Larhyss Journal, ISSN 1112-3680, n°27, Sept 2016, pp. 105-123
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EVALUATION DE LA MEILLEURE TECHNOLOGIE DISPONIBLE DANS LE DOMAINE DU TRAITEMENT DES EAUX USEES.

BEST AVAILABLE TECHNOLOGY ASSESSMENT OF THREE EXISTING PROCESSES IN WASTE WATER TREATMENT FIELD .

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RÉSUMÉ

Notre objectif principal dans cette étude expérimentale est de comparer trois technologies sélectionnées afin d'évaluer celle qui présente les principaux avantages avec moins d'inconvénients. C'est ce que nous avons tenté de démontrer à travers les outils de la directive intégrée du contrôle de la pollution (IPPC).

Cette évaluation met en application le concept fondamental de Meilleure Technique Disponible qui prend de plus en plus d'importance dans la législation environnementale européenne, et dans le Maghreb, c'est pourquoi il mérite d'être étudiée et appliquée en Algérie.

Les résultats de l'évaluation ont abouti à la conclusion selon laquelle le séquentiel réacteur en batch reste la technologie qui a été validée comme étant une MTD avec un abattement de la matière organique selon les pourcentages suivants : 95.6% de MES, 98% de DBO5, 93.5% de DCO and 75% de NH-3.

Comme recommandation générale, il est conseillé de choisir la technologie la moins chère en termes de capital, de fonctionnement et les coûts de maintenance, la technologie qui nécessite le moins de compétences et permettant d'être réutilisée en adéquation avec les normes internationales de réutilisation des eaux usées.

Mots clés : Eaux usées, MTD, séquentiel réacteur en batch, boues activées, biomembranes, étude comparative de trois technologies différentes.

ABSTRACT

Our main objective in this experimental study is to compare which one of the three technologies including Activated sludge process, sequential batch reactor technology and Bio membranes process has the main benefits with fewer disadvantages, that is what we have demonstrated through physical and chemical analyses of the above mentioned processes.

The assessment applies BAT guidelines based on the characteristics of the technology itself and of urban areas. These characteristics narrowed the choices for a fitted treatment and reuse technology to be used in a specific country context.

The assessment came to the conclusion, that there is one technology that fits all existing conditions which is SBR technology with removal efficiency by 95.6% of TSS, 98% of BOD_5, 93.5% of COD and 75% of NH-3.

As a general recommendation, it is advisable to choose the cheapest technology in terms of capital, operation and maintenance cost. In addition to lowest cost, the technology that requires the least skills in management should be selected and allowing to be reused accordingly to international Wastewater Reuse Standards.

Keywords: Sequencing Batch Reactor, Membrane BioReactor, Activated sludge, Wastewater treatment, Process efficiency comparison, best available technology (BATs).

INTRODUCTION

Although water is a renewable resource and we use little more than 10% of the total precipitation surplus for public water-supply, irrigation, and industrial processes, its availability is restricted through an uneven distribution, both in time and space. In this respect, there is no essential difference between ancient times and the present day; society has always experienced problems with water: too little, too much, too variable and too polluted. Over more than 6000 years mankind has tried to manage these water problems by intervening in its natural courses through redistribution, storage, and regulation, to accommodate their requirements for irrigation, drainage, flood protection, drinking water, sanitation, and power generation (Ghernaout, 2013), (falconer, 2005), (De veries,2007).

This work is dealing about water scarcity resources in Algeria during the last 25 years a severe drought, characterized by important deficit of country's rainfall, consequently, the quantities of water flowing into the catchment's basins of the dam have decreased and the basins are filled only partially. The Meffrouche dam, designed to provide 14 hm^3/year, has only delivered 4 hm3/year of drinking water on average during the recent years (ADE, 2007).

This scarcity is unfortunately distributed over the entire African continent and that has a negative impact on social and economic activities in these countries.

