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ScienceDirect
Energy Procedia 76 (2015) 67 – 76
Energy Procedia

European Geosciences Union General Assembly 2015, EGU

Division Energy, Resources & Environment, ERE

Georesources and environmental problems in Niamey city (Niger): a preliminary sketch

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Abstract

The present paper is about a preliminary study of the georesources of Niamey (Niger). The main goals are the qualitative and quantitative characterization of surface water, groundwater, and aggregates. There was a census of the wells and quarries, an *in situ* characterization and a consequent sampling survey. Laboratory analyses were performed to evaluate chemical and physical features of water and aggregates. Thanks to a dedicated Geodatabase, schematic forms reporting the available data of wells and quarries were produced. The study evidenced the actual condition of surface water, groundwater and active and closed quarries, also highlighting local phenomena of pollution.

Peer-review under responsibility of the GFZ German Research Centre for Geosciences

Keywords: groundwater; surface water; aggregates; quarries; GIS; Niger.

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Peer-review under responsibility of the GFZ German Research Centre for Geosciences
doi:10.1016/j.egypro.2015.07.848

1. Introduction

The present paper is about a preliminary study of the georesources (water and raw materials for construction) of Niamey city (Niger). Such research is part of an UNICOO project (funded by the University of Torino) and connected to the Edulink Cooperation Project (R.U.S.S.A.D.E.), a multidisciplinary project between Italy, Niger, Burkina Faso and Tchad, funded on ACP- EU cooperation program in Higher Education [1].

Niger is one of the poorest country in the world; in 2012, only 54% of the Nigeriens had access to safe drinking water. However, in rural areas, where over 82% of the population lives, less than one in two Nigerien have access to potable water. At the same time, the results of the survey on Living Conditions and Household Agriculture (ECVM/A) organized by the INS in 2011-2012, shows that the percentage of the population with access to sanitary toilets is only 19%, with 68% for urban residents and 7% for rural residents (http://www.watergovernance.org/niger) [2]. In Niamey city drinking water depends on groundwater and surface water. Water resources in Niger, such as in many African countries, are threatened by mismanagement and the following chemical degradation [3]. In the middle of 1980s, a severe drying up of the Niger River led to the drilling of more than one hundred boreholes, located in the fractured basement aquifers formed by hard-rocks, to ensure the water supply of the city. Nitrate pollution, due to uncontrolled urbanization and deforestation, was highlighted. Indeed, the development of urban infrastructures (extension of sewerage and water supply) could not follow the population uncurbed growth [4].

The main goals of the study are connected to the individuation of environmental and landscape problems of the Niamey urban area. Such problems are mainly linked to water resources (superficial and groundwater) and to quarrying activities (much attentions was paid to the characteristics and peculiarities of present and past exploitation activities). Specifically the topic of the research are:

- census of wells, superficial waters and quarries present in the Niamey area
- qualitative characterization of groundwater and surface water resources in Niamey city;
- technical characterization of the aggregates exploited in the quarries present in the Niamey nearby
- reuse of the quarry areas after the end of quarrying activities (potential environmental rehabilitation);
- Geothematic map collection of investigated areas, in-field data collection and georeferencing by means of Geographical Information Systems (GIS).

2. Geological and hydrological setting

Niamey city is located at the SW of Niger (13°28’- 13°35’ of latitude N and 02°03’ - 02°12’ of longitude E) (Fig. 1). The morphology of the investigated area is characterized by weak slopes, mainly linked to fossil dunes and small reliefs. While the urbanized area is set between 180 and 200 m a.s.l., the highest relief, indentified by the "Trois Soeurs" (the three sisters), reaches 250 m a.s.l. The unique permanent river that crosses the city is the Niger River, which is the third longest river in Africa; the others are just tributary seasonal rivers (koris), generally located on the left bank of the Niger River. The weather condition is generally arid, characterized by an annual temperature of 30° in average, while the maximum temperatures are reached at the end of the dry season, in April, and are nearly 45°C. The annual rainfall is 500 mm in average, all concentrated during the rainy season (from May to August).

The geological setting of the area, on a regional scale, is between the West Africa Precambrian Craton and the formations belonging to the sedimentary basin of Iullemmeden (paleo-Mesozoic and Tertiary covers). In particular, the bedrock consists of Precambrian intrusive rocks (granites and diorites) and micaschist, with quarzitic intrusions; the covering rocks pertain mainly to the so-called CT (Continental Terminal - Pliocenic age), which represents the upper end of the sedimentary deposits of the Iullemmeden’s basin (sandstones and sandy clay). These latter, finally, are covered by quaternary deposits, consisting of armour ferruginous laterites (formed at the end of the tertiary), by colluvial deposits, dunes and recent terraces, and alluvial sediments [4,5]. The alluvial and lateritic sediments, are the most interesting for quarrying activities: the alluvial ones are exploited to obtain gravels and sands for buildings activities (bricks, cements); the second ones are mainly quarried to be employed in major public works (roads).

