International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 34 No. 3 Nov. 2021, pp. 635-642

http://www.ijias.issr-journals.org/

Impact of wastewater from a textile industry used for irrigation in the nitrate contamination of *Allium schoenoprasum* crops in the city of Bouaké in Côte d'Ivoire

Bamba Massa Ismael, Siaka Sorho, and Soro Yaya

Laboratory of Industrial Synthesis Processes, Environment and New Energies, National Polytechnic Institute Houphouët-Boigny (INP-HB), PO BOX 1093 Yamoussoukro, Côte d'Ivoire

ABSTRACT: The objective of this study is to assess the impact of the use for irrigation of water containing liquid effluents from a textile industry on the nitrate contamination of *Allium schoenoprasum* crops via soils. To do this, nitrates were determined in soil, water, and *Allium schoenoprasum* samples and statistical analyzes were performed. It appears that the nitrate concentrations in the water studied, which are significantly different at the sites studied, are below the WHO standard for the use of water for irrigation. In addition, linear regression analysis showed that nitrate concentrations in soils were not related to watering with wastewater from the textile industry but resulted from the extensive use of nitrogen fertilizers. The analysis in principal component showed that the granulometry and the organic matter of the soil would greatly influence the absorption of nitrates by the plants of *Allium schoenoprasum* Thus, it would seem the waste water of the textile industry is not responsible for the levels in nitrates contained in *Allium schoenoprasum* plants.

KEYWORDS: Effluents, urban agriculture, *Allium schoenoprasum*, nitrates, contamination.

1 INTRODUCTION

Nitrates are compounds in the soil formed during the nitrogen cycle. These ions arise naturally from the fixation of atmospheric nitrogen and the decomposition of organic matter by micro-organisms [1]. Nitrates are the main source of nitrogen used by plants because of their high solubility in soil water and high stability [2]. However, concentrations in the natural environment can be increased by several anthropogenic activities. One of these is agriculture, particularly urban and peri-urban agriculture (UPA). As a producer of fresh vegetables and other foods for urban populations, AUP is characterized by excessive use of chemical fertilizers [3], [4]. This practice is related to the fact that nitrogen fertilizers are massively applied in the fields, due to the important role that nitrogen plays in crop quality and yield [5]. Although essential for the development of plants, nitrates can have harmful effects on human health. To this end, in the bibliography, it appears that nitrates have acute and chronic toxicities on human health [6]. Regarding acute toxicities, we can cite methemoglobinemia, which manifests itself when nitrites from reduced nitrates bind to hemoglobin [7], [8]. This disease is one of the biggest threats to human health linked to nitrates. Other authors have claimed that nitrates are responsible for the enlarged thyroid gland [9]. Beyond these acute toxicities, nitrates also exhibit chronic toxicities. In fact, nitrates can be a source of nitrosamines which have a carcinogenic effect on the human body [10]. The textile industry is one of the most polluting industries on the planet, discharging huge amounts of wastewater [11]. The finishing processes present in this industry are the most polluting. Indeed, during this activity, several chemicals, including dyes are used for dyeing fabrics. These dyes, in particular azo dyes, as well as products such as urea can be sources of nitrates. As a result, the wastewater from this activity may contain nitrates.

In Bouaké plants *Allium schoenoprasum*, very popular, usually eaten fresh, and constituted more than 90% water are grown around textile industry with either industrial wastewater textile, or with water contained in sumps located near this wastewater.

Knowing that its wastewater can be a source of nitrates for *Allium schoenoprasum* crops, that nitrates are highly soluble in water and that *Allium schoenoprasum* plants contain more than 90% water, a question arises: does the textile industry's wastewater contaminate *Allium schoenoprasum* crops with nitrates? To answer this question, the general objective of this study is to determine the impact of irrigation water on nitrate contamination of *Allium schoenoprasum* crops.

