Journal of Water Resource and Protection, 2017, 9, 1634-1644
http://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Impacts of Environmental Management on the Quality of Traditional Well Water in the Soubré Region (South-West of Côte d'Ivoire)

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How to cite this paper: Adelaïde, O.-Y.M.J., Yaya, O.L., Bernard, Y.O. and Veronique, M. (2017) Impacts of Environmental Management on the Quality of Traditional Well Water in the Soubré Region (South-West of Côte d'Ivoire). *Journal of Water Resource and Protection*, **9**, 1634-1644.
https://doi.org/10.4236/jwarp.2017.913102

Received: November 5, 2017
Accepted: December 25, 2017
Published: December 28, 2017

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Abstract

Water supply is a global problem. A study was conducted on twelve (12) traditional wells water in Daba Dagnogo and Gnipi 2 to determine their physico-chemical quality. Two sampling campaigns (dry season and rainy season), were performed on 16 physical and chemical parameters. The results show that the water is acidic with an average pH of 6.41 ± 0.4; moderately mineralized with an average conductivity of 731.14 ± 611.98 $\mu S \cdot cm^{-1}$; moderately saline with an average rate of 1.56 ± 1.22. The average temperature of 28.07 ± 0.86˚C is above the norm for all wells. All major ions are consistent with WHO standards except calcium and potassium. 41.67% of wells exceed the standard ammonium ion whose average was 1.43 ± 2.79 $mg \cdot L^{-1}$ nitrate and 100% with an average of 492.42 ± 434.02 $mg \cdot L^{-1}$. The ion concentrations are highest in the urban area and are higher in the dry season. The quality of the water sampled wells deteriorated. Several factors affect the degradation, namely the shallow wells, their proximity to toilet, the lack of sanitation and poor management of household waste. It will carry out a campaign to educate people to protect the immediate environment of the water points, avoiding the deposit of garbage and to provide the appropriate wells lids.

Keywords

Soubré, Traditional Wells, Physico-Chemical Quality, Environmental Management

1. Introduction

Groundwater is the main source of water supply and is currently most heavily consumed (over 70%) as a valuable natural resource for various human activities [1]. Water is fundamentally necessary for life, but its quality is continually deteriorated by anthropogenic activities [2], such as poor environmental management. Indeed, the uncontrolled expansion of African cities is obviously a serious threat of pollution for groundwater. The lack of sanitation infrastructure (presence of dumps of garbage, latrines and leaking septic tanks, landfill leaks) and the inadequacy of the storm and wastewater drainage system are at risk important of contamination to water in general resources and resources in groundwater in particular [3]. Specific works has addressed the impact of poor sanitation on the quality of water resources in cities in Asia and sub-Saharan Africa. This work highlights the nitrogen pollution of the superficial aquifers in Niamey [4]. [5] reveals in their study the pollution of the aquifer by leachates from an uncontrolled discharge. The objective of this study is to study the environmental factors of conditional pollution by analyzing the physico-chemical quality of these waters.

2. Material and Method

2.1. Location of Study Area

The study area (**Figure 1**) is located in the department of Soubré (South-West of