From a hydrogeological point of view, the city of Niamey presents two shallow aquifers with different permeability: the first, that characterizes the central part of the city, on the left bank of the River Niger, is set on the base of the altered precambrian bedrock, with a permeability linked to cracking; the second one, situated both on the left and on the right bank of the Niger River, is present in deposits belonging to the Continental Terminal and the recent alluvial deposits, characterized by permeable porosity.

Groundwaters are mainly recharged by indirect infiltration from surface waters (near ponds for example) and direct infiltration (on sandy dunes) [4]. Typically, water samples from aquifers formed by Precambrian altered hard-rock formations and Quaternary alluvial formations contain high amounts of bicarbonate, sodium, calcium and magnesium related to water-rock interaction and low flow in the aquifer. The chemistry of the groundwater in the Continental Terminal (CT3) sandy to clayey sandstone aquifer significantly differs from other groundwaters found in the altered and fissured hard rock aquifers. Higher levels of nitrate and sodium were observed in the CT3 aquifer due to contaminated recharge water. Nitrate is the main ionic contaminant and its content is seasonally or 9 0.81 meq.L-1 in 44 % of sampled wells, and reaching 816 mg L-1, more than 16 times higher than the standard. Fourteen percent of sampled boreholes show an increase in the groundwater nitrate content over the last twenty years. As expected, samples from dug-wells located in the central city with numerous pollutant sources had the highest concentrations of leached elements indicating that land-use is the primary control on groundwater contamination [4].

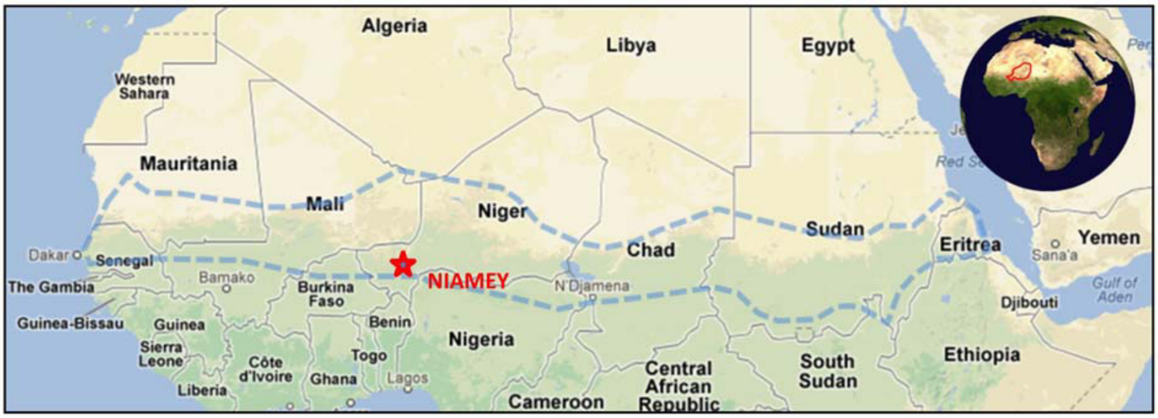


Fig. 1. Niger is a landlocked developing country located in Western Africa into semi-arid climate area, called Sahel Region (dashed blue).

3. Materials and methods

The study consisted of a census of wells and quarries in the Niamey area, with a consequent sampling survey (surface water, groundwater and aggregate sampling). After that, an *in situ* characterization was set: measure of piezometric levels in wells, water characterization and an *in situ* evaluation of the quarrying techniques and quarry exploitation (present and old quarries). The water samples were analyzed in Earth Science Dep. (UNITO) to evaluate the content of the main anions and cations and the size distribution of the materials coming from the investigated quarries. Schematic reports of wells and quarries (location and features) were produced with the support of a Geodatabase with all the available data (Fig. 3, 5). Geomatics instruments and methodologies (Geotagged Photos, Digital Mapping, GNSS Survey, Satellite Multitemporal Maps, Georeferenced Maps) were a basic starting point for the field data collection and a fundamental aid for data arrangement and final dissemination.

In the following, a detailed description of the adopted methods used for geomatic methodologies, the water resources and quarry investigation is provided.

