ISSN 2454-2008

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
September 2023 Vol.:25, Issue:3

The Influence of Exhausted Waters on the Pollution of the Underground Water Sheets: Case of the Industrial Wastes of Somaïr in Arlit (Niger)

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Submitted: 20 August 2023
Accepted: 22 September 2023
Published: 30 September 2023

HUMAN JOURNALS

ijsrm.humanjournals.com

Keywords: Exhausted water, Mine, Underground water sheet, Pollution, Water resources

ABSTRACT

Niger exploits uranium through the layers of the Aïr Mining Company (SOMAÏR), and the Akouta Mining Company (COMINAK) respectively to some kilometers from Arlit and Akokan cities since years 1970, and lately with the Azélik Mining Company (SOMINA) and Dasa Mining Company (SOMIDA). The dynamic treatment of this ore within the SOMAÏR requires the use of an important quantity of industrial water, estimated between 1,800,000 and 2,000,000 m^3 per year. The objective of this work is to determine the quantities of drinking and industrial water consumed in the industrial zone and then at the urban one (drinking water), but also to make the bacteriological analyses and the DCO/DBO5 measures of waters used in order to compare them to the Nigerien norms of releases and to seize their potential degree of pollution of the groundwater sheet. For this reason, bibliographic research has first been held, before making direct observations of the circuit of treatment of the exhausted waters, but also some investigations among the riparian populations. Finally, bacteriological analyses and Chemical Demand in Oxygen and Biochemical Demand in Oxygen measurements on 5 days (DCO/DBO5) have been done. The mining exploitation affects water resources through the pumping of the groundwater sheet for the treatment of the ore, but also by the sewage releases. Samples of drinking water and exhausted water have been taken for analysis. The results revealed a high uranium polluted underground waters, and a bacteriological and physio-chemical contamination of the superficial waters concentrations which go over Nigerien WHO of 1990 norms of releases. This also denotes a deterioration of the aquatic environment and the human health because these exhausted waters are reused for the gardening by the riparian populations who are therefore exposed to the water illnesses.

INTRODUCTION

The environmental issue is at the heart of proceedings since the 80ies, with the impulse given by the World Commission on the environment and the Development. According to the 2001 report of the Intergovernmental Group of experts on the climatic Changes (GIEC), these human activities essentially provoke the accelerated deterioration of the environmental resources. Among the concerned sectors of activities, the industry is indexed as the main responsible for the ecosystem deterioration in several surroundings, inciting each country thus to take in account the environmental dimension in their activities of production.

In Niger, the AÏR Mining Company (SOMAÏR) exploits and transforms the sedimentary originated uranium for the benefit of AREVA (ORANO since 2018) in Arlit, in the northern part of the country.

Indeed, the dynamic treatment of the uranium ore requires the mobilization of enormous quantities of water that end up in becoming exhausted waters and having negative impacts on the environment and the human health. Of these (negative impacts), one can mention among others, the water underground resources pollution, the deterioration of the environment, the proliferation of water illnesses, etc., which lays the necessity to treat exhausted waters before their release in the receiving environment.

In arid zone particularly, an integrated management of the natural resources is indispensable to preserve the ecological balance sustainable. The present zone of survey, because of its desert feature, and therefore of the scarcity of the precipitations and surface water plans, the population practices the gardening while exploiting the underground water sheet around the urban agglomerations. In this milieu, water is a limiting factor that the population must manage in a rational way for their survival, but also for the preservation of the exosystemic relics.

The main objective of this survey is to analyze the influence of exhausted waters on the pollution of water around SOMAÏR mines. It consists in determining on one hand, the quantities of drinking water exploited in the urban and industrial zones and on the other hand making the bacteriological analyses and the measurement of DCO/DBO5 of the exhausted waters.

PRESENTATION OF THE SURVEY ZONE

Localization of the urban township of Arlit

The urban township of Arlit is in Agadez Region the northern Niger. it is boarded in the East by the farming township of Iférouane, in the west by that of In Gall, in the south by the farming townships of Dannat and Gougaram and in the north by the People's Democratic Republic of Algeria. The city of Arlit was raised following the discovery of uranium in 1968 when exploitation is performed by two companies: SOMAÏR in the Northwest and COMINAK in the Southwest 6 km away.

