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Research Paper

Protection of Water Ponds for People's Water Provision in the Township of Natitingou, in the Republic of Benin

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ABSTRACT: *Potable water provision is essentially ensured by groundwater water-slicks. The quality of that water depends on the environment of those aquifers and their vulnerability to pollution. Vulnerability represents the easiness with which pollution penetrates the soil and reaches the slick and then the water pond device. As such, the township of Natitingou is entirely situated in an area with difficult geological socle in the one hand, and its geomorphology and its bowl-like position in the valley between two mountain chains, represent a major constraint for the protection of the water pond devices in the other hand.*
The present study is a contribution to the analysis of efficiency measures of the water pond devices. This analysis has been made following the French rule about protection of water pond perimeters from the public health Code.
From the obtained results, 86% of the drillings have a low pollution vulnerability level, 100% of the traditional drills have no disposition to ensure their protection against pollution, and finally 40% of the water provision devices are defective, and as such they are exposed to various kinds of pollution.
Keywords:*Natitingou; water pond devices; protection perimeters; vulnerability, pollution; efficiency*

I. PROBLEMATIC

Ground water represents more than 97% of the planet's drinking water with exclusion of the glacier and the glacial skullcaps). The remaining 3% are mainly made of surface water (lakes, rivers, humid areas) and grounds' moisture.Up to a recent period, ground water was essentially considered a as source of potable water (about 2/3 of inhabitants of the European Union depended on groundwater for their household needs. This resource is all the same important for industry use (for example cooling water) and agriculture (irrigation). It has yet become clear that groundwater should be considered not only as a reservoir for potable water, but also as a sensitive aquatic ecosystem. [1]

As such, groundwater is a key element in the water cycle, especially for maintaining humid zones and the rivers' outflow, playing the role of bumper in the dry periods. In other words, they ensure the basic level of the surface aquatic systems (that is, water nourishes rivers the yearlong) which systems are mostly used as water resources and / or in leisure activities. For many rivers, more than 50% of the annual inflow comes from groundwater. During the summery periods, this proportion can grow up to 90%. Then damage of the groundwater quality and its overexploitation could directly affect the dependent aquatic or earthy ecosystems. [2].

Since groundwater flows slowly under the earth surface (following the geological characteristics of the underground), the impact of anthropic activities can produce effects for very long periods of time. Pollution that has occurred over tens of years before, might it be due to agriculture, to industry or to other human's activities, can also threaten the phreatic clothes now and, in some cases, provoke their deterioration through many generations. As such, the heritage of the past is clearly visible in the areas of the high scale polluted sites, for example the industrial sites or the port sites where it is simply impossible, with today's technologies and the public and / or private funds, to clear such regional pollutions. Also, the acquired experience relative to rehabilitation of such sites through the past twenty years has showed that, in most cases, decontamination measures have not proved efficient enough to suppress every pollutants and that the pollution sources, even when they are partly eliminated, they continue spreading over long periods of time, mainly over many generations. Stress, then, should be put on preventing pollutions [3].

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Good management of water resource requires prior development and application of a legal framework which is adequate and convenient for promoting transparency and a participative management. In Benin, the available legal armory relative to the protection safeguard of natural resources including water resources is important and diversified. These legal instruments have regularly been reinforced with measures adapted to international commitments which the country is part of, and to the progress of the socio-economic and cultural framework. Then, many regulations have been adopted, or are being enacted or being signed [4].

Now, what are the observations on the field of study concerning the here issue?

Uncleanliness around the water ponds, the fact that farmers use pesticides and chemical products close to the water ponds, the presence of invading plants near the water basin, the fact that people throw garbage around the place, the severe erosion of the soil, the anarchic exploitation of natural resources, are among the many factors that pollute water at the water ponds in the township of Natitingou.

II. METHODOLOGICAL STEPS

2.1. General Presentation oftheResearch field

The township of Natitingou is situated in the middle of the Atacora department, in the North West of Benin. It is set between 1°12'11''and 1°36'43'' East longitude and 10°00'00'' and 10°27'36'' North latitude. The township of Natitingou is spread over 3,045 km2 land area, which represents 12.8% of the total land of the Atacora department. It is limited to the North by the township of Toucountouna, to the South and the East by the township of Kouandé, and to the West by the township of Boukombé. [5] (Fig. 1). It includes nine (9) districts which are: Natitingou I, Natitingou II, Natitingou III, Natitingou IV, Kotopounga, Kouandata, Perma, Tchoumi-Tchoumi and Kouaba. The township of Natitingou has 104010inhabitants according to the 2013census, with50, 990males and53, 020female, and a population growth rate (2002-2013) of2.87% [6]. Diversity is then 34 inhabitants/km². The population is mostly dominated with youth.

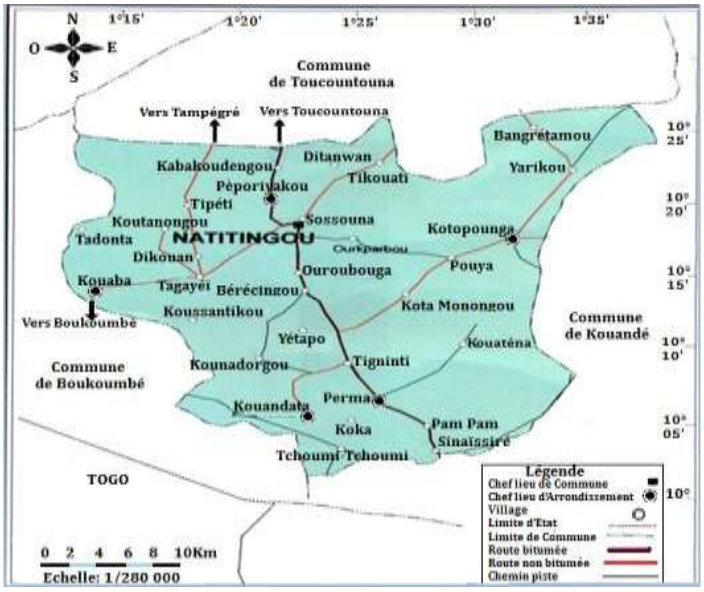

Fig. 1:Location of the township of Natitingou

Source: [7]