3.1. Geomatics

The results of an innovative approach to field data acquisition and interpretation, integrating geomatic techniques based on satellite remote sensing images, digital field instruments and GIS are presented here, as a suitable tool for supporting georesources screening missions. Satellite images (VHR from Virtual Globes and Landsat 7 ETM+ from NASA) have been analyzed in order to create a good knowledge of the local landscapes into specific Niamey area. A GNSS instrument was used to collect the POI (Points of Interest) needed for waters and quarries features. A GIS (Geographic Information System) was used for data management purposes. In the first step for data collection and mapping of existing sites surveyed in traditional topographic mode. The second step was dedicated to the land analysis and planning of the new sites identified. Spectral properties of images have been also used to extract further information about the geomorphological features of the area (i.e fluvial landforms) and about evidences of possible critical sites. Handled Pocket PC and traditional GNSS devices were used as necessary instruments for data collection. As a first-step, base maps are loaded into Mobile GIS environment, then surveyed features are classified by geometry and by related activity. Further alphanumerical data have been collected to complete descriptions and to support interpretations. Thus, the field survey becomes an integral part of a complete and easy-to-update GIS, without other intermediate passages. The results show that data collection and organization inside a GIS environment can be useful for managing information from these research programs.

3.2. Water resources

A field survey and groundwater sampling were performed between February and April 2014 in Niamey and surroundings. The field work consisted in a census of 14 wells and 12 surface water points. Particularly the surface waters were surveyed in correspondence of rivers (Niger River and tributaries) and waterholes. The location of groundwater and surface water points are reported in Fig 2. In correspondence of each water point information about the location (geographic coordinates and name of the place) and the well/surface water point features were collected. As for wells, diameter, depth and use were specified. In the wells the groundwater depth in respect to the soil level (m a.s.l.) were measured with a freatimeter. The water point were sampled, if possible, and water was stored in 100-ml polyethylene bottles. Particularly 13 groundwater samples and 12 surface water samples were collected. Some physical-chemical parameters (water temperature, air temperature, pH, EC and nitrite, nitrate and ammonia concentration) were measured *in situ* with field instruments. The equipments for field measurements consisted of handheld GPS instruments to locate points on a Landsat map through ArcPad, portable meters (Hanna Instruments) for the measure of electrical conductivity, pH and temperature, nitrate, nitrite and ammonia reagents set (Hanna instruments). The collected data about features and physical-chemical parameters were reported in technical reports with the pictures of wells and surface water points (Fig. 3). The technical reports also contain a picture showing the conditions of wells and surface water points and their location in a satellite image.

Water analyses were carried out at the Hydrochemical Laboratory of Turin University (Department of Earth Sciences). Major anions were analyzed using ion chromatography. The concentrations of HCO_3^- were measured by titration.

3.3. Aggregates

A first field survey phase was set in the Niamey area. Eleven quarries (7 active quarries and 4 closed ones) were investigated. The activities forecasted during the field survey were: aggregate sampling, georeferences of the area, description of exploitation activities, etc... The location of active and closed quarries is reported in Fig 2. A sieve for field activities was employed, to separate the coarse fraction (> 2 cm) from the fine one (< 2 cm). The fine fraction was collected and characterized in lab at the University of Torino (grain size analysis). Five aggregate samples in total were sampled. The sampled materials from the five quarries were mainly gravel and sand samples but also lime and laterite.

The collected data about exploited materials and quarrying activities (equipment and techniques) were reported in technical forms (Fig. 5). The technical reports also contain a picture showing quarrying context, the grain size analysis of the sampled material (if present) and the quarry location in a satellite image.