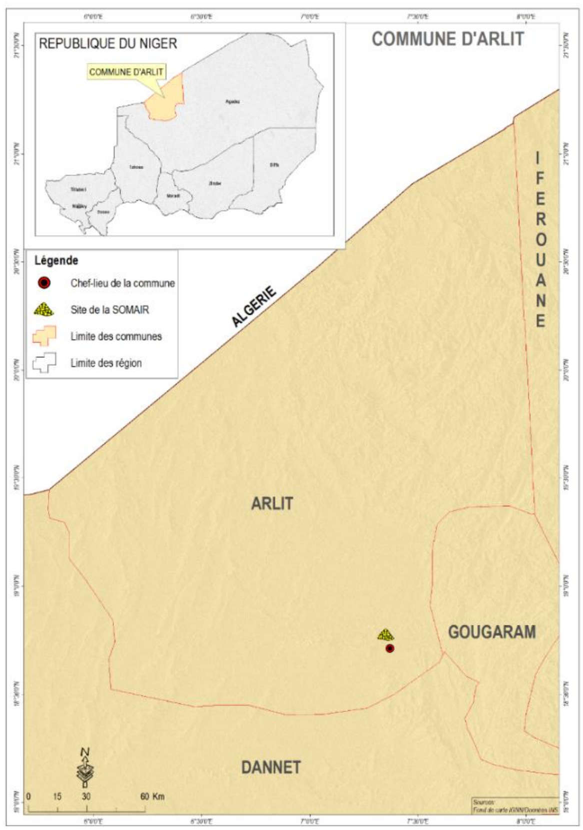


Figure No. 1: localization map of the urban township of Arlit

The geological and hydro geologic context

The city of Arlit lays on a granitic ground covering an old pedestal, what denotes the non-permeability or the weak permeability of the soil. Elsewhere in the township, one meets clay-craggy soils on the plateaus, sandy loam soils in the valleys and sandy ones on the plains. The geological context of the township of Arlit is characterized by the existence of two big units. The first is the massif of the AÏR, whose pedestal structure is that of a vast Northbound plunging anticlinorium, while the axial plans ended eastward. The second unit is the Tim Mersois basin, the northeast appendix of the vast intra-crater basin of the Iullemendens that constitutes a small North-South furrow, filled with sediments essentially of Palaeozoic age and edged in the East side by the massif of AÏR.

As for the water resources of the township, they essentially laid in three-stacked water sheets: the water sheet of Izégouande, water sheet of Tarat, and that of Guezouman (ORANO, 2022).

The water sheet of Izégouande, free, is strongly folded back because of the double impact of the proximity of the flexure fails and of the strong influences of pumping side the depressions created by the former careers. It constitutes the water sheet of subsurface exposed to the superficial pollution, in the mining zone. As for the Tarat water sheet, several polls achieved in the zone of survey showed that its power is subject to very important variations due all the same to the tectonic structures and then to the manner of fluvio-deltaïc sedimentation bound to the energy of the milieu deposit (Aman Project, June 2004). The Tarat water bearing being surmounted by impervious formations, the water sheet was at its origin loading. It contains the uraniferous layers of SOMAÏR and constitutes the source of provision in the water of the mine and the population. The water sheet of Guezouman does not have a big importance in the mining zone of Arlit, but it is especially affected by the mining works of the COMINAK, while the two first water sheets are important for those of SOMAÏR.

Indeed, the township of Arlit has no permanent or semi-permanent water plan because of the weak pluviometry. However, some temporary rivers give birth in the Koris that drain the rainwaters, while the city of Arlit possesses basins of decanting of exhausted waters that play an important role in the truck-gardening activities in its surroundings.

MATERIALS AND METHODS

Materials

To perform this survey, appropriate materials and software are used:

- ✓ Personal protective facilities (security shoes, Helmets, Gloves);

- ✓ Investigation and maintenance sheets;
- ✓ sterilized bottles that served to the withdrawal of water samples on the land;
- ✓ Lab materials for determining the physio-chemical parameters such as:
- The incubator that serves as the bacteria culture settings;
- The thermostat for the analysis of the DCO, and the OxiTop for the DBO5 analysis;
- ✓ A GPS receiver, and topographic maps to reinforce the analysis of the pictures.
- ✓ The Excel calculator for the execution and analysis of the statistical data and the performing of the diagrams, and then the SIG software, notably ArcMap 10.8 for the cartographic tasks.