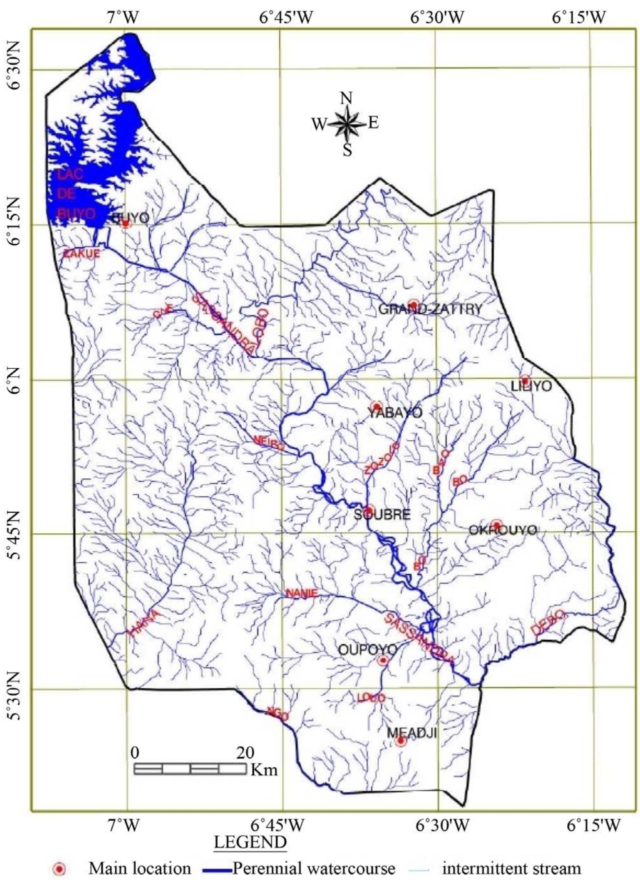

Figure 1. Location of study area: source (Yao, 2009).

Cote d'Ivoire) between latitudes 5˚19 N and 6˚34 N and longitudes 6˚12 W and 7˚08 W. The climate is the subequatorial type one (hot and humid) with abundant precipitation, which average is estimated at 1503 mm, high atmospheric humidity and a small annual variation in thermal amplitude.

January is the driest month and the main rainfall is recorded in June and July with an average of 223 mm. The temperature oscillates between 26˚C and 32˚C during the year. February is the warmest month with an average temperature of 27.2˚C. On the other hand, August is the coldest month with an average temperature of 24.4˚C. The soil study carried out by [6] revealed the presence of three types of soils, namely the rearranged or typical ferralitic soils with induration from the various granitoids and migmatites, hydro-morphic alluvial soils and brown soils. The aquifers of the region belong to the Eburnian domain and consist of flyschoic, volcano-sedimentary, plutonic and vein rocks.

2.2. Sampling and Measured Parameters

The study was conducted in the region of Soubré precisely in Gnipi 2 and Daba Dagnogo. The site of Gnipi 2 (G2) located 13 km from Soubré, in rural area, presents traditional wells as the only source of drinking water. It is located in an area where the main activity is intensive agriculture.

The site of Daba Dagnogo (DD) in urban area is one of the largest and most precarious districts of the city of Soubré. It is located on a marshy ground. The latter site is densely populated. The wells selected are the most used because they are best supplied with water even in the dry season. A questionnaire was administered to the households using the well water retained and concerned the method of household waste management, the mode of wastewater management, the well protection system and parameters like the well-latrine distance.

Two sampling campaigns were carried out on 12 traditional wells, including 6 in each locality. The first occurred in April, during the dry season and the second in August during the rainy season. Sampling was carried out on 16 physico-chemical parameters. Water samples were collected in 1 liter polyethylene bottles [7]. Each flask is rinsed with the water to be collected and then filled to be stored in an ice box containing ice.

Temperature and pH were determined using the HANNA HI 98150 multimeter, conductivity and salinity, the HANNA HI 9835 multimeter, turbidity the Turb 430 WTW turbidity meter IR and the depth of the water level with a decameter.

The Na^{+}, Mg^{2+}, Ca^{2+} and K^{+} ions were analyzed with the AAS (Atomic adsorption spectrophotometer) 20 spectrophotometer type VARIAN according to the standard NF T 90-112, the Cl^{-} and HCO_3^{-} ions by titrimetry respectively according to standards NF T90-014 and NF T90-051. The nutrients, PO_4^{3-}, NH_4^{+} and NO_3^{-} were determined spectrophotometrically at the respective wavelengths of 530 nm, 420 nm and 415 nm.

The mustache box of [8] was used as a statistical processing tool to represent schematically a distribution. Charts that use box-whisker boxes allow for a global overview and at the same time a local view of the data. Mustache boxes give an overview of the temporal variability of measurements. In x-axis, studied stations are represented (in our case these are the localities either seasons). On the ordinate is the parameter studied (for example, conductivity).

When the box is large, the extent of the observations is important. The coefficient of variation was used to assess whether the measurements were homogeneous or not.

3. Results and Discussion

3.1. Results

3.1.1. Analysis of Survey Results

The wells sampled have a very low static level with an average depth of 1.54 m. More than half of the wells are not covered or are protected by an unsuitable cover. Almost half of the wells are not shaped properly. None of these wells meet the WHO recommended minimum distance (well-latrine distance = 15 m). The survey also allowed us to observe the proximity of water points with probable sources of pollution, namely plantations, swamps, livestock pens and especially latrines, poorly maintained gutters where they exist, and runoff.