Thus, in a first step, nitrates will be determined in water, agricultural soils, and plants. In a second step, correlations will be made between the nitrate contents obtained in the different matrices, as well as between the nitrate contents and the physicochemical characteristics of the soils in order to determine the origin of the nitrates obtained in *Allium schoenoprasum* crops.

2 MATERIALS AND METHODS

2.1 PRESENTATION OF THE STUDY AREA

The city of Bouaké is part of the Gbêkê region located in north-central Côte d'Ivoire, 370 km from the economic capital Abidjan. It is located between latitudes 7 ° 45'N and 7 ° 38'N and longitudes 5 ° 7'W and 4 ° 58'W with an area of 71 km2. This city has enormous potential for the development of industrial activities. Indeed, Bouaké is a crossroads town and brings together several industries scattered within it.

2.2 DESCRIPTION OF THE SAMPLING SITES

The study area is located near a textile industry in the town of Bouaké. Figure 1 below shows the study area and the sites identified by points P1, P2 and P3.

Fig. 1. Location of sampling sites

Site P1 includes plots bordering a water reservoir that serves as a back-up reserve for the textile factory. These plots are therefore irrigated with water from this water reservoir. Located upstream of the plant's effluent spillway, the soils from this site also served as a control for this study. The P2 and P3 sites, downstream from the effluent discharge point of the plant, house the plots irrigated on the one hand with water from the water shortage formed by the waste water and on the other hand from sumps serving as retained water along this water court. Cultures of *Allium schoenoprasum* from these plots are the targets of the study.

2.3 COLLECTION AND PRETREATMENT OF SOIL WATER SAMPLES AND ALLIIUM SCHOENOPRASUM

The water, soil and *Allium schoenoprasum* samples were taken in February 2018 during the dry season in order to avoid the dilution effects of rain and to better assess the possible impact of the retained irrigation water on the *Allium schoenoprasum* crops via the soil.

During this campaign, water samples were taken in 1L polyethylene bottles that had been rinsed with the water samples they were to contain. Sampling was carried out by immersing the bottle in the water to a depth of about 30 cm from the surface. At each of the different sites, 10 spot samples were taken. To ensure a good state of preservation, the samples were kept away from light and transported at a temperature of 4°C in a cooler to the laboratory for analysis.

For the soil sampling, plots of 3 m in length and 1 m in width were randomly selected to cover all the plots on the site. With the help of a planting shovel, three samples were taken from each plank at a depth of 30 cm in a diagonal direction, with one sample taken from the center and two from the periphery. The samples from 5 plots were merged and a composite sample of one kilogram was formed for analysis. Five composite samples were taken from each site and transported to the laboratory in polyethylene bags free of contamination. In the laboratory, the samples are dried at room temperature (25 - 30 ° C) for two weeks by spreading out on floors protected from external contamination. After drying, the clods of earth contained in the samples are crushed to obtain homogeneous samples which are treated according to the method described by Bouyoucos, 1951 [12], sieved to two millimeters before being stored at room temperature in glass jars free of contamination.

2.4 Nitrate Determination

In the waters, the nitrate was determined according to the AFNOR NFT 90-045 protocol. It consists in carrying out a spectrophometric measurement of the yellow compound resulting from the reaction of nitrates with sulfosalicylic acid which is formed by addition to the sample of sodium salicylate and sulfuric acid after treatment with alkali (NaOH and Na2EDTA). The alkali helps prevent precipitation of calcium and magnesium salts. The addition of sodium azide (NaN_3) is carried for neutralize the interference of nitrites. The reading is taken at the wavelength of 415 nm.

In the laboratory, the *Allium Schoenoprasum* plants were washed, cut into small pieces (about 1 cm) and then mixed to collect the juice. The juice obtained was diluted fifty times. The determination of nitrates was done on the diluted juice according to the AFNOR protocol, NF T 90-045 as presented above.