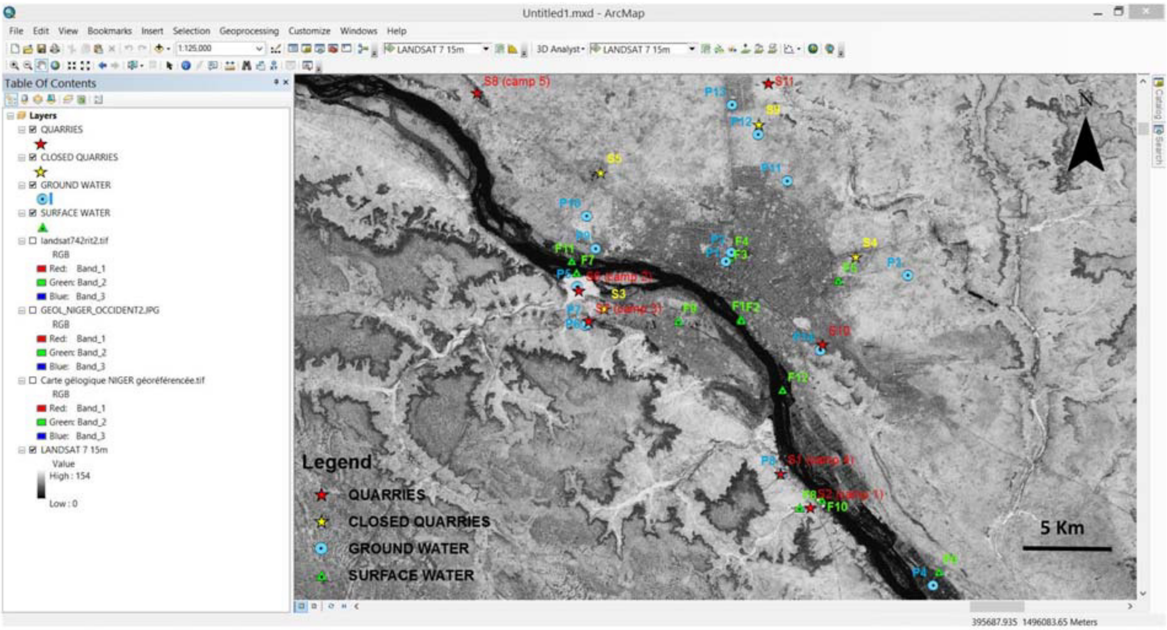


Fig. 2. GIS of Niamey Project. The base data is Landsat 7 Panchromatic (Pixel 15m). Vector data show the field data collection work.

4. Results

4.1. Water resources

The conducted research permitted to make a census of part of wells and surface water (Tab.1, Tab.2) in the urban and periurban of Niamey and to provide a rough qualitative assessment of the water resources of the city. The values of Ec and Ph are not reported in the Tab.1 and Tab.2, because comparable to lab analyses Tab.3. As for the status of water supply in the city, although the majority of houses is reached by the water network, there are some areas where water is drawn from wells or directly from the river Niger. The wells are distributed in an almost uniform way over the entire surface of the city and are used both for irrigation and for drinking purposes.

The study evidenced the current condition of surface water and groundwater (Tab.3). Moreover a local phenomena of nitrate pollution was identified. Nitrate in groundwater showed concentration up to 5 times the WHO limit (50 mg/L) in the well P2. In the Niger River and tributaries the nitrate, nitrate and ammonia levels are always very low (sample F1, F2, F7, F8, F10, F11 and F12). On the contrary, irrigation canals often are used for domestic water and sewage channeling, and as a consequence the N-compounds concentrations are very high (F3, F4 and F5 samples).

Table 1. Wells features and groundwater field data in Niamey city (n.d.: not determined; * water sampled from the tank; ** ditch dug by hand)

Sample	latitude	longitude	quote	site	well use	deph to water from land surface (m)	well depth (m)	T (°C)	NO_3^- (mg/L)	NO_2^- (mg/L)	NH_4^+ (mg/L)
P1	13.521177°	2.108881°	124.4	Niamey	irrigation	n.d.	n.d.	26.7	0	0	0
P2	13.524814°	2.110990°	188.6	Niamey	irrigation	3	5.25	26.1	250-500	0	0
P3*	n.d.	n.d.	n.d.	Niamey	domestic	n.d.	>50	34	0-10	0	0
P4	13.393501°	2.192878°	n.d.	Niamey - Liboré	irrigation	3.06	4.72	28	0	0	0
P5**	13.511002°	2.048817°	n.d.	Niamey	n.d.	n.d.	n.d.	27.8	0	0	0-10
P6	13.495812°	2.052379°	n.d.	Niamey - Kourterè	drinking water	6.24	7.07	28.4	25-50	0	0-10
P7	13.496623°	2.052957°		Niamey - Kourterè	drinking water	7.67	8.32	29.5	50	0	0
P8	13.437529°	2.131507°	n.d.	Niamey	drinking water	2.4	2.9	27.1	25-50	0	0
P9	13.525952°	2.056386°	n.d.	Niamey - Goudel	irrigation	2.42	4.6	29	0	0	0
P10	13.538790°	2.052658°	n.d.	Niamey - Goudel	n.d.	9.23	9.8	28.8	50-100	0	0
P11	13.553155°	2.133604°	n.d.	Niamey	drinking water	> 50 m	n.d.	n.d.	n.d.	n.d.	n.d.
P12	13.571482°	2.121620°	n.d.	Niamey	drinking water	17.54	19.85	21.6	0	0	0
P13	13.583033°	2.111175°	n.d.	Niamey	drinking water	19.55	38	n.d.	n.d.	n.d.	n.d.
P14	13.486323°	2.147138°	n.d.	Niamey - Pays Bas	drinking water	13.58	14.04	31.2	25.50	0	0

Table 2. Surface water features and field data in Niamey city. (n.d.: not determined)