All wells (100%) have a more or less appropriate curb. For the lining 83.33% of the Gnipi 2 wells have a cement coating. In Daba Dagnogo, 33.33% of the wells are cemented, 50% have bricks and 16.33% is provided with an iron barrel as a casing. The latrines and showers, which are often only one, used by a large number of people, are at best only about ten meters from the well when it is not the conveniences of the neighborhood that are close to it. The waters stagnate in the vicinity of these wells and there is a lack of drainage system of the waste water. These waters are thrown into the courtyards near the wells, to reduce the dust. The absence of an excreta evacuation system should also be noted. In Gnipi 2 all households surveyed are in the wild, unlike Daba Dagnogo, where all concessions have a latrine, but they are located less than 15 meters and often upstream of the wells. Household waste is stored in old buckets in the middle of the courtyards or in front of the concessions near the roads. The site of Daba Dagnogo is near a wild dump.

3.1.2. Analysis of Physico-Chemical Results

The analysis involved 16 physico-chemical parameters. However, it is the results of physical parameters (temperature, pH, conductivity), as well as some ions characteristic of environmental management (PO_4^{3-}, NH_4^+, NO_3^-) that will be exposed in this work.

1) Physical Parameters

The temperature varies between 29.8˚C and 30.6˚C in the dry season and between 22.8˚C and 28.7˚C during the rainy season. In the dry season, the small size of the box and the high position of the median indicate a very low spatial variability of this parameter, the value of which remains high at all the wells, exceeding the norm set at 25˚C. All wells have a temperature above the WHO recommended limit of 25˚C (Figure 2). These temperatures vary during this study between 26.3˚C and 29.40˚C with an average of 28.07˚C ± 0.86˚C and a CV = 0.03 (CV < 0.2), thus showing a very homogeneous distribution of values.

The pH values obtained during this study range from 5, 66 to 7, and 1 in the dry season and between 5.40 and 7.90 in the rainy season. Mustache boxes indicate greater spatial variability observed in the rainy season with a median below the minimum of the accepted values. The acidity of the water is more pronounced at Gnipi 2 with a slight temporal variability given the size of the box and the low level of the median; in contrast to Daba Dagnogo, the pH remained high throughout the study period (median around 7). These waters have a generally acid and aggressive (corrosive) tendency with an average of 6.41 ± 0.56 and a CV = 0.09 also reflecting a homogeneous variation of values.

The water conductivity of the different wells varies in the dry season, from 147.10 µS/cm in well P5 and 1801 µS/cm in well P7, and in the rainy season it varies between 120.20 µS/cm at well P5 and 1582 µS/cm at well P7. The rate of mineralization of water decreases during rainy season with spatial variability observed during the two periods of the study.

The mean values in this study ranged from 200.3 to 1801 $\mu S \cdot cm^{-1}$ with a mean overall of 731.14 ± 611.98 µS/cm and a CV = 0.84 (heterogeneous variations).

2) Chemical Parameters

Orthophosphate ions (PO_4^{3-}) (Figure 3) in the studied waters range from 0.00 to 0.98 mg/L in the dry period and 0.00 to 5.65 mg/L in the rainy season. Low spatial variability was observed during both study seasons. In the rural area, there is also a very low temporal variability with an almost zero value of the median; unlike the city where a very high temporal variability is observed. These