2.1.1. Biophysical Characteristic of the research field

- **The climate**

According to [8], the movements of the FIT (Inter-Tropical Front) in the lower atmosphere bet (confluence zone between the North and North-East sector flow, and the South and South-West sector flow) are more or less alike each year. The climate is of Soudan-Guinean type, nuanced by the Atacora relief with two well distinctive seasons, one dry season going from mid-October to mid-April, and one rainy season going from mid-April to mid-October. It is marker with important rainfall variations. Indeed, rainfall varies from 1,000 mm and 1,400 mm with the highest rain quantities recorded in the mouth of August and September. The average temperature is about 27°C with variations from 17°C to 35°C during the harmattan [5].

- **Vegetation and soil type**

Vegetation and soil are among the factors that influence the hydrogeological indicator, that is, they determine the efficient rain flowing and infiltration. Natural vegetation in the township of Natitingou is composed of wooded savannah with a few shrub species and big trees like the caïlcedrat, the baobab, the néré

tree, the karité tree, the kapok tree, the tamanoir tree, the rônier, the ficus, the false cashew tree, some palm oil trees... and some forestry gallery along the river stream. This vegetation is based on generally lateritic, clay-sandy soils with high quartz pebble proportion, and iron concretions (pebble and lateritic ironclad). Inappropriate cultural techniques and the weak capacity of managing water contribute to the severe damage to the soils which, when they are washed out, become poor, reducing then the farming yield [9].

- **The Geomorphology**

In the Natitingou area, there are three morphological units. In effect, the township of Natitingou spreads over quartzite channels (resulting from the Atacora channel) and has on its sides two plains that are [10]:

- ✓ The Toucountouna plain to the North, which is a small portion of the Atacora structural unit, drained by the upper flow of the Pendjari (Kounné) ;
- ✓ The Perma plain to the South which is a small portion of the plain of Benin also named crystallinesoclewhich is drained by the Perma River and its affluents from the North to the South. They are: Tiatiko, Sina-issiré and Wémou.

The relief there is very uneven with uncashed water streams. The valley zones are slightly weathered with lands having inclinations towards the nearest water streams. As for the slops, they present abrupt reliefs, accidental at times. This type of relief, favorable to soil erosion often represents a major constraint for the accessibility to the sites mainly during the rainy season. Generally, the Atacora channel is directed North East – South West. It reaches 650m in North West altitude of Natitingou, precisely at Kotopounga, and is 50 Km wide [5].

- **Hydrogeology**
  - ***Hydrogeological Potentials***

The underground of the study area is made of with combination of quartzites, schistes, filons, quartz filonnets and gneiss rocks, mainly in the Perma area. Implantation and drilling control research show that those areas are altered and diversely tectonized (shells and fractures).In short, there are [11], three different zones: the schist substratum zone; la zone à quartz substratum zone; the migmatito-gneiss substratum zone (figure 3).

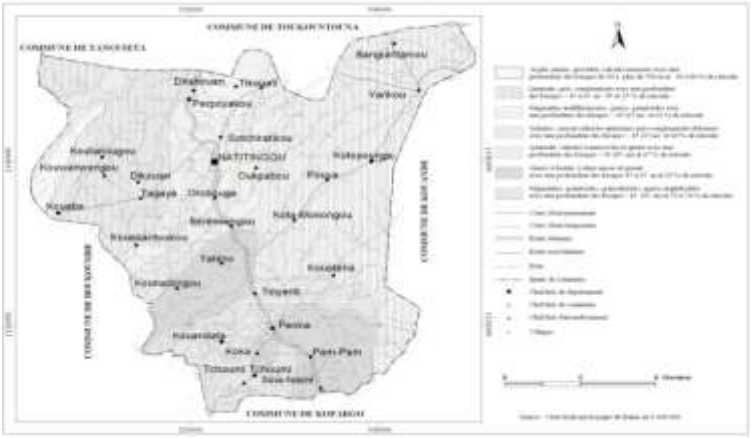

Fig. 2*:* Hydrogeological map of the township ofNatitingou**.**

Source: Hydrogeological map ofBenin

- ***The schiste substratum zone***

Situated in the North, this zone is les large and is composed of schists with filon quartz intercalations; those schists belong to the Tagayéï formation. It is a zone where inflow water productivity depends on the presence of quartz filons and / or filonnets, and at quartz intercalations. The thickness of the alterite's bed is inferior to 25m. The flows are generally weak and reload is very slow.

- ***The quartz substratum zone***

This zone is represented by the sites situated on the versant and miraced quartz hill plains; the zone is the most extended. This formation shows many levels of fracture, sometimes full of quartz folded at many sides. Nevertheless, its productivity is better than the one of the previous zone.

- ***Themigmatite-gneisssubstratum zone***

This zone is situated in the South, and characterized by alterite beds that could stock a certain quantity of water which can be locally improved by the existence of different fracture network with stitches sometimes

compact especially when the latter are full or alteration clay. It is the potentially favorable zone where the exploitation average flow reaches 10m3/h.