The determination of nitrate in soils was carried out according to ISO 14256-1 of 2003. The principle of this method consists of extracting nitrates using a 1M KCl solution and then determining them in the extract according to the protocol for determining nitrates in water samples. Thus, 40 g of samples are dissolved in a 500 mL polyethylene bottle containing 200 mL of 1M potassium chloride solution. After one hour of agitation using a mechanical shaker at 120 3000 revolutions per minute, 60 mL of the suspension is centrifuged at 3000 3000 revolutions per minute for 10 minutes. The supernatant is used for the determination of nitrate. A blank test containing only 1M potassium chloride is carried out under the same conditions and the nitrates are then determined according to the AFNOR standard, NF T 90-045.

2.5 Statistical Analysis

All the data obtained were processed using the free software R. The data processing consisted of establishing the arithmetic means of the individual values and the standard deviations on the one hand, and the differences between the groups by analysis of variance (ANOVA) on the other. When the ANOVA revealed significant differences ($p < 0.05$) between the groups, the Student-Newman-Keuls test was used to determine the specific differences between the means. In addition, linear correlation coefficients were determined for potential relationships between the nitrate concentrations of the different matrices used.

3 Results And Discussion

3.1 Spatial Variation Of Nitrate In Water, Soil And Allium Schoenoprasum Plants

Nitrate can be a source of nitrite toxic to human health, its measurement in water used for irrigation and watering of crops is necessary. below shows the spatial variation of nitrate in irrigation water at the study sites.

Table 1. Spatial variations in nitrate concentrations in irrigation water and nitrate levels in soils and crops of Allium schoenoprasum

	Nitrates concentrations		
Sites	Water (mg. L^{-1})	Soil (mg. g^{-1})	*Allium* (mg. g^{-1})
P1	2,60±0,54a	4,94±0,09a	12,28±0,54a
P2	5,83±0,45b	9,53±0,30b	20,08±0,31b
P3	1,452±0,39c	14,09±0,28c	21,78±0,47c

Table 1 shows that all waters have fairly low nitrate concentrations and well below 50 mg.L^{-1} which is the limit recommended by the WHO in its guide on the use of wastewater for irrigation in 2006. The effluents from the P3 site have the lowest nitrate content (1,45 ± 0,34 mg. L^{-1}) while the then waters of site P2 have the highest average nitrate content (5,83 ± 0.45 mg. L^{-1}). As a result, irrigation water does not provide significant amounts of nitrates to agricultural plots. Furthermore, our results obtained in liquid effluents from the textile industry are much lower than those obtained by Hussain and al., 2006 [13], which were between 120 mg.L^{-1} and 627 mg.L^{-1}. According to these authors, the nitrates contained in wastewater from textile industries come either from the impurities of the chemicals used in the various processes or from certain dyes such as azo dyes [14]. The fact that site P1 located upstream from the textile industry has a higher nitrate concentration than site P3 can be explained by the fact that the dam contains surface water which receives several plant debris and animal and human excreta.

The analysis in shows that the nitrate content of the soils is 4,94 ± 0,09 mg.g^{-1} at site P1 and 14,09 ± 0,28 mg.g^{-1}. Sites P2 and P3 have higher nitrate contents than site P1. These results can be explained by the fact that sites P2 and P3, located downstream of the plant's effluent discharge point, are home to plots watered with liquid effluent from the plant, which contain nitrate concentrations between 1,45 ± 0,34 mg.L^{-1} in P3 and 5,83 ± 0,45 mg.L^{-1} in P2. Indeed, irrigation water is one of the major differences in agricultural practices on the three agricultural sites.

Nitrate levels in *Allium schoenoprasum* range from 12,21 mg.g^{-1} (P1) to 21,81 mg.g^{-1} (P3). It should be noted that optimal nitrate concentrations for plant growth are between 10 and 30 mg.g^{-1} [15].