Currently, 15,770 hectares are being irrigated with treated wastewater, with plans to grow this number to 40,000 hectares during the period from 2010 to 2014. And as climate change has proven to have increasingly adverse impacts on regularity of freshwater supply, demand for treated wastewater has increased. It is because of this demand that nearly 100 wastewater treatment plants have been constructed. (Hammouche, 2011).

Conventional Activated Sludge Process (ASP) System which is located in the western region of Tlemcen (Algeria) is the most common and oldest biotreatment process used to treat municipal and industrial wastewater. Typically wastewater after primary treatment i.e. suspended impurities removal is treated in an activated sludge process based biological treatment system comprising aeration tank followed by secondary clarifier. The aeration tank is a completely mixed or a plug flow (in some cases) bioreactor where specific concentration of biomass (measured as mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS) is maintained along with sufficient dissolved oxygen (DO) concentration (typically 2 mg/l) to effect biodegradation of soluble organic impurities measured as biochemical oxygen demand (BOD_5) or chemical oxygen demand (COD). (Arun, 2011).

SBR technology is a method of which all phases of the treatment process occur sequentially within the same tank. Hence, the main benefits of the SBR system are less civil structures, inter-connecting pipework, and process equipment and the consequent savings in capital and operating costs (Metcalf & Eddy,2003). The plant is located in the Southern area of Doha (Qatar).

The membrane bioreactor (MBR) concept is a combination of conventional biological wastewater treatment plant and membrane filtration. The plant is located in the Westhern area of Doha (Qatar).

The concept is technically similar to that of a traditional wastewater treatment plant, except for the separation of activated sludge and treated wastewater. In an MBR installation this separation is not done by sedimentation in a secondary clarification tank, but by membrane filtration (Buisson et al., 1998; Visvanathan et al., 2000).

The high performance of membrane technology has been proven in recent years in a wide range of field, such as chemical industry, medical technology, drinking water treatment, biotechnology and environmental technology. The continuous development of membrane materials and membrane design on the one hand and the knowledge of operational management on the other hand have fostered the growth of membrane technology in wastewater treatment (Atasoy et al., 2000; Yoon et al., 2000).

MATERIAL & METHODS

BAT assessment methodology

The selection of an appropriate treatment and reuse technology is based, not only, on engineering criteria but on other, sometimes more important, variables such as social acceptability, economics, climate, skills, cost, etc (Cikankowitz, 2008).

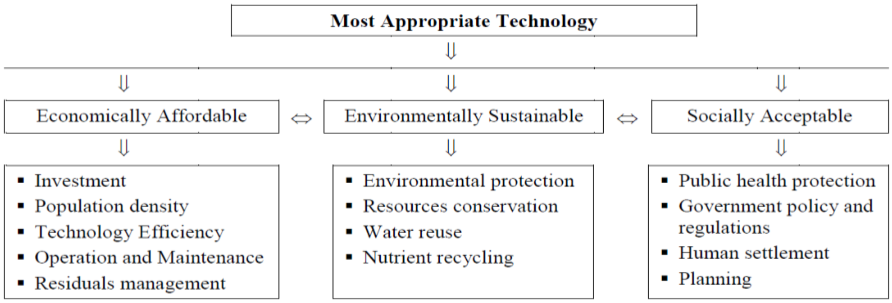

Figure 1 : Reference Document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW BREF), 2007.

Sampling Methodology

Wastewater samples were collected on a monthly basis during 3 years from the effluent of the treatment system in sterile plastic containers and transported to the laboratory for analysis. All samples were kept refrigerated until analyses were done a few hours after sampling.

Analyses performed

The lab measurements followed either the APHA Standard Methods

for the Testing of Water and Wastewater or the equivalent Hach standard methods.

The bulk of the in-house analysis utilized a Hach DR/2500 Spectrophotometer. The parameters that were tested include: Chemical Oxygen Demand (COD), Ammonia (NH3) and Total suspended solids (TSS).

