UNESCO Johnson, L. (1999). Artisan enterprise baseline survey. A UNESCO study. Johnson L (ed.). Aid to artisans. A case study. African Enterprise Study. Mozambique.

Upadhyay, K. K., and Panday, A. C (2015). Occupational exposure and awareness of occupational safety and health among cloth dyeing workers in Jaipur, India. *Iranian Journal of Health and Environment*, 3 (2): 540-546.

Wang, C., Yediler, A., Lienert, D., Wang, Z., and Kettrup, A (2002). Toxicity evaluation of reactive dyestuffs, auxiliaries and selected effluents in textile finishing industry to luminescent bacteria *Vibrio Fischeri. Chemosphere*, 46: 339-344.

Weber, E. M., Seaman, V. Y., Stewart, R. N., Bird, T. J., Tatem, A. J., Makee, J. J., Bhaduri, B. L., Moehl, J. J., and Reith, A. E. (2017). Census-independent mapping in northern Nigeria. Remote Sensing of Environment. 10.1016/j.rse.2017.09.024.

WHO/UNEP (1997). Water pollution control- A guide to the use of water quality management principles. Helmer, R., and Hespanhol, I (Eds). United Nations Environmental Programme, the Water Supply and Sanitation Collaborative Council and World Health Organization. E and F Spon, London.

Yalcin-Enis, I., Kucukali-Ozturk, M., and Sezgin, H (2019). Risk and management of textile waste. Gothandam et al. (Eds.). nanoscience and Biotechnology for Environmental Applications, Environmental Chemistry for a Sustainable World 22. Springer Nature, Switzerland AG. https://doi.org/10.1007/978-3-319-97922-9_2 .

Yaseen, D. A., and Scholz, M (2019). Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. International Journal of Environmental Science and Technology, 16: 1193-1226.

Yukseler, H., Uzal, N., Sahinkaya, E., Kitis, M., Dilek, F. B., and Yetis, U (2017). Analysis of the best available techniques for wastewaters from a denim manufacturing textile mill. Journal of Environmental Management. http://dx.doi.org/10.1016/j.jenvman.2017.03.041 .