Samples from sites P2 and P3 had the highest levels compared to those from the control site P1. The nitrate content of *Allium schoenoprasum* seems to be proportional to the nitrate content of the soil. Thus, the higher the nitrate content of the soil, the higher the nitrate content of the *Allium schoenoprasum* samples. This is related to the fact that nitrate is the main source of nitrogen available to higher plants [16], [17]. In addition, nitrates are an essential element in the synthesis of amino acids in plants. They therefore tend to store them for later use. Beyond that, the nitrate content in *Allium schoenoprasum* plants is higher than that generally found in plants. It would be a peculiarity of *Allium schoenoprasum* to specifically accumulate nitrate in different tissues. In addition, in the bibliography, some authors have shown that in neutral pH soils such as those in our study, nitrate mobility is high [18], thus justifying the concentrations of nitrates obtained in *Allium schoenoprasum* plants.

The study of the variation in nitrate concentrations in the different matrices studied shows us that the irrigation water from the P2 and P3 sites as well as the soils and *Allium schoenoprasum* crops from these sites have the highest nitrate values. compared to the P1 control site of the dam. A linear regression analysis between the nitrate concentrations of the different matrices would be interesting to shed light or not on the impact of irrigation water on the nitrate contamination of *Allium schoenoprasum* crops.

3.2 CORRELATIONS BETWEEN THE NITRATE CONTENTS OF THE MATRICES STUDIED AND THOSE OF ALLIUM SCHOENOPRASUM

This correlation was evaluated by linear regressions between the nitrate contents of the matrices studied and those of *Allium schoenoprasum*. The results obtained are presented in below.

Table 2. Correlation of nitrate content in water, soil, and crops of Allium schoenoprasum

	Correlation water-soil	**Correlation soil-*Allium schoenoprasum***
Nitrates	**-0,29**	**0,93**

From this table 2, soil nitrate levels are strongly correlated with those of *Allium schoenoprasum* with a value of 0.93. This strong correlation between soil nitrate levels and *Allium schoenoprasum* crops is certainly logical in relation to the fact that nitrogen is a major nutrient in plants development.

For nitrate levels in water and soil, the correlation is weak (-0.29) and negative. This would indicate that the nitrate levels in these two matrices are not related. Thus, the nitrate content of soils would have a source other than irrigation water, although according to some authors [14], [19], wastewater from the textile industry can be nitrate precursors due to the use of azo dyes. In our case, the nitrates in the soil would rather come from the use of nitrogen fertilizers. Several authors have shown that mineral fertilizers, NPK and urea, are generally widely used in urban agriculture [3], [20]. These fertilizers would therefore be the source of soil nitrates and consequently of *Allium schoenoprasum* crops.

3.3 Principal Component Analysis

The ANOVA showed that the nitrate levels were significantly different between the matrices studied and the sites. Moreover, this analysis showed that the levels in sites P2 and P3 were higher than those in the control site, thus showing at first sight that irrigation water is the main cause of these results. However, linear regressions showed that the nitrates in the soils would come from the nitrogen fertilizer amendment. Therefore, a principal component analysis (PCA) would be beneficial to relate the nitrate levels to the physicochemical characteristics of the soils bearing the crops; with a view to identifying the real source of nitrate contamination of *Allium schoenoprasum* crops. This statistical analysis of the physico-chemical data of the soils was carried out on a data matrix made up of eleven variables (parameters studied) and three individuals, which are the sites P1, P2 and P3. below shows the physico-chemical parameters of the soils studied

Table 3. Physico-chemical parameters of the studied soils [21]

Parameters	P1	P2	P3
pH eau	6,88±0,25a	6,55±0,42a	6,48±0,20a
CEC (cmol/kg)	0,10±0,06a	0,11±0,05a	0,07±0,02a
MO (%)	1,21±0,17a	1,23±0,12a	0,54±0,05b
C/N	5,56±0,70a	6,99±0,40a	6,52±1,06a
EC (µS/cm)	665,99±2,44a	621,96±10,94b	755,13±1,41c
Clay (%)	6,7±0,3a	10,3±0,7b	7,2±0,2a
Silt (%)	8,5±0,1a	8,7±0,2a	6,4±0,2b
Sand (%)	72,1±0,3a	68,4±0,6b	76,4±0,5a