- ***HydrogeologicalCharacteristics***

The township of Natitingou in particular, and the Atacora region in general is a domain of socle where the aquifers are essentially composed of non colmateredcleavage or fractured rocks, and by the recovering of alterites at the level of which the interstite porosity is dominant. In other words, the exploitable water resource is essentially located in the zones of alterites and / or fractured rocks.

Since the hydrogeological characteristics vary following formations, those of existing devices can nevertheless be provided[12]:

- The exploited productive aquifers are in relation with the fracturation and the alterite bed ;
- The static level is generally set between 5 and 17m ;
- The average alteration thickness is clearly lower (less than 20m for all facies);
- The average exploitation flow is 0.7 to 10m3/h in gneiss and quartz areas while the schist formations are less productive with 0.3 to 5m3/h of exploitation flow;
- The success rate for achieving drills and wells is 40 to 70%.

In short, two types of reservoirs are recorded [13]:

- ❖ An upper reservoir made of alterites and residue from the mechanic desegregation of the original rock.The drills made in these aquifer formations present a succession of armored or stoned alterites, of clay and arena alterites. The thickness of the alterites has been evaluated to 17 m ;
- ❖ A lower reservoir made of:
- ✓ crannies destroying the socle, and favoring water infiltration into the crystalline rocks. This type of reservoir surmount the safe rock ;
- ✓ fractures that represent waterway zones. Those deep fractures often spread over tens of kilometers and are then rather favorable reservoirs.

Previous researches have allowed understanding that the thicker the alteration bed is, the more important water resources in the socle regions are, the development of the alteration being in connection with the nature of the rock, to the fissuraton intensity and to the climate conditions. Water storage is dependent on the density of their opening fracturation, on the thickness of the fractured zone and on communication among those fractures. Research of water resources then means (in socle domain) research of fractures and open cleavages capable of storing and driving water.

2.2. Materials and methods

2.2.1. Materials

The study field has discontinued aquifers with cleavage porosity and surface water processing.

2.2.2. Methods

It is then advised to shape the limits of the three (03) protection perimeters going from circles which rays are predetermined (figure 3) in order to analyze efficiency of the existing protection. Those circle will then have to be adapted to local conditions(Tables 1and 2) and (Figures 4 and 5) [14].

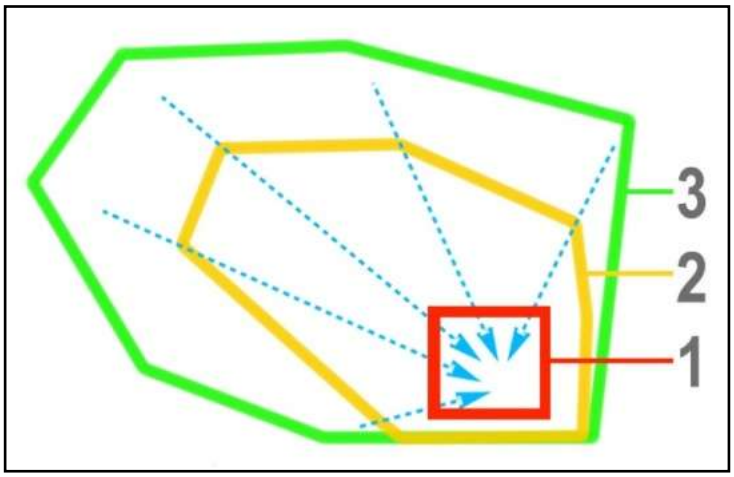

Figure 3: Protection perimeters

Source : [15].

1. Immediate Protection Perimeter (**PPI)** = water provision device implantation zone, fenced, legally acquired, cared by the community that use the water.
2. Close Protection perimeter (**PPRI)** = Zone where some practices are prohibited (pesticides, non-biological agriculture, industry, etc.) allowing imitation of pollutant input to the water cloth. The area of that land is calculated following the speed and the duration of water transfers, as well as the capacity of the underground to stop pollutants following the water dispersion capability. Land can be owned by the community. Distant Protection Perimeter (not compulsory) (**PPE)** = main supply zone, even the whole slope basin in case it is vulnerable. This perimeter is determined when there is a potential risk for the water cloth pollution, despite the distant position from the water supply device. Activities there are regulated.
   The blue discontinued arrows represent the water circulation direction in the water cloth, from the geologic beds that supply the water supply device.

- **Groundwater supply**

1. **Ascendency** to the protection perimeter

Table I: Size of the protection perimeters, standard in the socle

Immediate Protection Perimeter(PPI) Water supply Zone	**Close Protection Perimeter(PPR) Protection Zone**	**Distantprotectionperimeters(PPE) Alertness Zone**
Minimum 15 m ray circle In case of complex wells, or drain supply source, adapt the PPI form to the drain emprise	Circle with ray R equal to : ✓ 150 m for Q<5 m3/h ✓ 200 m for **Q**set between 5 and 10m3 /h ✓ 250 m for **Q**set between 10 and 15m3/h ✓ 300 m for **Q**>15 m3/h	Cerclewith 500 m ray

Source : Results of enquiries, 2014

figure 4 presentsthe differentpossibleprotections that can be adapted to ground water supply.