Methodological approach

The methodological strategy consisted of the observation of land, the collection, the treatment, the analysis and the interpretation of the data.

The observations of land

It was about the visual reports made on the activities led by different task and water use units as well in the filtering basins. It made understand the working and the purification of exhausted waters of these basins and to identify the pertaining risks.

The sampling

Exhausted water Samples have been drawn in a litter bottle previously cleaned to distilled water in order to control and to confirm the reproducibility of these parameter measurements. Thus, some withdrawals are done in the **basin I** (entrance) and in the **basin VI** (exit) of the factory, then a sample of drinking water in the water tower of the city.

The analysis of the samples

The drawn samples have been analysed at the laboratory and the results interpreted. The parameters that were focus subject of analysis are the bacteriological parameters (total coliforms and faecal streptococci) and the DCO/DBO5 measurement (Chemical Demand in Oxygen/ Biochemical Demand in Oxygen along 5 days). The choice of these parameters stows to the national official regulation in Niger, in relation to the release of the liquid sewages that clear in a purification station.

The bacteriological analysis of the exhausted waters

For the bacteriological analysis, the chosen parameters are the faecal coliforms and the faecal streptococci (indicatory to the faecal contamination), and it took place in three following phases, *filtration, the numbering of the colonies and the expression of the results.*

- ***The filtration***

It consisted in extracting, out of the packing, the number of necessary culture milieus, then marking on every kneading trough the number of the sample, and the corresponding dilution, before distributing 3.5 ml of distilled water in every kneading-trough to rehydrate the culture milieus. Then, to appropriately and to pour in the funnel 5ml of dilution, to start the pump light and rinse the partitions of the funnel with about 50 ml of distilled water, then to put the sowed kneading trough in the bacteriological steam room adjusted to 36°C and let hatch the boxes in the steam room during 24 hours.

- ***The numbering of colonies***

After the required time of incubation, we take the kneading trough of the steam room then count the colonies on the box presenting less of them (of colonies). Therefore, the colony meter will be set going, in order to sprout each of them at hand on the filter with the numbering probe, knowing that all pointing will be posted with the meter.

- ***The expression of the results***

To get the number of bacteria, we first determine that of the colonies of bacteria indicated by the meter (of colonies), multiplied by the inverse of dilution made, then multiply by five (5). So, we get the exact number of bacteria from the analysis.

Number bacteria = Number colonies × Inverse dilution × 5.

DCO/DBO5 analysis of exhausted waters

For the analysis of the Chemical Demand in Oxygen (DCO), we put 2ml of the appropriated sample in a tube of reactor (of DCO), that we shook before putting it in the thermostat for 2h at 148°C temperature until the final outcome.

As for the measurement of the *Biochemical Demand in Oxygen over 5 days* (DBO5) with the OxiTop system, it is based on the principle of pressure, which measurement is made by the dint of the piezo-electronic resistant pressure probes. For that reason, 432ml and 164ml samples have been appropriated and have been put in small bottles, to which are added two tablets of carbonate sodium then put in the incubator under 5 days 20°C pressure.

THE OUTCOMES

Settling of the quantities of drinking and industrial water of the industrial zone

Settling of the quantity of drinking water

The drinking water comes from a system of ten (10) drilled wells in the fossil skeets from the Tarat and the Izégouande geological formations. The on-going quantity varies from 1 500 000 to 2000 000 m^3 per year, but can any way vary according to years and circumstances and is determined by the Niger water management company (SEEN) in Arlit, at SOMAÏR.

Settling of the quantity of industrial water

The daily and yearly consumption

The quantity of water was assessed by people in charge of the ore treatment, who estimated the industrial water consumption to be approximately 4808m^3 per day, and that of the human needs to be approximately 550m^3 per day. These quantities of water are obtained thanks to the different meters installed on the water tower that supplies the industrial zone and those installed by SOMAÏR. As for the yearly consumption of industrial water by SOMAÏR, it varies from 1800000 m^3 to 2.000 000 m^3 per year since 2013.The below N°2 figure represents the daily consumption of industrial and drinkable water in the factory.