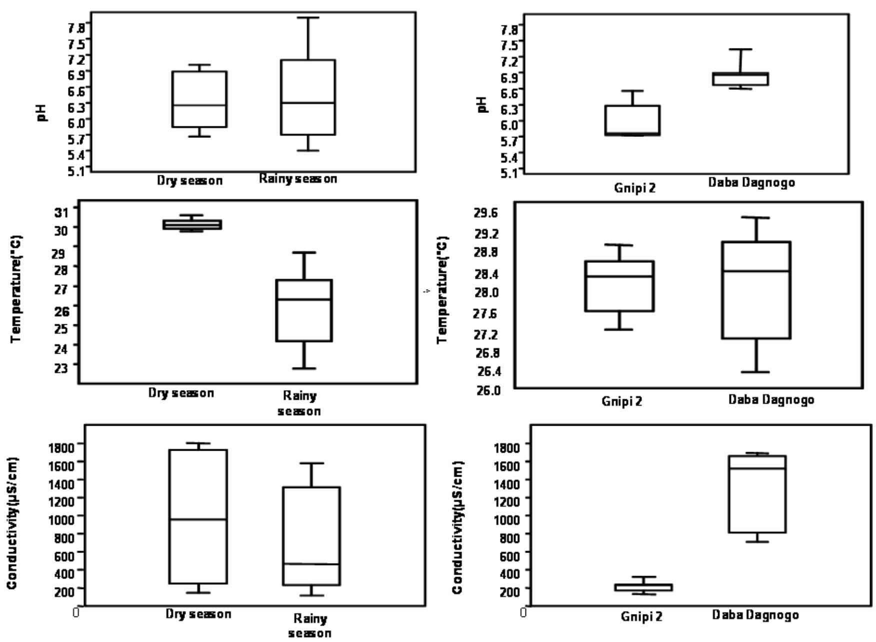

Figure 2. Temporal and spatial variability of pH, temperature and conductivity.

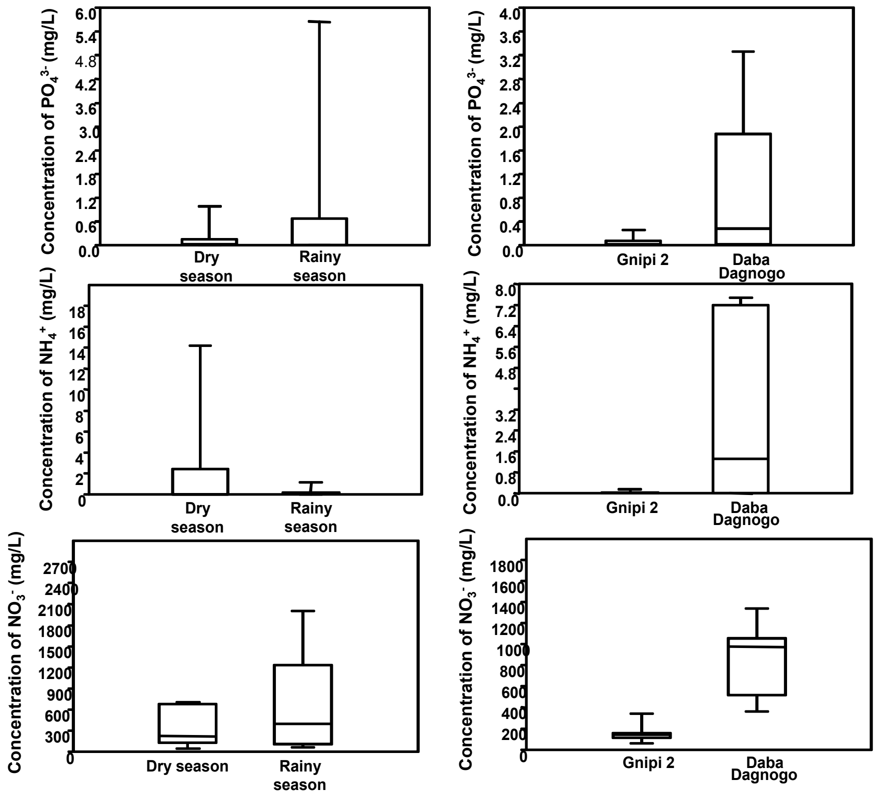

Figure 3. Temporal and spatial variability of PO_4^{3-}, NH_4^+ and NO_3^-.

ions have mean values between 0 and 3.26 mg/L with an overall mean of 0.46 ± 0.97 mg/L. The wells (P7 and P12) have a content exceeding the required standard of 0.5 mg/L. Ammonium concentrations range from 0.00 to 14.19 mg /L in the dry season and 0.01 mg /L and 1.17 mg /L in the rainy season. A marked decrease in ammonium levels is observed in the rainy season. A broad temporal variability of Daba Dagnogo wells is obtained in contrast to Gnipi 2 where all wells have substantially the same ammonium ion value during the study period. Mean values ranged from 0 to 7.48 mg/L with an overall mean of 1.43 ± 2.79 mg/L with CV = 1.95 (heterogeneous variations).