The application of principal component analysis on eleven parameters (8 parameters of physico-chemical characterization of soils and nitrate concentrations of soil water and *Allium schoenoprasum* plants) resulted in two main factors contributing to 69.53% of the total variance (Figure 2). This percentage is therefore significant, and the first plane represents well the variability contained in the whole active dataset with respectively 44.69% for the F1 axis and 24.84% for the F2 axis. Only the first two dimensions will be used to interpret the analysis.

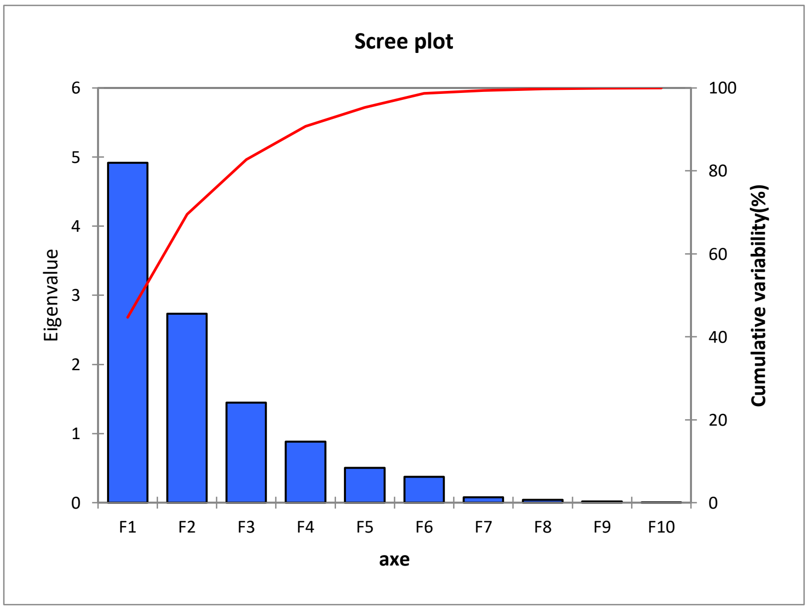

Fig. 2. histogram of eigenvalues

Figure 3 below shows the projections of the variables (parameters studied) and individuals (sampling sites) in the F1-F2 factorial plane. presents the correlations between the parameters studied and the axes of the factorial plane.

The Principal Component Analysis (PCA) correlation matrix shows in quantifies the correlations between the different variables (chemical compounds). In this matrix, the values reflect the degree of correlation and their sign indicates its positive or negative nature [24].

Table 4. Correlation matrix between the variables

Variables	C/N	OM	CEC	silt	clay	sand	EC	pH	Nit soil	Nit water	Nit Allium
C/N	1										
OM	0,022	1									
CEC	-0,014	0,240	1								
silt	-0,189	0,712	-0,036	1							
clay	0,136	0,142	-0,166	0,643	1						
sand	0,052	0,320	-0,141	0,798	0,975	1					
EC	-0,229	-0,782	-0,108	-0,686	-0,437	-0,545	1				
pH	0,212	0,265	-0,006	0,423	0,649	0,634	-0,525	1			
Nit soil	0,391	-0,801	-0,027	-0,638	0,034	-0,159	0,402	-0,119	1		
Nit water	0,285	0,715	0,055	0,666	0,487	0,578	-0,974	0,477	-0,289	1	
Nit Allium	0,570	-0,596	-0,049	-0,516	0,207	0,012	0,174	0,225	0,879	-0,108	1