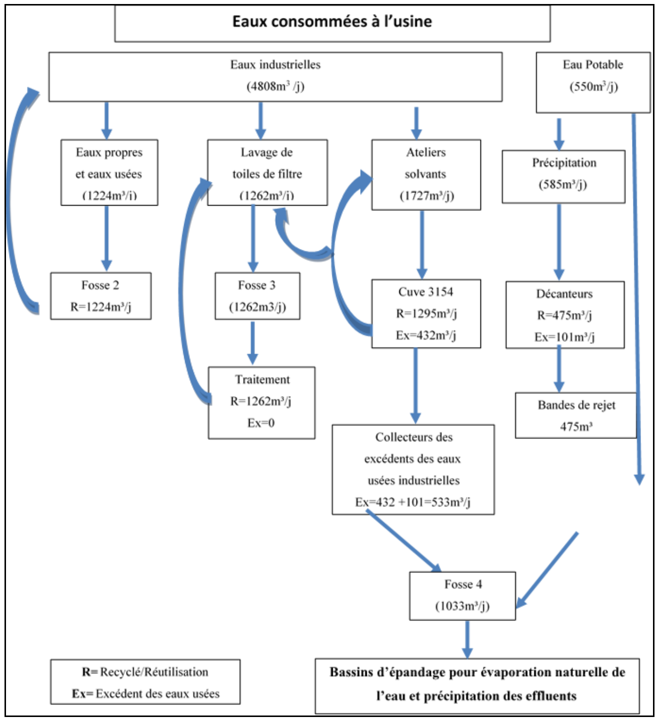
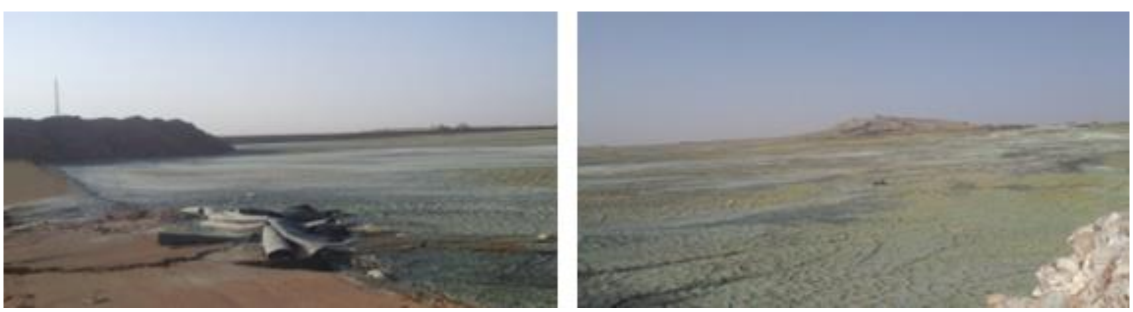


Figure No. 2: Daily balance of waters in the factory. Source SOMAÏR, 2022

The quantities of released waters at the SOMAÏR

The sewages and the clean waters (non contaminated) generated by the ore treatment activities are 75% recycled and reused for washing and the watering of the in use tracks and careers, while 25% are released in the release area. However, there does not exist a method or a particular technique within SOMAÏR used to determine the exact quantity of released water, that one being estimated from the water-recycling device in use.



Picture No. 1: Natural releases of exhausted waters used from SOMAÏR. Source: Land data, 2022

The circuit of the exhausted waters

The urban exhausted waters are collected from the **pit IV** of the purification station. This last is made of six (6) basins where the exhausted waters are sent to the **basin I** (the entry basin) in which they will remain for two (2) or three (3) days before flowing to the following basin until their exit in the **basin VI** (the exit basin) where they will partly be reused for gardening.

The circuit was schematized below by the figure No. 3.