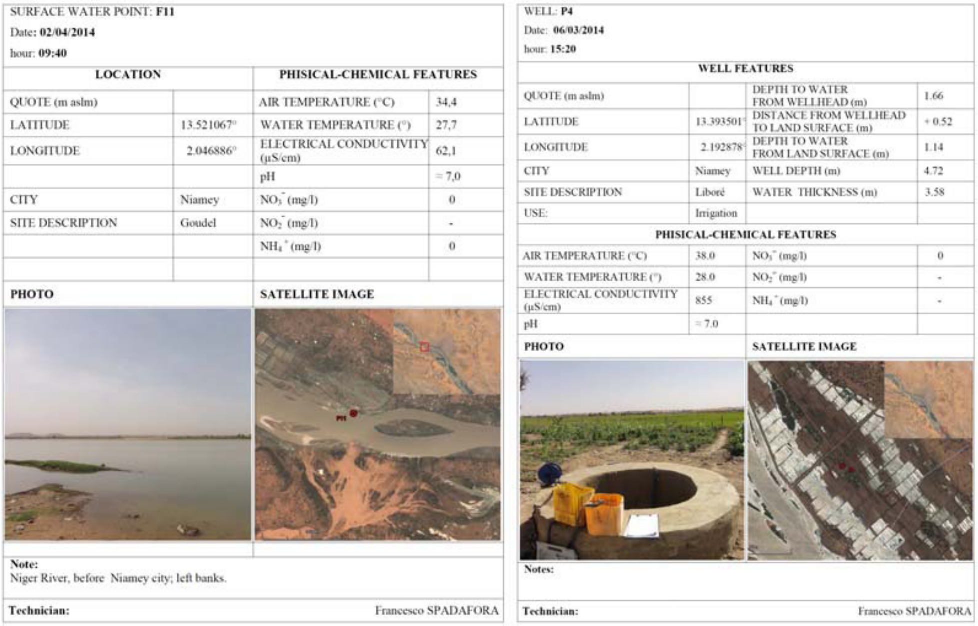
Sample	latitude	longitude	quote	Site	description	T (°C)	NO_3^- (mg/L)	NO_2^- (mg/L)	NH_4^+ (mg/L)
F1	13.295510°	2.065451°	179.3	Niamey	Niger River	23.8	0	0	0
F2	13.295405°	2.065510°	171.5	Niamey	Niger River	24.3	0	0	0
F3	13.522665°	2.110425°	189.5	Niamey	Irrigation canal (the canal is used for the channelling of domestic water and sewage)	24.7	10-25	0	100-200
F4	13.524337°	2.110919°	184.7	Niamey	pool from irrigation canal (the canal is used for the channelling of domestic water and sewage)	25.4	250-500	0	0
F5	13.513981°	2.154328°	n.d.	Niamey - Poudriere	lake from canal (channeling of domestic and industrial water)	28.5	0	0	100-200
F6	13.398884°	2.195414°	n.d.	Niamey - Liboré	lake from rice fields	30.5	0	0	0
F7	13.516645°	2.048788°	n.d.	Niamey	Niger River, upstream to Niamey	26.4	0	0	0-10
F8	13.424165°	2.139097°	n.d.	Niamey - Gorou Kirey	Gorou Kirey river (tributary on the right bank of the River Niger)	32	25	0	0
F9	n.d.	n.d.	n.d.	Niamey	pool from precipitation	29.5	0	0	10
F10	13.427550°	2.147914°	n.d.	Niamey - Gorou Kirey	Niger River, downstream to Niamey	27.6	0	0	0
F11	13.521067°	2.046886°	n.d.	Niamey - Goudel	Niger River	27.7	0	0	0
F12	13.470755°	2.132120°	n.d.	Niamey - Pays Bas	Niger River	31.2	0	0	0

Table 3. Groundwater and surface water chemical analyses (ions concentration = mg/L; EC = µS/cm)