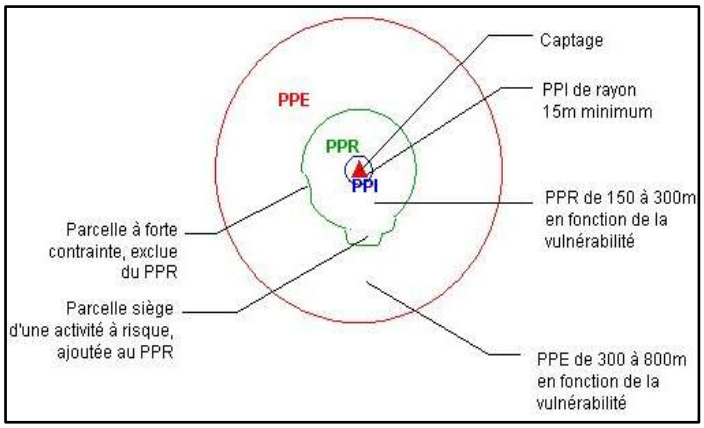

Figure 4: Ground water protection Perimeter

Source : Results of enquiries, 2014

In zone of socle, one should be carefull, as in the other contexts, about human's pollutions. But it is likewise important to be carefull about some natural mineral components that can pollute water, even far from every anthropic pollutants.

1. Prescriptions

- ✓ ImmediateProtection Perimeter (PPI) :It is the strict or immediate purification or protection zone. It is an essentially administrative or physical protection zone of the water source with controlled and restricted access (**zone 1**: zone of supply). Forbid everything except activities concerned with exploitation of the water supply device. In case of use of motor pomp, fuel has to be stoked outside the PPI premises
- ✓ Close Protection Perimeter (PPR):It is called close protection zone. This perimeter aims at protecting efficiently a ground water supply against bacteriological pollution, and set a security margin for acting in case of accidental chemical pollution.

In that zone water flow can be extremely rapid inside the aquifer, transfer of pollutant in the aquifer should then be avoided.

- ✓ Distant protection perimeter (PPE):It includes the distant protection zone or aletnesszone. It allows protecting water resources from long term pollutants, mainly from the less damaging chemical pollutants.Strictly respect the existing regulation. Sensitize and inform the populations on the domestic risks. Exchange with farmers by the means of the CARDER

- **Superficial water supply**

This study will have to evaluate the degree of protection of the water stock from three (3) principal [16]:

- ✓ Direct pollution of water due to humans and animals, in case of uncontrolled access to the water supply place,
- ✓ Risk of filling the water pond with carted particles, with water streams and runoff water that converge there.
- ✓ Risk of eutrophisation and pollution of the water pond with organic pollutants contained in the runoff water

1. Ascendance to theprotectionperimeters

Table II: Protectionperimeter for a superficial water storage

Immediate Protection Perimeter (PPI) Water supply Zone	Close Protection Perimeter(PPR) Protection Zone	DistantProtection Perimeter (PPE) Alertness Zone
Some few meter Zone around the whole water supply place	Zone spread over 100 m to 1 km following vulnerability of the water supply place (determined by the specific land area), inside the slope basin	The wholeslope basin

Source: Results of enquiries, 2014

Figure 5presentsthe different possible protections that can be adapted to a superficial water supply.

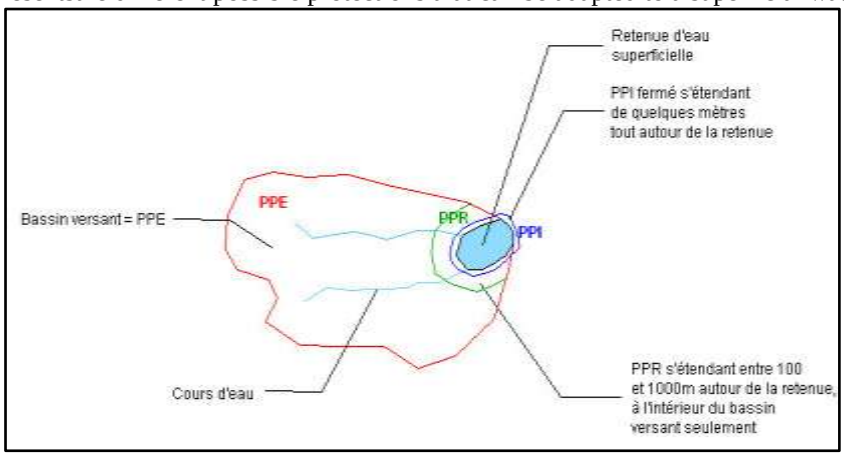

Figure 5: Superficial Protection Perimeter

Source: Results of enquiries, 2014

2. Prescription

- ✓ Immediate Protection Perimeterof the (PPI)

The PPI will fully become property of the community and it will be forbidden to people and animals visit the place, by the means of appropriate measures (fence dams,)in order to prevent every activity such as passing through, animal drenching, fishing, car washing, solid and liquid wastes throwing, fetishism activities.

- ✓ Close Protection Perimeter (PPR) : This perimeter aims at :
- ➢ Limiting soil erosion (fighting against the filling of the water pond); setting up better cultural practices.
- ➢ Limiting diffused pollutions (fighting against eutrophisation), forbidding spreading of fertilizers and pesticide.
- ➢ Avoiding the punctual throwing of pollutants: avoid infiltration of rainwater and polluted water from latrines, rejection of polluting substances, fuel storage, engine washing spaces, car parking, underground transportation of polluted water /substances (fuel in particular).
- ✓ DistantProtection Perimeter (PPE)

Setting up the best cultural practices to fight erosion;strict control of the respect of the existing regulation.Sensitize and inform the populations about home and agricultural risks. Exchange with farmers through theAtacora-Donga CARDER.