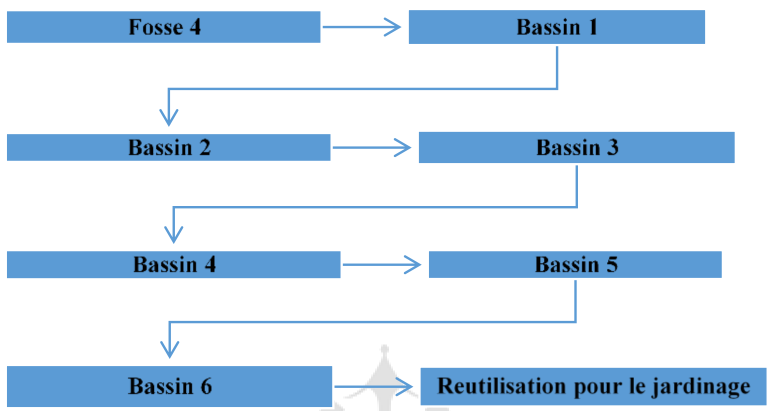


Figure No. 3: Circuity of the urban exhausted waters. Source SOMAÏR, 2022

As for the exhausted waters descending from the dynamic treatment of the SOMAÏR ore, they are directly recovered after first use, to be recycled and reused. Then, these waters reach to the eye collector to be then sent to the spreading basins for natural evaporation.

Description of the exhausted waters treatment (filtering basin)

The filtering is a simple, ecological, rustic technique, reliable and a little costly because of its non-mechanized functioning, with satisfactory results concerning decontamination. So the exhausted waters collected in **pit VI** are sent to **basin I** (entry) where they will remain for two (2) or three (3) days under a 37°C temperature, suitable for the multiplication of bacteria. Then, the exhausted waters step to **basin II** then to **basin IV** where the temperature rises to 40°C, encouraging the deterioration of the bacteria thus. Once at **basin V**, these waters become less loaded and terminate in **basin VI**, very little loaded.

Picture No. 2: Bassin I (exhausted waters entry)

Picture No. 3 : Bassin VI (exit of exhausted waters).

Source**:** Land data, 2022

The (AC) treatment load flapping

The (AC) treatment load flapping is the connection between the entrance and the exit of the polluting loads of the exhausted waters all along the process of the treatment. It allows verifying the efficiency of the treatment, and is obtained with the connection:

$$\mathbf{AC} = \frac{\mathbf{Exit}}{\mathbf{Entrance}} \times \mathbf{100}$$

For the SOMAÏR purification station, which rate of polluting loads flapping of the exhausted waters was calculated, (total coliforms and the fecal streptococci notably) the results of January to October months of the analyses are shown below on the table No. 1.

Table No. 1: Rate of load flapping (in %)

Months	Total coliforms		A C (in%)	Faecal Streptococci		A C (in%)
	Entry	**Exit**		**Entrée**	**Sortie**	
January	45 000	28 450	63,22	13 400	9 520	71,04
February	3 000 000	22 200	0,74	1 200 000	2 680	0,22
March	4 500 000	9 000	0,20	352 000	900	0,26
April	7 000 000	35 000	0,50	750 000	2 000	0,27
May	13 500 000	8 900	0,07	1 975 000	8 000	0,41
June	50 000 000	1 033 500	2,07	3 000 000	19 590	0,65
July	96 000 000	95 724 000	99,71	1 000 000	2 149 500	214,95
September	4 753 000	18 150	0,38	255 000	110 100	43,18
October	11 500 000	15 500	0,13	9 000 000	380	0,00

Source: Land data, 2022

Table No. 1 indicates that the flapping pollution load rate (total coliforms and faecal streptococci) is at its high level in January and July months for the total coliforms, with active values reaching 99.71%, and 71.04% rate in January for the fecal streptococci. However, a weak rate has been recorded for the total coliforms and the faecal streptococci from February to October (except in June-July), which values vary between 0% and 0.74%., thus indicating a considerable decrease of the efficiency of the treatment. This reduction (decrease) explains itself by the absence of the withdrawals of samples in **basin VI** (exit of the exhausted waters), because this last one is invaded by herbs and algae that prevent the withdrawal. What makes the recorded results of the entry samples in February, March, April, September and October months more important than those of the exit is.

Bacteriological analyses and DBO5 measurements and DCO, and their comparison to the Nigerien norms of release

The appropriated samples of industrial and domestic exhausted waters at the collectors of exhausted waters and the filtering basins are analyzed at the SOMAIR production laboratory.