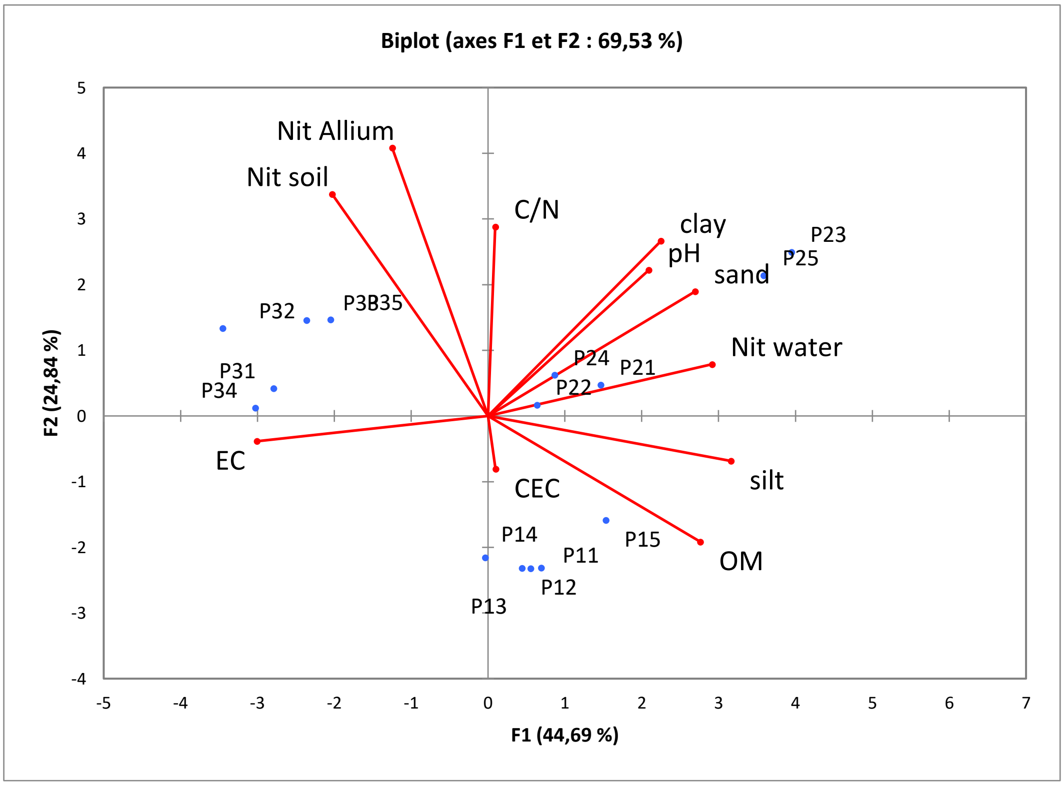

Fig. 3. Projections of the parameters and study sites onto the factorial plane

The F1 axis is expressed at its positive pole by organic matter, water pH, silts, clays, sands, and nitrate concentrations in water. This axis is expressed at its negative pole by electrical conductivity. Nitrate concentrations in soils and *Allium schoenoprasum* and the C/N ratio are positively related to the F2 axis (Table 4). The other parameters are certainly related to the other factors.

It emerges from that along the F2 axis, the nitrate content of the soil and the nitrate content of *Allium schoenoprasum* plants are in the positive part of this axis, and they are very close to each other. The proximity between these variables indicates that they are strongly correlated. This positive correlation could be justified by the fact that in urban agriculture producers use large quantities of nitrogenous fertilizers in mineral form (nitrate) [3], [19], thus providing the nutrients necessary for the development of higher plants such as *Allium schoenoprasum* following their adsorption to the soil.

The lack of correlation between the nitrate contents in the soils and those in irrigation water can be justified by the sandy nature of the soils studied. Indeed, such soils with high porosity, would allow the nitrates contained in the water to infiltrate with the latter into the deep layers, unlike soils rich in fine particles which would retain nitrates in the surface layers of the soil [22].