II. Results

3.1-Situating the Study Field

The present research is limited to the township of Natitingou, whose main water provider is SONEB. As stated in this study, the township of Natitingou includes town areas and districts of Natitingou I (Tchirimina, Yokossi, Bagri, kanchagou-Tamou, Sotchirantikou); NatitingouII (Ouroubona, Dassakaté) and Natitingou III (Ouroubouga, Winke, Yimporma, Bèrècingou). Only central town areas of Natitingou, limited by the mountain channels have been considered here. Such geomorphological position of the city of Natitingou exposes theinhabitants to a severe water shortage. The rain water from the upper slope basins flows through natural waterways, which is the Fourigninkèrè River. This River starts from the Sountchirantikou area, alongside the mountain and goes to the Yaripao which flows towards the Kéran in the nearby Togo. It is in such narrow environment that people live and practice prosperous activities while exercising an anthropic pressure over the ecosystems of de Fourigninkèrè. In that area, the main water provision device is the Fourigninkèrè River whose water is used for various purposes (household, market gardening, building, cars washing, etc…..). Land occupation in that city leaves no space for safeguarding the ecosystem which plays a crucial part in the life of the population. The other devices are made of both traditional wells for the households and modern wells (PM) for the community use, which were set up by the government. Apart from those wells, there are other water devices (FPM) set up by the government with the assistance of technical and funding partners for the community and equipped with motor (PTF). The national water company SONEB is in charge of most superficial and underground devices that provide the whole city of Natitingou as well as people living around the FourigninkèrèRiverwith potable water.

3.2-Inventory oftheDifferent water Provision Devices

This inventory concerns water provision devices only, that are wells and drills. They are devices situated within the urban area limited by the mountain channel. The area goes from the Atacora / Donga CARDER place and ends at the KABA crossroad at the East entrance of the Natitingou city. Yet, it has appeared essential to lay an exhaustive list of devices sending water through the whole SONEB network simply because the processed water is used by most of the population. Water is collected and processed in the same area before being distributed. Exposing one of those devices to a pollutant will lead to contamination of the whole water. Tables III, IV and V present the distribution of devices according to their geographic position, as well as other pieces of information.

TableIII: List of drills which needs human energy for usage (FPM or PMH*)*

N°	District	Village	Area	Device N°	Funding	Total Depth (M)
1	Natitingou I	Tchirimina	Orphelinat Centre D'accueil	A-2460	Belge	51
2	Natitingou I	Yokossi	Hopital De Zone	A-3342	Ppea	49,31
3	Natitingou II	Dassakate	Dassaga Centre	A-306f1	Bid	49,27
4	Natitingou III	Ouroubouga	Foyer Sainte Blandine	A-2522	Pays Bas	
5	Natitingou III	Ouroubouga	Ourbouga Centre	A-914	Boad	49,44
6	Natitingou III	Ouroubouga	Ourbouga Centre	A-1252	Boad	76,67
7	Natitingou III	Ouroubouga	Père Sambeni	A-3225	Soneb	
8	Natitingou III	Ouroubouga	Sœurs Espérance Du Christ	A-3151	Autres	55,83
9	Natitingou III	Ouroubouga	Village D'enfants Sos	A-2521	Pays Bas	
10	Natitingou III	Winke	Orphelinat St Maria	A-2524	Pays Bas	
11	Natitingou III	Winke	Ceg I	A-3344	Ppea	49,23
12	Natitingou III	Winke	St Innocents	A-2523	Pays Bas	
13	Natitingou III	Yimporma	Koukpatikou	A-2532	Pays Bas	38758
14	Natitingou III	Yimporma	Lycee Militaire	A-2529	Pays Bas	
15	Natitingou III	Yimporma	Petiyeri	A-115f2	Bid	43,1

Source : [17]

TableIV: List of drills with electrical pomp (under management of Soneb)

N°	District	Village	Area	Date Of Setting Up	Device N°	Funding
1	Natitingou II	Ouroubona	Ourbonna	05/07/2002	A2326	Bn
2	Natitingou	Berecingou	Berecingou	01/06/1992	Fn8	Soneb

	III					
3	Natitingou III	Berecingou	Ferme Agrue	01/06/1992	Fn12	Soneb
4	Natitingou III	Ourouboug a	Chez Tchambeni	01/06/1992	Fn3	Soneb
5	Natitingou III	Ourouboug a	Chez Tchambeni	01/06/1992	Fn7	Soneb
6	Natitingou III	Ourouboug a	Ourbouga Centre		Fn1b(A1 75)	Soneb
7	Natitingou III	Ourouboug a	Tchambieni	30/06/1991	A1250	Boad
8	Natitingou III	Yimporma	Domaine Sbee		Fn10	Soneb

Source *:* [17]

TableV: List of modern wells for community use

N°	District	Village	Area	Date Of Setting Up	Device N°	Funding	Exhaure Type
1	Natitingou I	Bagri	Bagri	18/12/1993		Carder	Bucketwit hrope
2	Natitingou I	Kanchagou-Tamou	Sossouna		Nat-C-8623-02	Belge	Pulley With Human Force Use
3	Natitingou I	Sotchirantiko u	Sotchirantiko u	20/08/2001	A1540	Carder	Winch With Human Force Use
4	Natitingou III	Ouroubouga	Aspirana	14/04/1995	A56	Plan Benin	Winch With Human Force Use
5	Natitingou III	Ouroubouga	Ourbouga Centre	30/06/1970		Fed	Bucketwit hrope
6	Natitingou III	Winke	Rezerie				Bucketwit hrope

Source : [17]

3.3-Protection of the potable water provision devices

3.3.1-Different types of protection around the existing devices

3.3.1.1-Ground water provision devices

✓ **Traditional Wells**

Generally, those wells are not very deep. Most of those drills reach less deep aquifers. The risk of pollution of traditional water wells is very important. Household activities take place not far from the wells: washing clothes, washing dishes, bathing children, washing motorbikes are some activities carried out about no more than two meters away from the wells. Those wells are hardly cemented inside; more over the height of the wall protecting the wells is very low, increasing the risk of seasonal collapse. Those wells usually present various damages: naked paroi, non-resistant bricks. Access to some of the devices is easy but the risk of bacteriological contamination of water remains. Traditional wells do not guarantee any real potable water. (Photo 1).