As for the measures of the global physio-chemical parameters, they have been done on prompt appropriated samples three times per day (7h-8h; 12h-13h; 17h-18h). Regarding the specific physio-chemical parameters (uranium, sulphate, aluminium, nitrogen, phosphor, Zirconium and molybdenum), the measurements are made on daily composite samples.

Results of the bacteriological analyses

The figure No.4 and No 5 below present the results of bacteriological analyses of exhausted waters at SOMAÏR from January to October 2022, compared to the Nigerien norms of releases.

The results in conformity with the Nigerien norms of releases have the sign letter C (conform letter), and those that are not in conformity have NC sign (non-compliant).

The figure No.4 below presents the results of the analyses of the total coliforms of the industrial exhausted waters of SOMAÏR performed from January to October 2022.

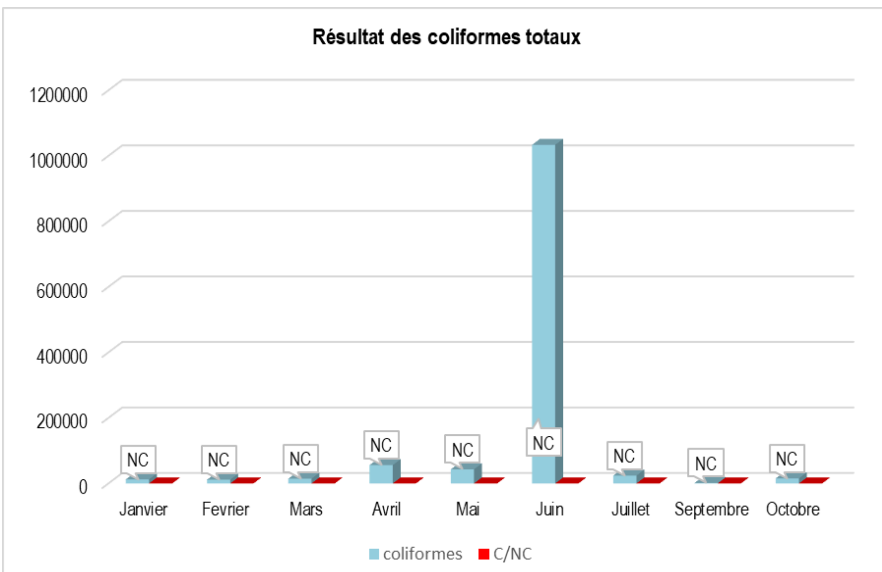


Figure No. 4: Result of the total coliforms

The figure No.5 below present the results of the analyses of the faecal streptococci of the industrial exhausted waters of SOMAÏR performed from January to October 2022.

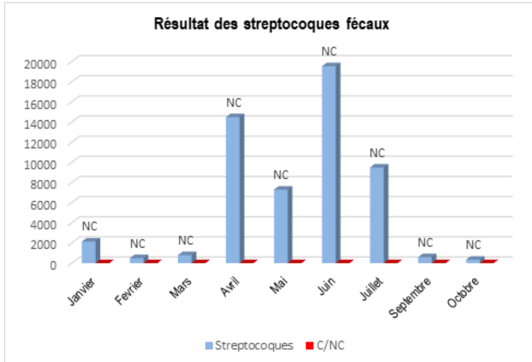


Figure No.5: Result of the fecal streptococci

Indeed, the results show that the total coliforms and faecal streptococci are not in conformity with the national norms of releases. We also notice that it is in June that the highest rate of total coliforms (up to 1000000 active) and of fecal streptococci (19550) has been recorded, extensively high above the national regulation.

DBO5 and DCO analyses results

The results of the DBO5 (Biochemical Demand in Oxygen over 5 days) and DCO analyses (Chemical Demand in Oxygen) done for the active period from January to October 2022 show that these are not for most in conformity with the Nigerien norms of releases as the figure No.6 and No.7 below indicate it. The results of the comparative survey of the DBO5 illustrated in figure No.6 face show that exhausted waters of the filtering basins are strongly polluted with the organic substances and overreach the assay value of those (organic matters) authorized by the Nigerien norms of releases. They vary from 58 to 689 mg/l from January to October 2022.