Also, along the F2 axis we notice that on the P1 site the low nitrate values in the plants of *Allium schoenoprasum* could be explained by the high contents and organic matter and silts which would retain nitrate ions in the soil, thus causing a low entry of these ions into *Allium schoenoprasum* plants [15].

In addition, the fact that sites P2 and P3 have the highest nitrate content in *Allium schoenoprasum* plants can be explained by the fact that the soils at these sites are more acidic than those at site P1, which are close to neutral. Indeed, in the literature [23], it appears that the degradation of azo dyes depends on the pH of the environment. The lower the pH, the greater the degradation of azo dyes; thus, releasing nitrates into the soil solution which will be recovered by *Allium schoenoprasum* plants. In addition, when the soil is close to neutral, the azo dyes will tend to persist in the soil.

4 Conclusion

The objective of this study was to determine the impact of wastewater from a textile industry on the nitrate contamination of soils and *Allium schoenoprasum* crops grown on these soils. It appears that wastewater from the textile industry has significantly different nitrate concentrations on the sites and well below the WHO standard for irrigation water. Linear regression analysis and principal component analysis revealed that nitrate concentrations in soils were strongly correlated with those obtained in *Allium schoenoprasum* plants. In addition, these analyses showed a weak negative correlation with nitrate concentrations in irrigation water and soils. Principal component analysis showed also that particle size distribution and organic matter greatly influence the uptake of nitrates by *Allium schoenoprasum* plants. The nitrate concentrations in plants can be related to the use of nitrogen fertilizers.

References

[1] V. V. Ramakrishnan and A. E. Ghaly, “Nitrogen Sources and Cycling in the Ecosystem and its Role in Air, Water and Soil Pollution: A Critical Review, ” J. Pollut. Eff. Control, vol. 03, no. 02, 2015, doi: 10.4172/2375-4397.1000136.

[2] B. M. Chen, Z. H. Wang, S. X. Li, G. X. Wang, H. X. Song, and X. N. Wang, “Effects of nitrate supply on plant growth, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetables,” Plant Sci., vol. 167, no. 3, pp. 635–643, 2004, doi: 10.1016/j.plantsci.2004.05.015.

[3] J. A. Ondo, “Vulnérabilité des sols maraîchers du Gabon (région de Libreville) : acidification et mobilité des éléments métalliques,” Université de Provence Spécialité Sciences de l’Environnement Terrestre. École doctorale des Sciences de l’Environnement, 2011.

[4] L. Temple and P. Moustier, “Les fonctions et contraintes de l‘agriculture périurbaine de quelques villes africaines (Yaoundé, Cotonou, Dakar),” Cah. Agric., vol. 13, no1, pp. 15–22, 2004.

[5] F. Gastal and G. Lemaire, “N uptake and distribution in crops: An agronomical and ecophysiological perspective,” J. Exp. Bot., vol. 53, no. 370, pp. 789–799, 2002, doi: 10.1093/jexbot/53.370.789.

[6] M. Parvizishad, A. Dalvand, A. H. Mahvi, and F. Goodarzi, “A Review of Adverse Effects and Benefits of Nitrate and Nitrite in Drinking Water and Food on Human Health,” Heal. Scope, vol. In Press, no. In Press, 2017, doi: 10.5812/jhealthscope.14164.

[7] S. S. Mirvish, “The Significance for Human Health of Nitrate, Nitrite and N-Nitroso Compounds,” Nitrate Contam., pp. 253–266, 1991, doi: 10.1007/978-3-642-76040-2_18.

[8] W. J. Gowans, “Fatal methaemoglobinaemia in a dental nurse. A case of sodium nitrite poisoning,” Br. J. Gen. Pract., vol. 40, no. 340, pp. 470–471, 1990.

[9] M. H. Ward et al., “Workgroup report: Drinking-water nitrate and health - Recent findings and research needs,” Environ. Health Perspect., vol. 113, no. 11, pp. 1607–1614, 2005, doi: 10.1289/ehp.8043.