Photo 1: Traditionalwells in Kantaborifa
Picture by:A .Ramane, February, 2014

✓ **Modern Wells**

Cementing of the inside of those wells generally starts from top to down. The wells are fully covered with concrete, and a mouth is left for extracting water for household needs. Risk of pollution is weak, but the water is still exposed since the mouth of the wells is covered with an iron door that is progressively deteriorated, and the wells mouth then will remain open. Those wells systematically cemented in the inside with holes over many meters that let water come through. Risks of landslide and water drying up are weaker here than for the traditional wells. They are equipped with more or less improved exhaure systems.Many of those wells are equipped with a trapdoor and a winch with ropes at both sides holding a bucket each. This double system allows pulling a bucket full of water from the wells while sending the other bucket down into the wells. Despite this equipment, the sanitary situation of the great majority of those large wells is bad (stagnant water around the wells, non-existent or inefficiency of a system meant to evacuate the dirty water, damaged wells door system), so many pollution sources that could have severe consequences on the quality of water used in the household. Note that modern open wells are not taken into account in the national strategy of potable water provision.

Photo assembling1:*Large wells in Bagri* (the one on the left is covered and quipped with a winch; the on the right allows human force for water extraction and has no door)
Photoby:A. Ramane, February, 2014

✓ **Drills equipped with motor with human force use for water extraction (FPM)**

The drill equipped with motor with human force use for water extraction (FPM) is the common water provision device in the rural areas in the 1970s. The wells walls and the surrounding arrangements represent «the superstructure » that takes into account conditions for acceding to the device, the easiness of its use, its conservation and cleanliness. The conception of the superstructure varies according to the projects.

Photo assembling2: Drill equipped with motor with human force use for water extractionset up inside the Natitingou Secondary School No 1,in the Winkè area
Photo by:A. Ramane, February, 2014

✓ **Drill by SONEB**

SONEB disposes of eight (8) drills with electrical pomp set up since 1987. For those different devices, the immediate protection perimeter is delimited.Moreover, SONEB has always processed water with some chemical but harmless products before distributing it to the population for consumption.

Photo assembling 3:SONEB *water provision device protected with a grid fence*
Photo by: A. Ramane, February, 2014

3.3.1.2- Surface water device

They are concerned with the Fourigninkèrè River and the SONEB water detention area.

✓ **The Fourigninkèrè River**

The Fourigninkèrè River passes through eight (8) Natitingou city areas. They are Kantchagou-Tamou, Sountchirantikou, Yokossi, Tchirimina, Yimporima, Ourbouga, Winkè and Bagri. Many factors contribute to polluting the water from that river, making it unsuitable for home use unless processed.These factors include:

- Natural factors: rain water flowing, which carries the garbage produced by people in the city into the river.
- anthropic factors: erosion at the level of the river through extraction of sand by the population, anarchic throwing of garbage along the river, mainly in the area of Tchirimina, defecation in the open air along the river sides, washing up clothes in the river beds, market gardening and subsistence farming along the river. Lastly, there is also the problem bond to building infrastructures along the river.The main consequence from those different practices is the disappearance of the biodiversity along the river sides, mainly at some crucial areas(photo assembling 4 et 5).
-

Photo assembling4: Upper side of the Fourigninkèrè River, in the Soutchirantikou area/ Market gardening sites along the Fourigninkèrè River

Photo by:A. Ramane, February, 2014

✓ **The SONEBwater detention place**

This is the structure that has helped SONEB in increasing its water provision capacity in the Natitingou city since 1985.It is situated at Tiatiko in in the East of the city, in the Pouya village (Oroubona area), and it has recently been revisited at the occasion of the August 1st, 2011 national celebration in the Natitingou city. This infrastructure helps to stock an important quantity of water so that SONEB is able to meet people's needs of water as much as possible (photo assembling 5). SONEB meets difficulties for processing water due to the l illegal traditional gold miners who have use the river. Those miners wash metal in the river, which turns the water into turbid.

Photo assembling5*:* Spillway of the SONEBwater detention in Ouroubona

Photo by:A. Ramane, February, 2014

III. DISCUSSION

4.1-Analysisof the efficiency of the Natitingou water provision device

Basing on inventory of the water provision device in the study area and the existing protection device, it is remarked that apart from the FMP, the other types of water provision systems are equipped with devices protection devices that are not very efficient so as to preserve water from pollution.

The issue of analysis of device efficiency will be dealt with from on two sides.

- In the one hand the analysis will base on the physical device and the condition of its setting up.
- In the other hand the analysis will concern efficiency of the device based on respect of prescriptions of the protection perimeters by the nearby populations.

4.1.1-Efficiency of thephysical device protection

a- Surface water

Surface water are collected either artificially through water detention by the Benin National Water Company (SONEB), either naturally from theFourigninkèrè River. Then, concerning water detention, the here research have allowed realizing that it is not protected at all against pollution factors. No protection measures show the different protection perimeters. This situation allows the pollutant anthropic action (agriculture, breeding, illegal gold mining) to take place in the slope basin of the water reserve.