Nitrate levels are extremely high, especially in urban and rainy areas, ranging from 59.86 mg/L to P5 well and 1339.66 mg/L to P12 well with an average of 496.42 ± 434.02 mg/L and a CV = 0.87 (CV ± 0.3) implying the heterogeneous distribution of values.

3.2. Discussion

The results of this study are discussed by discussing the mean values of the parameters measured during the study period, including in situ and laboratory measurements. The temperatures found during our study, the average of which is estimated at 28.07˚C ± 0.86˚C, are close to those obtained by [9] in Buyo in south-western Côte d'Ivoire and practically identical to those obtained by [10] with an average of 28.43˚C ± 0.68˚C. The high values recorded during this study could have as their common origins the influence of ambient temperature.

Indeed, according to these authors, the high temperatures could be explained by the influence of the ambient heat on the collected waters but also by the geothermal gradient of the zone which is par excellence a tropical zone. However, these values are slightly higher than those obtained in Guiglo-Duekoué (Côte d'Ivoire) between 25.7˚C and 28.9˚C [11]. This difference could be explained by the greater depth of the water levels of these authors who worked on drilling waters.

In addition, these high temperatures can contribute to the growth of pathogenic biological agents, in particular microorganisms of the environment [12]. Indeed, according to [13] [14], high temperature values indicate the opening of the aquifer system, and consequently its vulnerability to pollution. Moreover, they pose a problem of acceptability because fresh water is generally more pleasant to taste than warm water [15].

The waters of our study area are acidic tendency. This is one of the essential characteristics of the groundwater of Côte d'Ivoire, as already observed [16] on the waters of the disadvantaged neighborhoods of four communes in Abidjan (Côte d'Ivoire). The values obtained during our study have an average of 6.41 ± 0.56 and a CV = 0.09. Eight (8) wells, representing 66.67% of the wells taken, have a pH below the WHO standard of between 6.5 and 8.5.

These wells being located in rural areas, this acidity could be of agricultural origin as observed [17]. Indeed, these authors believe that the decomposition of organic vegetable matter under the action of oxygen gives off carbon dioxide (CO_2) whose presence in water facilitates the hydrolysis of silicate minerals and the formation of ions Bicarbonates (HCO_3^-) source of acidity of water. This hypothesis is confirmed by [18] which also attribute the acidity of groundwater to the presence of free carbon dioxide (CO_2) in these waters. Our values are comparable to those obtained by [6] in Soubré (south-west Côte d'Ivoire), with values between 5.9 and 7.6, which showed that the acidity of the waters is related to the nature of the soil.

The geological origin of water acidity was also reported by [10] and [19], who consider that the pH characteristics are related to the geological nature of the aquifer formations and the lands traversed. However, the average obtained in this study is relatively higher than that found by [17] in Abengourou (Côte d'Ivoire) with an average of 5.13; But is still lower than that obtained by [14] in Abia (Côte d'Ivoire) and estimated at 7.15 ± 0.09.

The conductivity values of the wells vary from 200.3 to 1801 $\mu S \cdot cm^{-1}$ with an average of 731.14 ± 611.98 $\mu S \cdot cm^{-1}$. These waters are moderately mineralized. According to [20], many factors can influence polluting the local conductivity of water as the quantity of mineral or organic matter in suspension, the physico-chemical quality of urban, agricultural or industrial discharges and the phenomena of evaporation thus polluting the waters of these wells; because of their shallow depth. The hypothesis of the low piezometry of the aquifer was also emitted by [18] who found much mineralized waters in the region of Biskra

(Algeria).

Orthophosphate ions (PO_4^{3-}) have values between 0 and 3.26 mg/L with an average of 0.46 ± 0.97 mg/L. The wells P7 and P12 have a content which exceeds the required standard of 0.5 mg/L. These values are higher than those obtained in Adiaké (south-eastern Côte d'Ivoire) by [21], varying between 0.007 mg/L and 1.01 mg/L and are comparable to those obtained at Pobé in Benin by [22] which range from 0.22 mg/L to 2.84 mg/L. The high levels observed at the wells P7 and P12 could have several origins. [18] [23] suggest that water contamination by orthophosphates is related to domestic discharges to waste sites, in waters receiving discharges of water waste or leaching of cultivated land containing phosphate fertilizers or treated with certain pesticides.