Sample	pH	EC	Li^+	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	HCO_3^-	PO_4^{3-}	SO_4^{2-}	NO_2^-	NO_3^-
P1	6.7	111	0.00	7.7	2.6	0.24	5.4	1.7	0.57	1.9	36.6	0.82	5.1	0.12	6.8
P2	7.3	1321	0.00	84.3	90.9	2.57	101.7	0.0	0.00	78.3	209.9	0.00	48.4	1.57	233.0
P3	7.4	194	0.07	12.7	1.0	1.87	14.8	8.5	0.46	6.8	75.7	0.00	23.1	1.66	4.3
P4	7.8	720	0.28	66.8	4.9	1.01	33.1	38.9	1.52	22.3	439.3	0.00	19.6	0.73	2.3
P5	7.8	302	0.00	23.0	5.7	0.71	22.7	9.1	0.54	11.0	136.7	0.00	6.0	0.00	21.9
P6	6.9	102	0.06	3.8	2.6	0.02	9.3	2.7	0.62	1.2	32.2	0.00	0.7	0.00	21.5
P7	7	196	0.00	10.0	3.3	0.31	16.9	6.4	0.67	2.7	78.6	0.00	1.2	0.00	19.3
P8	7.1	297	0.11	30.2	11.2	7.17	7.8	2.1	0.50	31.0	48.8	0.00	0.3	0.72	19.5
P9	7.1	471	0.29	22.5	1.3	1.00	37.8	19.2	0.64	14.2	111.5	0.00	7.9	0.00	71.6
P10	7.3	339	0.00	21.0	26.4	1.73	30.0	0.4	0.58	9.8	92.7	0.00	26.0	17.60	32.0
P12	7.2	108	0.00	2.6	1.4	0.07	17.0	0.8	0.15	1.2	52.7	0.00	0.3	0.00	4.2
P13	7.1	291	0.00	10.3	7.2	0.07	47.4	2.5	9.35	2.5	139.1	0.00	0.5	0.00	21.2
P14	6.9	68	0.13	15.2	1.8	0.44	13.8	5.0	3.40	9.2	43.2	0.00	4.0	0.00	14.6
F1	6.9	68	0.00	5.6	2.9	0.07	4.6	2.2	0.06	2.5	43.9	0.00	0.1	0.00	0.1
F2	6.8	70.5	0.00	6.0	2.6	0.10	4.7	2.2	0.13	2.9	46.4	0.00	0.2	0.00	0.8
F3	6.6	1317	0.00	150.2	51.4	0.00	62.2	19.5	0.00	192.9	166.0	16.99	28.8	0.00	278.6
F4	7.4	1210	0.00	89.8	73.4	0.00	75.8	25.7	0.00	113.4	219.6	0.00	35.8	0.00	297.5
F5	6.6	1825	0.40	194.0	81.0	20.72	42.3	15.7	0.00	152.2	97.6	22.13	5.6	0.00	36.6
F6	6.8	162	0.00	21.8	10.3	0.00	7.7	2.6	0.71	3.3	85.4	0.00	0.0	1.38	9.1
F7	7	65.5	0.00	4.8	2.6	0.07	4.8	2.4	0.10	0.8	43.9	0.00	0.0	0.09	0.0
F8	6.7	77.7	0.00	7.8	1.4	0.09	4.3	2.0	0.18	2.8	28.1	0.00	1.4	0.00	18.1
F9	6.8	133.2	0.00	19.5	7.2	0.14	14.2	3.1	0.41	6.7	94.4	0.00	13.8	0.39	3.1
F10	6.8	65	0.00	5.1	2.6	0.09	4.5	2.2	0.14	0.8	41.5	0.00	0.0	0.00	0.0
F11	7.1	67.7	0.00	5.3	2.7	0.07	4.4	2.4	0.16	0.9	43.9	0.00	0.0	0.00	0.0
F12	6.8	80.2	0.00	8.2	3.0	0.08	4.5	2.5	0.14	1.4	51.3	0.00	0.0	0.00	0.0

4.2 Aggregates

The conducted research let the authors make a census of the quarrying activities (Tab.4) in the urban and periurban of Niamey and provide data, where possible, about exploited materials, quarrying techniques, etc… Indeed, thanks to the local quarry survey it was possible to evaluate how the quarries work (open air pits) and what is the destination of the closed ones (most of the time the closed quarries are abandoned, not monitored and used as dumping areas, increasing the possibility of groundwater contamination). The knowledge about the use destination of abandoned or closed quarries is really important; such areas are potentially dangerous if used as unmonitored landfills (Tab. 4). The safety conditions of workers are very scarce: no protection devices, hard works and not safe yards (narrow tunnels, dug by hand and without protections).



SURFACE WATER POINT: **F11**
Date: **02/04/2014**
hour: **09:40**

LOCATION		PHISICAL-CHEMICAL FEATURES	
QUOTE (m aslm)		AIR TEMPERATURE (°C)	34,4
LATITUDE	13.521067°	WATER TEMPERATURE (°)	27,7
LONGITUDE	2.046886°	ELECTRICAL CONDUCTIVITY (µS/cm)	62,1
		pH	≈ 7,0
CITY	Niamey	NO_3^- (mg/l)	0
SITE DESCRIPTION	Goudel	NO_2^- (mg/l)	-
		NH_4^+ (mg/l)	0
PHOTO		SATELLITE IMAGE	

Note:
Niger River, before Niamey city; left banks.

Technician: Francesco SPADAFORA

WELL: **P4**
Date: **06/03/2014**
hour: **15:20**

WELL FEATURES			
QUOTE (m aslm)		DEPTH TO WATER FROM WELLHEAD (m)	1.66
LATITUDE	13.393501°	DISTANCE FROM WELLHEAD TO LAND SURFACE (m)	+ 0.52
LONGITUDE	2.192878°	DEPTH TO WATER FROM LAND SURFACE (m)	1.14
CITY	Niamey	WELL DEPTH (m)	4.72
SITE DESCRIPTION	Liboré	WATER THICKNESS (m)	3.58
USE:	Irrigation		
PHISICAL-CHEMICAL FEATURES			
AIR TEMPERATURE (°C)	38.0	NO_3^- (mg/l)	0
WATER TEMPERATURE (°)	28.0	NO_2^- (mg/l)	-
ELECTRICAL CONDUCTIVITY (µS/cm)	855	NH_4^+ (mg/l)	-
pH	≈ 7.0		
PHOTO		SATELLITE IMAGE	