The organic load removal efficiency was calculated based on the following formula:

$$Er = [(C_0 - C_e) / C_0] \times 100\% . \qquad \ldots (1)$$

Er – Efficiency of removal

C_o – Concentration of the raw effluent

C_e – Concentration of the final effluent

Determination of Total Suspended Solids: filters have been washed and dried prior to use by rinsing the filter with deionized (DI) water three times while vacuum was applied through the vacuum, record of the weight of the pre-washed and prepped filter on the appropriate worksheet, the sample collection time has been recorded, as well as pH, and temperature from the field logbook. After filtering the sample aliquot, it is transferred to an aluminum or glass weighing dish as a support.

After drying is complete, the filters are reweighed and calculated using the following calculation to determine TSS.

$$TSS\left(\frac{mg}{L}\right) = \frac{(residue + filter)(mg)}{sample\ filtered\ (ml)} \xleftarrow{-filter\ (mg)} * 1000\left(\frac{ml}{L}\right) \ldots (1)$$

COD is a two-step process: Digestion and Determination, we’ve added 2 mL of sample into the vital marked sample then 2 mL of organic free deionized water into the vial marked blank, after mixing , we placed the vials in the DRB200 reactor and let them digest for 2 hours at 150°C.

After digestion, warming and cooling. We read the reacted sample on temperature using a spectrophotometer.

Biochemical Oxygen Demand is the amount of oxygen, expressed in mg/L, we filled bottles past the neck with dilution water and invert to mix, Dissolved oxygen concentration were measured prior to incubation via LQ10/20 laboratory LDO Meter, samples were transferred to 20ºC incubator and incubated for 5 days. After 5 days, we remove d the samples from incubator and measured final DO.

$$BOD_5\ (mg/L) = (Initial\ DO - Final\ DO)\ 300/S \qquad \dots (2)$$

Ammoniacal nitrogen was determined by Nesslerization method. To 10 ml sample in a test tube, we've added 2 ml Nessler's reagent. After 10 minutes, we've measured the absorbance at 460 nm in a spectrophotometer.

The organic load removal efficiency was calculated based on the following formula:

$$Er = [(C0 - Ce) / C0] \times 100\% . \qquad \dots (3)$$

Er – Efficiency of removal

C_o – Concentration of the raw effluent

C_e – Concentration of the final effluent

Environmental impact assessment

Sludge generation, chemical and energy consumption as well as water reuse rates were evaluated in order to compare between the three different technologies.

RESULTS AND DISCUSSION

Assessement of the best available technology (BAT)

The assessment has been done based on Integrated pollution prevention and control (IPPC) requirements and its 12 indicators (see table 1)

Table 1 : Integrated pollution prevention and control (IPPC) requirements and its 12 indicators which are:

1-	Quality of the effluent	7-	Footprint
2-	Management	8-	Sludge production and reuse
3-	Investment cost	9-	Treated water reuse
4-	Maintenance cost	10-	Energy consumption
5-	Chemical consumption	11-	Reliability and Risk
6-	Environmental impact	12-	Skills requirement

Organic load removal efficiency assessment

Fig.2 is representing the removal percentage efficiency of the three studied technologies and it shows that MBR technology is the one who had the maximum removal efficiency among all with 99.83% with TSS, 98.97% with BOD_5, 95.93% with COD and 89.95% with $NH\text{-}_3$ .SBR comes after with 95.6% of TSS, 98% of BOD5, 93.5% of COD and 75% of NH-3. ASP process comes at last with 88.25 % of TSS, 88% with BOD_5, 95% with COD and 78% with NH_{-3} .