Ammonium ion (NH_4^+) levels ranged from 0 to 7.48 mg/L with an average of 1.43 mg/L. These results are lower than those obtained in Attécoubé [24], which ranged from 0.1 mg/L to 11.5 mg/L. However, they are superior to those obtained by [25] in Buyo, with an average of 0.44 mg/L and by [22] with a reported mean of 0.193 ± 0.28 mg/L. These high values could be due to the incorrect handling of the drainage cords (lug placed on the ground). These high values may also result from the lowering of the water table leading to high concentrations.

As for nitrate ions (NO_3^-), they represent the most abundant nutrient in all wells with values above the WHO recommended standard (50 mg/L). The values obtained are extremely high, especially in urban and rainy areas, and range from 59.86 mg/L to P5 well and 1339.66 mg/L to P12 well with an average of 496.42 ± 434.02 mg/L and a CV = 0.87 involving a heterogeneous distribution of values and reflects the fact that the contamination of these waters by this nutrient is due to the immediate environment of each well. These high concentrations could be due to point pollution. Our results are superior to those obtained in the water table of Yeumbeul in Senegal by [26]. These authors obtained results varying between 43 mg/L and 359 mg/L, and estimate that these high levels would come from organic waste coming from low-latrine latrines, poorly constructed septic tanks, waste water streams. Similarly, in Bafoussam (West Cameroon) [27], nitrate and ammonium levels were higher in the rainy season, in line with our results. These authors found in rainfall season a maximum of 220.5 mg/L and in the dry season a maximum of 92.9 mg/L for nitrate and ammonium, up to a maximum of 15.6 mg/L dry season and a maximum of 36.5 mg/L in the rainy season. This could be explained by the effect of runoff water loaded with animal and human faeces, but also by the infiltration of latrines, septic tanks, rivers and landfills. These authors noted that wells with high nutrient concentrations are generally very close to high use latrines. This observation was made by [25] in Buyo (Cote d'Ivoire). Our results are consistent with those obtained by [16] [25] and many others [28], who have shown that nitrogen content, a sign of anthropogenic contamination of groundwater, is higher in Areas with high population density. Groundwater pollution by nitrogenous fertilizers has also been widely supported by numerous studies. According to [29] [30] agriculture contributes to groundwater pollution because of the sometimes irrational use of fertilizers and pesticides that farmers add in order to increase the productivity of the plot. [15] [28] and many authors explain the presence of high levels of nitrates observed in some regions due to low groundwater piezometry and certain agricultural practices. [31] attributes high levels of nitrate mainly to lack of good housing planning, location of water wells in the vicinity of sewage treatment basins, and unhygienic sanitary conditions prevailing in the community. Diffuse sources of diffuse nitrates are decomposition of organic matter, leaching of chemical fertilizers, leaching of animals and discharges from septic tanks and sewers. Shallow well depths are also contributing factors.

4. Conclusion

At the end of this study, it appears that the quality of the wells water studied is strongly degraded. Nitrate is in the forefront with extremely high values at all wells followed by ammonium. This pollution is due to poor maintenance of the environment, inter alia, the infiltration of poorly managed domestic wastewater from households and poorly constructed and poorly designed toilets, coupled with poor water management. In fact, no sinks comply with the 15 m regulatory distance required by the public health services. A good awareness campaign will be needed to educate people to protect the immediate environment of water points.

Acknowledgements

We wish to express our sincere thanks and gratitude to Professor TIDOU Abiba Sanogo, President of the Jean Lorougnon Guédé University of Daloa (UJLoG) for giving us the opportunity to carry out this study through the Continuing Education School (EFC). All our gratitude and our deep gratitude to our supervisors, Professor YAPO Ossey Bernard, Lecturer at Nangui Abrogoua University and Dr. Ohou-Yao Marie-Jeanne Adelaïde, Assistant Professor at Jean Lorougnon Guédé University in Daloa. Our thanks to the members of the Laboratory of Industrial Processes for the Synthesis of the Environment and New Energies (LAIPSNE).

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