Notes:

Technician: Francesco SPADAFORA

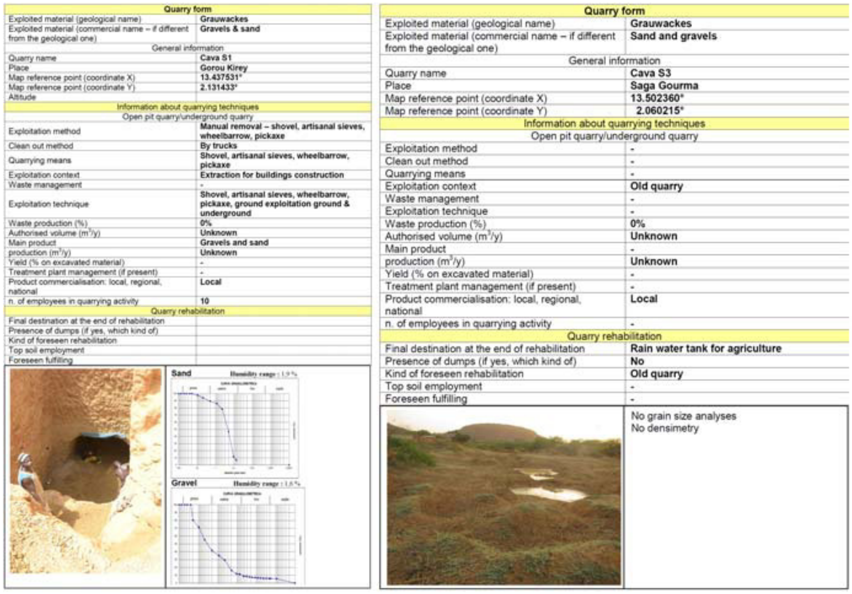
Fig. 3. Example of a schematic report for a groundwater sample point and surface water sample point (location and features)

The investigated quarries are mainly present in Niamey nearby. They are intended to aggregate exploitation (sands and gravels), which is strictly connected to building activities. The aggregate quarries are generally present on the screes, where the secondary steams pour out in the Niger river. The quarry pits are mainly exploited by means of hand shovels (Fig 4.a) and the basic sieving activities directly in the open yard. The quarries shows a steep profile and the quarried material is launched from the bottom to the top to reach the surface, by means of hand shovels. Very few times quarry exploitation is by means of mechanic shovels (Fig. 4.b).

The closed (abandoned) quarries are used for different purpose. Some of them are used as water reserve storage: the voids produced during the quarrying activities are filled up with water during the raining periods and the stored water is used for irrigation purposes during the dry periods (Fig.4.c).

Fig. 4. (a) Quarry exploitation (S of Niamey city): exploitation from the bottom to the top. (b) Sand quarry in the NW of Niamey city. It is possible to underline the employment of mechanic shovels. (c) Closed quarry. Water collected during the raining periods is used for irrigation purposes during the dry periods. (d) Abandoned sites shall become uncontrolled dumping areas

On the contrary, other sites (abandoned quarries) are used for not authorized landfilling activities. This context is really critical because uncontrolled dumping activities involve the disposal of different kinds of waste (plastic, hospital waste, etc…); everything becomes more dangerous because children and house animals generally look for food in such areas (Fig. 4.d).



Quarry form	
Exploited material (geological name)	Grauwackes
Exploited material (commercial name – if different from the geological one)	Gravels & sand
General information	
Quarry name	Cava S1
Place	Gorou Kirey
Map reference point (coordinate X)	13.437531°
Map reference point (coordinate Y)	2.131433°
Altitude	
Information about quarrying techniques	
Open pit quarry/underground quarry	
Exploitation method	Manual removal – shovel, artisanal sieves, wheelbarrow, pickaxe
Clean out method	By trucks
Quarrying means	Shovel, artisanal sieves, wheelbarrow, pickaxe
Exploitation context	Extraction for buildings construction
Waste management	-
Exploitation technique	Shovel, artisanal sieves, wheelbarrow, pickaxe, ground exploitation ground & underground
Waste production (%)	0%
Authorised volume (m^3/y)	Unknown
Main product	Gravels and sand
production (m^3/y)	Unknown
Yield (% on excavated material)	-
Treatment plant management (if present)	-
Product commercialisation: local, regional, national	Local
n. of employees in quarrying activity	10
Quarry rehabilitation	
Final destination at the end of rehabilitation	
Presence of dumps (if yes, which kind of)	
Kind of foreseen rehabilitation	
Top soil employment	
Foreseen fulfilling	