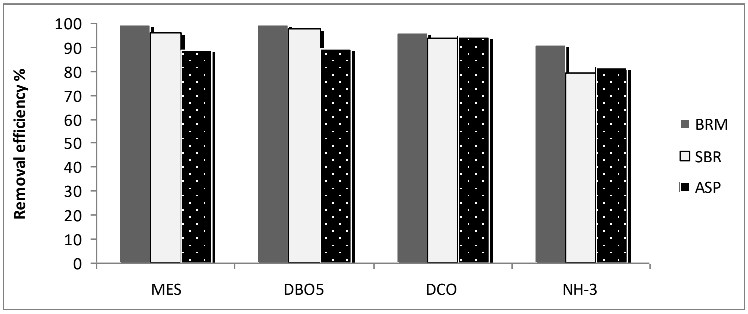

Figure 2 : Average removal efficiency of the different parameters for the three technologies

(Table2) related to Fisher test and standard deviation have been calculated based on the performance of each parameter via LSD test (Least Significant Difference) using QI macros 2014 software.

Table 2 : ***Fisher test and standard deviation***

	Unit	P	F	LSD	STDV
TSS	mg/L	0.000	0.05	± 0.37	26.19
BOD_5	mg/L	0.000	0.05	± 0.20	16.13
COD	mg/L	0.000	0.05	± 0.13	9.15
NH-3	mg/L	0.001	0.05	± 0.10	6.55

TSS reduction of 0.67 mg/L has been recorded under MBR Technology, 7.39 mg/l under SBR technology and 34.04 mg/l under ASP process (see Fig.3).

The maximum BOD_5 reduction was observed to be very high under MBR tech., with a concentration of 1.27 mg/L. As far as BOD_5 reduction is concerned, it was proven that the use of MBR Tech. is more effective than SBR Tech. (3.54 mg/l) and ASP tech. (29.5 mg/l) (Fig. 4).

According to Arun, (2011), due to membrane filtration, the treated effluent quality in case of MBR system is far superior compared to conventional activated sludge, so the treated effluent can be directly reused as cooling tower make-up or for gardening etc.

The maximum COD reduction was observed under MBR tech., with a concentration of 18.45 mg/L. ASP (30.08 mg/l) and SBR technology (26.08 mg/l) have been found to be less effective than MBR system. (Fig.5).

In ASP plant, the nitrification has been achieved satisfactorily with 9.79 mg/l, as it was under the standards limits allowed of 50 mg/l, even, with a difference of 4.26 mg/l higher from SBR (5.53 mg/l) regardless to the issues encountered, previously explained, and higher than MBR plant, with a difference of 7.56 mg/l as it has reached the maximum reduction 2.23 mg/l.

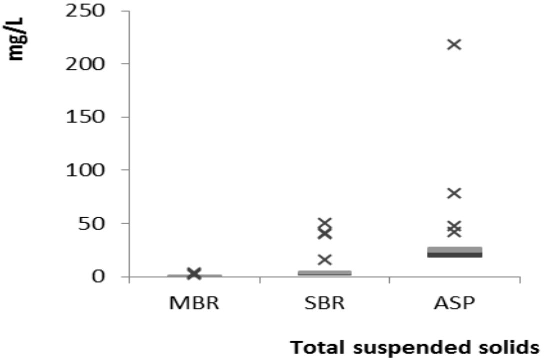

Figure 3 : ***TSS Effluent Concentrations within the Activated Sludge, SBR and MBR***