As for the Fourigninkèrè River, an ecosystem conservation plan has been elaborated thanks to the National Water Partnership (PNE Benin) and headed by the Local Water Partnership whose headquarter is in the premises of the NGO IDDE-BENIN. The conservation plan is set up in the framework of the heading Initiative

for integrated conservation of the Fourigninkèrè. This plan states a certain number of activities aiming at protecting and safeguarding the environmental ecosystem in a GIRE approach (Integrated Management of Water Resources) and at highlighting the resource. By the time implementing that conservation plan becomes effective, an embryonic protection device for the river is set up. This has consisted in setting sensitizing and prohibiting boards to have people respect the prescriptions mainly at the upper side(upper source) of the river (photo 4 and 5). It is essential to note that water from the upper side of the river is used as drinking water with no prior processing [18].

Photo1:A board for sensitizing the population for protecting the river (upper side of the Fourignèkèrè River).
Photo by: A. Ramane, February, 2014

As such, protection must occur at two levels that have appeared priory well distinctive, but that are complementary [19]. They are:

- **conservation of the water resource** which is concerned with global scale (reservoir, water provision area). Actions in this context aim at preserving in the long run the water area and rather have for target the spread pollution that could affect quality of the water. ;
- **protection of the water provision device** that has focused on preserving the quality of the water **processed**there.The conservatory decided measures in this framework account for a sanitary preoccupation. The protection perimeters aim at maintaining a quality water provision that goes along with the provision of potable water. The final objective is then to let the water consumers have in their home water taps water that meets legal norms.

b- Ground water

The ground water provision devices are made up with wells (traditional, modern) and drills equipped with pomp that require human force or electricity for use.

- Then, concerning traditional wells, the participative observation during the present research allow realizing that they have been set up in households with no cleanliness. The traditional wells' wall is not efficient to prevent pollution let alone the water fetching system. Also, the cultural practices with some sociolinguistic groups allow burial in the household. Management of household garbage is a great issue. Household chores (doing the washing up, washing the dishes, washing motorbikes) take place in the household yard near the wells. This environment is disrespectful of the protection prescriptions of the water resource in the socle area. In short, no protection perimeter of the wells is circumscribed. The resource from those wells is then not protected.
- The modern wells are for communitarian use. They are set up in public places to allow access of the populations. Those wells are equipped with a device that does not protect water efficiently, since the wells do not always have covers, and when they have one, that cover is most the time defective. The water fetching system (buckets with rope and a winch) is sometimes defective. The protection perimeter, even when it exists, is not materialized.
- As for the drills equipped with pomp with human force use (FPM),or with electricity from the Benin National Water Company, water is relatively protected with the superstructure (wall, unclean water evacuation canals, and a retention hole).But the geomorphology of the area makes the water vulnerable since in socle zone, water flowing is fragile and is not mastered. Pollution can come from households or from unexpected sources. Anyway, water from those devices is exposed and this threatens the efficiency of the protection device.Thegrid-enclosure of the drills by The Benin National Water Company protects the equipment rather than the water.This can no doubt be explained by the fact that they know that they process water before distributing it to the population.

According to [20], setting clearly the limits of the protection perimeter is based in the one hand on hydrogeological criteria that allow justifying the area of those perimeters, and in the other hand on the environmental criteria. The hydrogeological context must represent the base for justifying the prescriptions to set up with the aim to conserve the quality of the water got from the water fetching place.

Indeed, vulnerability of ground water corresponds to an insufficiency of protection or of natural defense of the aquifers against pollution threats, following local hydrogeological conditions [21]. According to the same author, two main criteria have been considered for the setting up of protection perimeters: intrinsic vulnerabilityof the area and specific or induced vulnerability, and even pollutant pressure.

4.1.2-Legal measures for efficient protection

a. Surface water

Gold mining is an activity that requires important quantity of water. The secret condition of that activity increases the risk of pollution of the SONEB water pond.Since SONEB has not clearly marked the limits of the protection perimeter of the water provision area, every pollutant action could take place with no respect of the associate regulations

As for the Fourigninkèrè River, the river management action plan has not yet been implemented. Nevertheless, sensitizing boards draw the attention of nearby people over prohibited activities in the river bed. There is no certitude that those populations can read the message on the boards since they are mostly illiterate. To that difficulty bond to communication, one could add the non-respect of people of the public things. The pressure linked to water shortage in the city worsens the situation of non-respect of the protection measures, which negatively impacts the water provision device.

The role of the protection perimeters of the devices that provide water to people for their consumption consists in reinforcing the global regulation concerning protection of water in the environment of the water devices so as to ensure permanency of the water quality and guarantee the public health.Yet, they do not represent a unique instrument that ensures protection of water quality for humans' consumption, since the latter are also taken into account for other regulatory measures [3].

b. Ground water

Humans' activities around the traditional and modern wells clearly show that the hygienic and cleanliness rules are not respected. Activities in the households do not guarantee water to stay potable.At the end of the National potable water provision strategy, wells as they have been observed in the city of Natitingou do not provide any potable water. This situation is worsened by the non-marking of the limits of the water provision environment, but also and mainly by the non-respect of protection prescriptions stated in the socle.

Most of the existing potable water provision devices in the study area have been set up by the national or private institutions, but to the benefit of the community. The officials of those institutions have taken measures to guarantee the protection of the device and the water. They also care about respect of hygienic rules around the water ponds.

Development of anthropic activities around the water provision device areas increases the risks of water pollution. Indeed, farming activities are carried out around the grid enclosure of the drills of the Benin National Water Company. The zonal hospital water provision device deserves a better protection with a well delimited and marked perimeter. Along the main road sides in Natitingou, people have sold smuggling petroleum products, disrespectful of the law, in doubtful security conditions. (photo 2).

Photo 2: Sale of falsified petroleum products

Photo by: A. Ramane, February, 2014

According to [22], presently, as for the protection of the devices, the tendency is that people consider the close protection perimeters represent the immediate zone between the water provision device and the rest of the aquifers over which the global protection measures are applied.Setting up the perimeters in completed according to the vulnerability of the aquifer through alerting systems (probably with a watching network) and a processing device the close protection perimeters can be of shorter height, with stronger constraints.