Quarry form	
Exploited material (geological name)	Grauwackes
Exploited material (commercial name – if different from the geological one)	Sand and gravels
General information	
Quarry name	Cava S3
Place	Saga Gourma
Map reference point (coordinate X)	13.502360°
Map reference point (coordinate Y)	2.060215°
Information about quarrying techniques	
Open pit quarry/underground quarry	
Exploitation method	-
Clean out method	-
Quarrying means	-
Exploitation context	Old quarry
Waste management	-
Exploitation technique	-
Waste production (%)	0%
Authorised volume (m^3/y)	Unknown
Main product	-
production (m^3/y)	Unknown
Yield (% on excavated material)	-
Treatment plant management (if present)	-
Product commercialisation: local, regional, national	Local
n. of employees in quarrying activity	-
Quarry rehabilitation	
Final destination at the end of rehabilitation	Rain water tank for agriculture
Presence of dumps (if yes, which kind of)	No
Kind of foreseen rehabilitation	Old quarry
Top soil employment	-
Foreseen fulfilling	-

Fig 5. Examples of a schematic report for an open quarry and a closed quarry (location and features)

Table 4. Quarries field data in Niamey area. (°) S&G =sands and gravels; S= sands; SL =silt (*Final destination: Rainwater tank for agriculture purpose; **Final destination: Landfill for plastic, paper, domestic waste. ***Final destination: Abandoned and unmonitored dump)

Sample and quarry site	Latitude	Longitude	Exploited material (°)	Quarrying equipment	Exploitation context
S1 (Gorou Kirey)	13.437531°	2.131433°	Grauwackes (S&G)	Shovel, sieves, wheelbarrow, pickaxe and trucks	Active quarry: aggregates for buildings and infrastructures
S2 (Gorou Kirey)	13.424131°	2.143549°	Grauwackes (S&G)	Mechanical shovel, sieves, pickaxe and trucks	Active quarry: aggregates for construction
S3* (Saga Gourma)	13.502360°	2.060215°	Grauwackes (S&G)	-	Closed quarry
S4** (Niamey)	13.523213°	2.161428°	Laterite rock	-	Closed quarry
S5 ***	13.556071°	2.058334°	Grès argileux du Moyen Niger (S&G)	-	Closed quarry
S6	13.509525°	2.049740°	Grauwackes (S)	Shovel and trucks	Active quarry: brick production
S7	-	-	Schistes ou séricitoschistes (S&G)	Shovel and trucks	Active quarry: brick production
S8 (Karma)	13.587618°	2.008501°	Dunes mortes (S&G)	Mechanical shovel and trucks	Active quarry: aggregates for road construction
S9 ***	13.575632°	2.122239°	Grès argileux du Moyen Niger (S&G)	Trucks	Closed quarry
S10	13.488698°	2.148051°	Grès argileux du Moyen Niger (SL)	Shovels and transport by donkeys	Active quarry: brick production
S11	13.591683°	2.125910°	Grès argileux du Moyen Niger (S&G)	Mechanical shovel, Sieve, pickaxe and trucks	Active quarry: aggregates for construction

5. Conclusion

The activity conducted during the present research let the authors collect some information about quarrying activities and surface water and groundwater quality in the Niamey area (Niger). It was possible to gather data about quarrying techniques, characterization of the exploited materials, condition and management of the closed quarries, together with data about the features of rivers and wells.

The quarry exploitation is useful for the economic development because it is the basis for building and infrastructure activities. However, it can cause some environmental and safety problems, eg. on water quality, on the landscape, security, soil pollution. Some abandoned quarries are used as not authorized dumps where people discharge and, sometimes, burn the waste. Thus, abandoned quarries generate some problems as soil and groundwater contamination. A sustainable management of natural resources and an appropriate environmental recovery are recommended, in order to prevent pollution and environmental deterioration. Furthermore, in quarry yards the safety conditions are not well guaranteed.

Concerning water quality, Niger is quite an arid country and groundwater and surface water are important sources for the population (drinking, agriculture, domestic uses). However, the sewage net is often lacking and sewage and domestic water are poured into canals that cross the city. The water quality of these canals is poor, because of the N compounds high levels. Moreover, local phenomena of nitrate pollution were identified also in groundwater. The Niger River and tributaries, on the contrary, show low and very low N compound concentrations.

All the information arising from the present work are useful for the local decision administrative committee to enhance Niamey georesources management. At last, the information on water quality is fundamental in a wider perspective of food security and for life quality improvement. A final GIS project was prepared in order to have a good overview of the data and for dissemination purposes.

Acknowledgements

The survey phase was possible thanks to the logistic help of the Facoulté de Agronomie de l'Université Abdou Moumouni de Niamey and of some local ONG, such as CISV and Terre Solidali.

The authors thank also Ségolène DADILLON, Anaïse BENHEDANE, Benjamin SIMARD, Romain GOSSET from ESAIP (St. Barthelemy d'Anjou Cedex – France) for their collaboration during the laboratory activities.

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