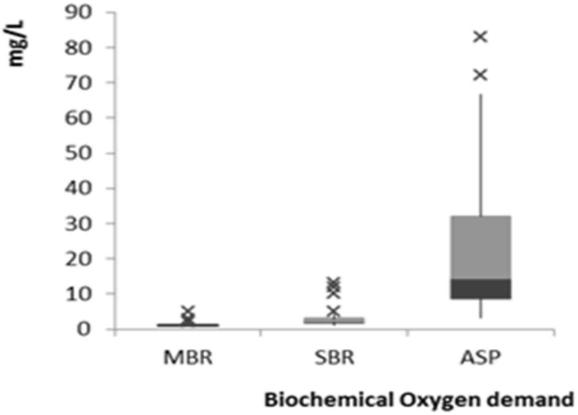

Figure 4 : BOD Effluent Concentrations within the Activated Sludge, SBR and MBR

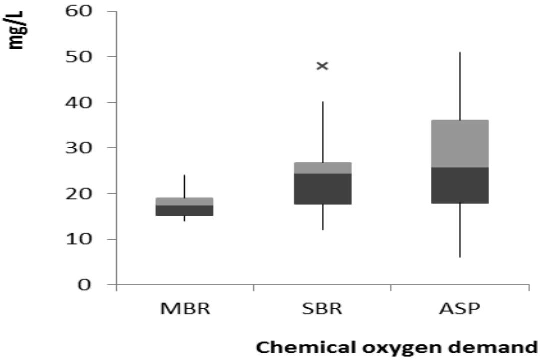

Figure 5 : COD Effluent within the Activated Sludge, SBR and MBR

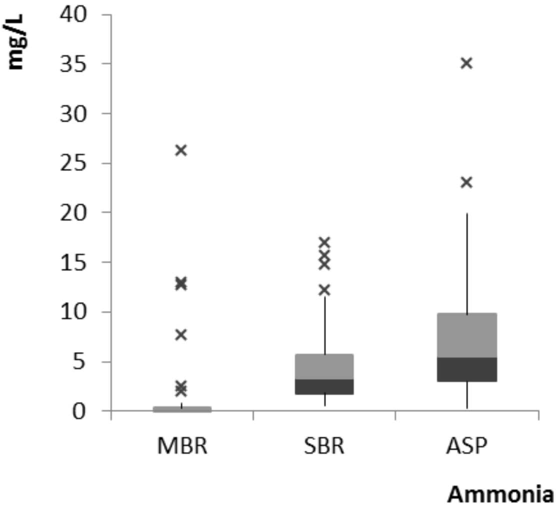

Figure 6 : Ammonia Effluent within the Activated Sludge, SBR and MBR

Flow and Power consumption

For MBR technology treatment plant, its flow design capacity supposed to be of 165,000 m^3/day, but it's working above it, so, this led to more energy consumption as 2 to 3 blowers were running continuously to maintain a good DO in aeration tanks. With the overload, there was more pollution to treat, so more power consumption to record in parallel (fig.7).

For the treatment using AS technology, the raw wastewater flow from the pumping stations was averaged +/- 30,000 m^3/day unfortunately, we couldn't record the power consumption so, we were unable to compare between flow rates and power consumption.

For SBR technology the raw wastewater flow was averaged +/- 162,000 m^3 /day. Which is 11% higher than the yearly average for 2012, and approximately 45% above original plant design value (112 MLD). This continuous overload led to an over power consumption to overcome the excess pollution (fig.8).

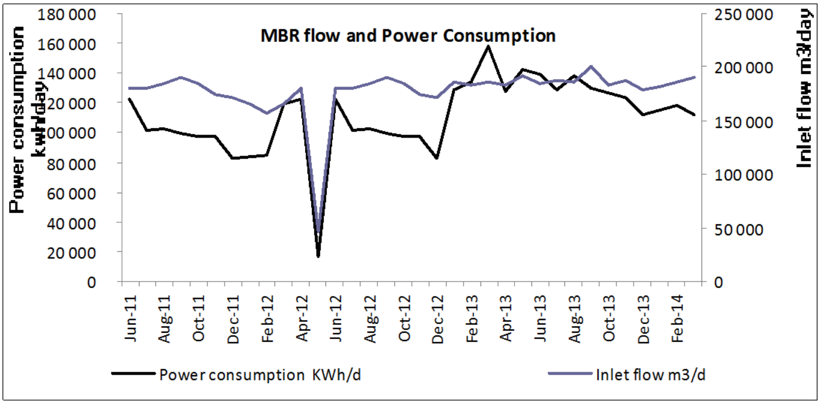

Figure 7 : MBR flow and power consumption (Gaouar et al, 2014)