The protection perimeters can be hierarchized as follows: [19]:

- The immediate protection perimeter and the good management of the water provision devices preserve the latter from risks of direct introduction of pollutants in the device or in its surrounding;
- The close protection perimeter is meant topreserve the quality of the obtained water from quality degradation resulting from punctual or accidental (and not diffused) pollution;
- The distant protection perimeter is essentially meant to attract the attention of people over existence of potable water resource, then over obligation of alertness.

In short, according to [23], for an efficient protection of the physical device, diverse criteria are used in order to determine the protection zones. The values accorded to those criteria represent limits above or below which the meant criteria stop guaranteeing the expected protection degree. The following criteria are taken into account in the delimitation of the protection zones: the protecting or purification power of the soil, abasement, the transfer time(circulation), the distance (arbitrary) and the flowing limit. According to the same author, the choice of criteria depends on technical, socio-economic and regulatory considerations. The target goal could be:

- ✓ Either the delimitation of a zone allowing a sufficient acting time in case of pollution, so that the device will not be contaminated ; in that case, the chosen criteria will be the transfer time, on condition that this implies the possibility of acting successfully on all pollution sources. In case of pollution at the soil surface, the transfer time includes the vertical migration time inside the non-saturated zone (formation set between the soil and the static level of the water bed), then the horizontal migration inside the water bed towards to processing device;
- ✓ Either the delimitation of a zone through which concentration of the pollutants will be soothened before it reaches the device; in this case, the soil and the non-saturated zone's purification power are chosen. Pollutant thrown over the soil surface will cross the non-saturated zone in which adsorption, filtration, biodegradation mechanism will occur, which will reduce concentration of the pollutant at its entrance into the water bed; to those mechanisms, dilution inside the water bed will be added;
- ✓ Either the management of a protection zone around the device over a large area in the meant zone ; the chosen criteria will be the one concerned withreduction
- ✓ Ether, at last, protection of the whole device provision area; in that case, the flowing limits that could suit the small water beds and above all in karstic area.For the water beds, such a choice could lead to an« overprotection » of the aquifers.

✓ **4.2-Results of analysis of the Natitingou city water provision device efficiency.**

4.2.1-Faecal Contamination of the water

According to [17], globally in Natitingou, every types of water device are concerned with feacal contamination with diverse proportions though. The systems of The Benin national Water Company are far less contaminated (8.8%) at the source with feacalcoliforms surpassing the Borne fountains (40.43%) and the drills equipped with pumps that require human's handling (52 %). Alternativesources(wells 100% andautonomous water ponds 75%) are the most contaminated.

Analysis of those results from the Atacora department Unit for water quality control, a division of the National Office of Public Health in 2013, has confirmed the observed tendency concerning the results from the central laboratory of the Office. Indeed, contamination based on feacalcoliforms and Escherichia Coli (E. Coli) is lower for conventional water provision sources than for alternative sources. As such, it is noticed that SONEB provides a better quality water, then comes the Borne Fountains and the drills equipped with pump that require human's handling. As it is the case with the National Laboratory results, alternative sources provide water highly contaminated with feacalcoliformsand by the E .Coli as well.

According to [24], globally in the city of Natitingou, conventional sources are the most incline to provide potable water more than the alternative sources.Indeed, alternative are contaminated respectively 96% and 84% with the feacal coliforms and the E. coli for 35% and 16% for the conventional sources. The plants of SONEB have the lower contamination rates (10%) certainly because of the water processing with calcium hypochlorite.Note that efforts are need to make for improving that situation. The devices set up in the context of the village hydraulic program come just behind those by SONEB with respective rates of 44% and 57% for the Village Water Provision and the drills equipped with pumps and needing human's handling. Alternative sources (wells and Private autonomous Water Ponds) are highly contaminated with more than 99% for the wells and 75% for the Private Autonomous Water Ponds.

4.2.2- Evolution of the source water conformityto consumption points

In the city of Natitingou, when taking into account only households having got non-feacal source contaminated (absence of feacal coliformin the water source), the potability rate moves from 66.70% at the transportation end, to38.10% at the place of usage. This rate decreases considerably as water reaches the stock buckets. [17].

IV. CONCLUSION

In all, twenty-eight (28) water provision devices and some traditional wells recorded have been taken into account in carrying out the present research work. Some of the devices are defective due to the lack of care for them. 86% of the studied drills have a weak pollution vulnerability level and they mostly have their zone 1 ensured. As for the traditional wells, no measure was taken to ensure the protection against pollutions. The geomorphology of the here study area, represents a major constraint for the provision of potable water to the population. The city of Natitingou is fully situated in the difficult hydrogeological socle zone. To that constraint one can associate the fact that the city is situated in the hollow-like valley between two mountain channels. The houses situated on top of the mountains have hard life with fetching water. But those who live in the hollow are exposed to flood risks and garbage invasion from flowing water.

The provision zones set at the depth of the hollow are exposed to all pollution risks. The user of the main road crossing the city transport petroleum products and gaz. Also some social and cultural practices (burying the dead at home) and hard availability of home and public latrines lead people to the defecation in the open air. Those excrements are then taken to the natural water way (Fourigninkèrè) through the other water provision places (wells, FPM and SONEBdrills).

Determination of the protection perimeters and the setting up of protection measures to the water provision device zones is essential for the township as well as the township officials. Sensitizing and information campaigns for the population must be done to preserve the physical integrity of the device and the water through an integrated management of water resources (GIRE).

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