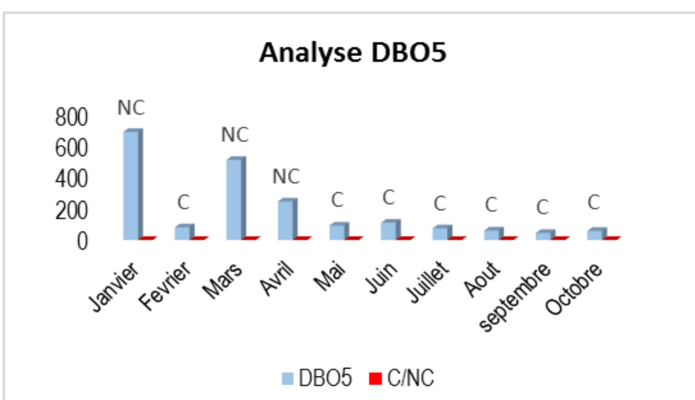


Figure No.6 :DBO5 analysis

The figure No.7 presents the results of the DCO analyses performed on exhausted waters at SOMAÏR, and compared to the Nigerien norms of release.

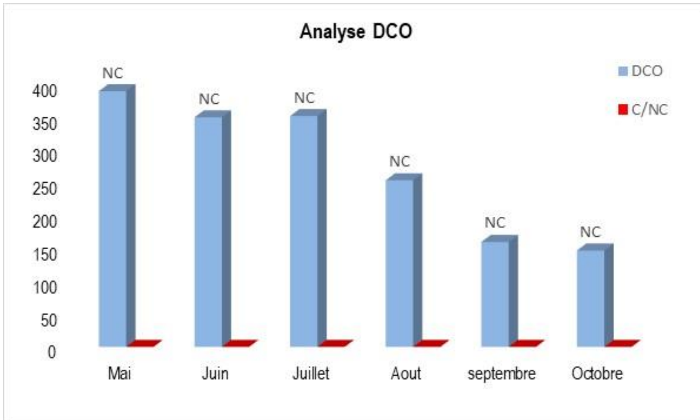


Figure No. 7: DCO analysis

The analysis of the achieved DCO results shows that exhausted waters in the city (mining city, hospital) are strongly loaded in biodegradable and non-biodegradable organic substances overreaching the admissible fair value by the Nigerien norm of releases which is 100mg/l. They vary from 147 to 390 from January to October 2022.

Influence of exhausted waters at SOMAÏR on the pollution of the water sheet

Although SOMAÏR has a station of the purification of exhausted waters, the results of the analyses show that they are not well purified to the **basin VI** exit before being reused for gardening. The results are well above the Nigerien norms of releases, which shows the inefficiency of the treatment in use by SOMAÏR.

Indeed, the problems bound to the exhausted waters especially worsen to the rhythm of the development of the industrial activities of which the intensification of the production started in 2013. The exhausted waters pollute the sites in which they are released, with impacts on aquatic surroundings but also on human health. The excessive presence of phosphate encourages eutrophication for example, that means the proliferation of alga, which decreases the quantity of oxygen contained in water. The exhausted waters damage the quality of the water sheets if the tightness of the purification station or of the lagoon is deficient or when the non-collective system of purification presents some dysfunctions and therefor favours the development and the proliferation of the water illnesses. The presence of faecal contamination germs has a domestic origin rather than industrial one, because of their strong content recorded at the lagoons situated west of the city. Globally, the set of bacteriological analyses has made to identifying a domestic origin insofar as their concentrations are higher at the lagoons of the city than at the industrial zone basins.

Indeed, the exhausted waters treated at the station of purification are reused by the market gardeners, whereas these (exhausted waters) are treated badly and don't respond to the national norms of releases, and their use can be source of various water illnesses. The population of Arlit currently faces problems of health bound to the use of the exhausted waters descending from the mining cities, notably in terms of the market gardening activities at the periphery of the city. It is proven by the proliferation of illnesses such as typhoid fever, cholera and tuberculosis, registered in the city since 2007 (table No. 2).