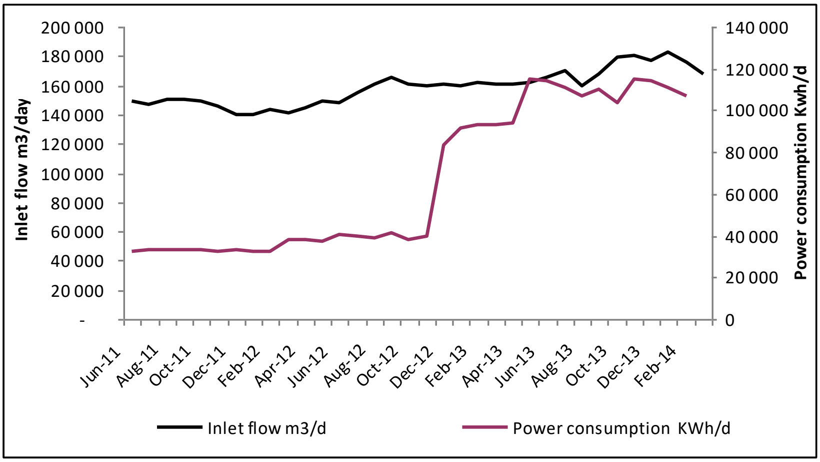

Figure 8 : SBR flow and power consumption (Gaouar et al, 2014)

Sludge production and MLSS

MLSS concentrations for MBR are between 8,64 g/L and 10.30 g/L; for SBR, the range of the MLSS is between 6.83 and 8.95 g/L; MLSS at AS are between 4.68 and 6,75 g/L.

The ability of MBR holding higher concentrations of MLSS, and having much longer SRT than in SBR, allowed the MBR system to produce less waste sludge

(1,938 m^3/year) compared to SBR (819,901 m^3/y) or AS (790,050 m^3/y) systems and consequently needs less sludge disposal frequency (Table 3) .

According to Ashley and al (2012), a typical MBR design will operate at an MLSS of 12,000 mg/l, while a typical SBR design will have an MLSS in the range of 3,000 mg/l. as well as ASP design. This difference in biomass concentration leads to much smaller process basins for MBR technology, and results in the MBR system having an overall plant footprint 50 – 70% smaller than an SBR system.

With membrane bioreactors, the production of surplus sludge is lower than with conventional activated sludge systems, a fact that has been confirmed in a large number of analyses. There is, however, no consensus about the dimension of the reactions and their respective causes. In order to examine these, at the University of Hanover a pilot plant with a capacity of 220 l was run for one year without any extraction of surplus sludge. The plant was started with 2 g MLSS/l; after one year, this value had risen to approximately 18 g MLSS/l. The emerging result was that in contrast to conventional systems the sludge growth was lower, but still continuously existing. Then, comparisons with theoretical approaches were run – among others with the ASM1-Model – which confirmed the findings. (Wagner and Rosenwinkel, 2000).

Table 3 : Comparison of sludge waste production between the three treatment plants (Gaouar et al., 2014)

	Sludge wasted from SBR process (average)	**Sludge wasted from AS process (average)**	**Sludge wasted from MBR process (average)**
Unit	m^3/day	m^3/day	m^3/day
Daily average over 12 months	1,928	2,159	121
Over 12 months m^3/year	819,901	790,050	1,938

Chemical consumption

Disinfection of the effluent is required to meet the anticipated discharge requirement of an average coliform count of less than 23 MPN/100 mL. It is anticipated that the effluent suspended solids will have to be reduced to 10 mg/L or less in order to allow effective disinfection. 2 options were considered: gas chlorination, liquid sodium hypochlorite.

According to (figure 9), evidence of chemical consumption for MBR is more important than for SBR, especially for caustic soda (NaOH) and sodium hypochlorite (NaClO). However, and due to the hydraulic capacity of the two treatment plants, we can easily deduce that the chemical consumption is highly correlated to the flow capacity and hydraulic charge of each treatment plant.