[10] S. Boukerche, W. Aouacheri, and S. Saka, “abc Les effets toxiques des nitrates :,” vol. 65, no. 4, pp. 385–391, 2007.

[11] A. Z. Bouyakoub et al., “Traitement combiné d ’ un effluent textile contenant des colorants réactifs par coagulation-floculation et électroflottation Combined treatment of a textile effluent containing reactive dyes by coagulation-flocculation and el,” vol. 23, 2020.

[12] G. J. Bouyoucos, "A Recalibration of the Hydrometer Method for Making Mechanical Analysis of Soils," Agron. J., pp. 434–438, 1951.
[13] J. Hussain, I. Hussain, and M. Arif, "CHARACTERIZATION OF TEXTILE WASTEWATER," J. Ind. Pollut. Control, no. September, 2006, doi: 10.1177/0022185606066143.
[14] H. Ben Mansour, O. Boughzala, dorra Dridi, D. Barillier, L. Chekir-Ghedira, and R. Mosrati, "Les colorants textiles sources de contamination de l'eau: CRIBLAGE de la toxicité et des méthodes de traitementTextiles dyes as a source of wastewater contamination: screening of the toxicity and treatment methods," Rev. des Sci. l'eau, vol. 24, no. 3, p. 209, 2012, doi: 10.7202/1006453ar.
[15] S. Firdous, S. Begum, and A. Yasmin, "Assessment of soil quality parameters using multivariate analysis in the Rawal Lake watershed," Environ. Monit. Assess., vol. 188, no. 9, 2016, doi: 10.1007/s10661-016-5527-5.
[16] Z. Wang, Z. Zong, S. Li, and B. Chen, "Nitrate accumulation in vegetables and its residual in vegetable fields," Huanjing Kexue/Environmental Sci., vol. 23, no. 3, p. 79, 2002.
[17] J. Liang, H. L. Fang, T. L. Zhang, X. X. Wang, and Y. D. Liu, "Heavy metal in leaves of twelve plant species from seven different areas in Shanghai, China," Urban For. Urban Green., vol. 27, pp. 390–398, 2017, doi: 10.1016/j.ufug.2017.03.006.
[18] B. J. Allred, J. M. Bigham, and G. O. Brown, "The Impact of Clay Mineralogy on Nitrate Mobility under Unsaturated Flow Conditions," Vadose Zo. J., vol. 6, no. 2, pp. 221–232, 2007, doi: 10.2136/vzj2006.0064.
[19] O. Nourah, "Decontamination des eaux contenant les colorants textiles et les adjuvants par des materiaux naturels et synthetique," Universite Mouloud Ouzou, Tizi Sciences, Faculte des sciences, Departement de Chimie, 2011.
[20] A. Diop, "Diagnostic des pratiques d'utilisation et quantification des pesticides dans la zone des Niayes de Dakar (Sénégal)," Université du littoral de Côte d'Opale, 2014.
[21] B. Massa, Ismael, S. Sorho, and Y. SORO, "schoenoprasum et de parcelles agricoles arrosées aux effluents non," Afrique Sci., vol. 16, no. 6, pp. 114–125, 2020.
[22] S. Firdous, S. Begum, and A. Yasmin, "Assessment of soil quality parameters using multivariate analysis in the Rawal Lake watershed," Environ. Monit. Assess., 2016, doi: 10.1007/s10661-016-5527-5.
[23] C. Derradji, "Traitement des eaux usées industrielles: Dégradation des colorants azoïques par un procédé intégré couplant un procédé d'oxydation avancée et un traitement biologique.," p. 13, 2012.
[24] R. P. Thio, D; K; Konan, K. K; Koffi, and A. K. Yao, Characterization of raw silica sand from the Ivorian sedimentary basin for silica glass making. Journal of Materials and Environmental Science, vol. 11, no. 12, pp. 2016-2024, 2020.