Table No. 2: Illnesses provoked by the contaminated waters

Microorganisms	**Origins**	**Illnesses**
Shigelles	Exhausted waters	bacillary Dysentery
Brucella	Exhausted waters	Brucellosis
Hystolytica	Farming Exhausted waters	amoebic Dysentery
Salmonellas	Exhausted waters	typhoid Fever
Vibrio Cholerae	Exhausted waters	Cholera

Source: Given of land, 2022

DISCUSSION

As most mining industries, SOMAÏR generates releases due to the use of important quantity of water its or drilling and treatment activities. At the mining company, the treatment of the sewage is performed through natural biologic method in the purification station made of six (6) filtering basins. However, we note that these sewages contain strong load polluting substances, making thus complex their treatment, and denote the stroke the weak efficiency of the system for the treatment of exhausted waters.

The bacteriological analyses made on samples of exhausted waters and on drinkable ones (wells, water towers and public fountains) show that the results are exempt of total coliforms and faecal streptococci concerning the drinking water. Thus they conform with the norms of safety of the WHO (1994) that stipulate that water destined to the consumption must contain no pathogenic germ.

However, if the results of the analyses of the drinking water don't indicate a bacteriological pollution, a radiological pollution of this water overreaching the admissible level fixed by the WHO exists, according to a survey achieved by the CRIIRAD (Independent Commission for Research and information on the Radioactivity) in collaboration with the local NGO AGHIR MAN from 2003 to 2005 in SOMAÏR. Analyses of the water samples that the mining companies provide to the city of Arlit permitted to note a contamination made of uranium driving to an indication of global activity of 10 to 100 times superior to the level from which the WHO recommends complementary investigations. The CRIIRAD demonstrated that the concentration made of exploited uranium 238 and uranium 234 in the waters of the well in 2002 by SOMAÏR was of 0.6 Bq/l and 1.4 Bq/l in February 2005, driving respectively to an annual dose superior to the recommendations of the WHO.

As for the exhausted waters, the bacteriological analyses done in the filtering basins also show that all basins recorded important microbial load in total coliforms and faecal streptococci. These are considered beyond the limit admitted by the national norm in use. This result stows with that of the CRIIRAD that seemingly concluded in its survey done on lagoon samples of exhausted waters in 2005.

The results showed that the exhausted waters don't respect the national norms and those of the WHO concerning release, with notably negative impacts on the underground water sheet.

CONCLUSION

In SOMAÏR, the dynamic treatment of ore requires the use of the important quantity of industrial water (4808 m³/day), of which the sewages and generated non-contaminated waters are recycled and are reused to 75% for the washing of the shops and the watering of the tracks and careers. The excesses of the sewages (25%) from the dysfunction of a part of the process are collected to be evacuated to the spreading basins where they will be left for natural evaporation. For human needs and other secondary needs (washing, shops, laundry, etc.), the industrial zone uses drinking water with 550m³/day delivery. The exhausted waters stemming from the use of the drinking water are collected at the same time as the sewages for the same destination. As for exhausted water of the urban zone (mining city, hospital and the city), they are collected and conducted to the purification station where they are reused thereafter for the irrigation after their natural biologic treatment.

Indeed, the bacteriological analyses, the DBO5 (Biochemical Demand in Oxygen over 5 days) and DCO (Chemical Demand in Oxygen) on exhausted waters done from January to October 2022 period showed that the results are above for most the authorized level, and therefore not in conformity with the Nigerien norms of releases. This proves that the exhausted waters used for the irrigation of the gardens that nourishes the city of Arlit in fruits and vegetables present a sanitary risk for the local population because these releases are liable to pollute the underground water sheet. It also appears that more than 80% of exhausted waters that the mining companies provide to the market gardeners are not in conformity with the norms of irrigation. These waters come from the purification lagoons of mining cities (Arlit and Akokan) that are not censored for more than 20 years. Conscious and anxious of the sanitary risks bound to water, the SOMAÏR puts a device to follow-up the quality of water and water sheets in use, as well as the health and the security of the workers. This company (SOMAÏR) was committed also to reducing its consumption of water and to increase its rate of retraining of more exhausted waters and to find other more efficient treatment mechanisms in order to get some results in conformity with the national norms of releases. There lays the necessity to make a regular follow-up of the exhausted waters and facilities (basins) from the purification station and to verify their tightness in order to prevent all infiltration of these waters into the water sheets.

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