Regarding chlorine ($C_{20}H_{16}N_4$), There is an equivalent consumption; the ASP treatment plant of Ain Al Hout, doesn't require any chemical treatment as it's performing biological treatment only.

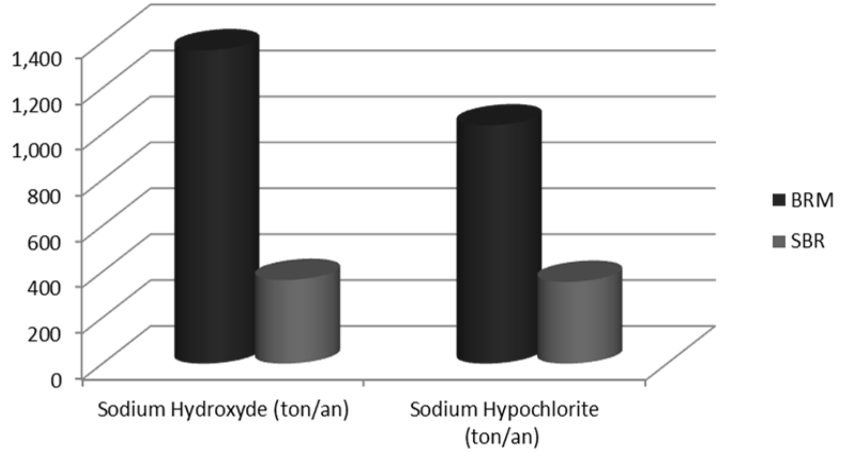

Figure 9 : Chemical Product consumption (BRM &SBR)

Reuse of treated wastewater

First of all, components found in wastewater can contain useful and valuable nutrients that are required by plants. These nutrients and fertilizers can reduce the input of artificial fertilizers, which not only results in a reduction of the environmental impacts associated with the use and production of artificial fertilizers, but also has positive impacts on farmers' incomes[24]. Farmers therefore benefit through increased productivity and yields and faster growing cycles, while decreasing their needs for artificial fertilizers and additional water sources (Who, 2006).

Another benefit of wastewater lies in its availability. In urban areas where alternative water supplies are lacking, wastewater is an advantageous resource because it is available all year round and is a low-cost option for farmers. Figures 10&11 are summarising the distribution of the treated water over the farms.

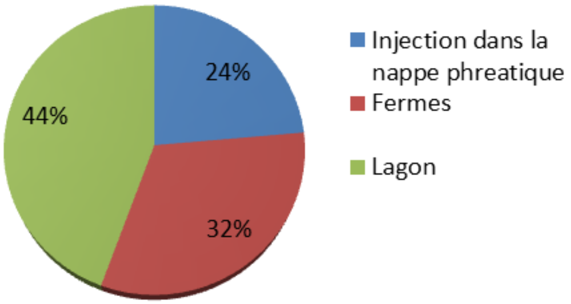

Figure 10 : Average treated water distribution over the farms linked to SBR plant over different sectors (2013)

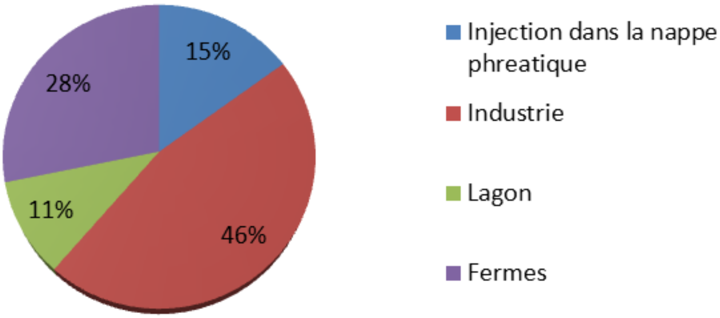

Figure 11 : Average treated water distribution over the farms linked to MBR plant over different sectors (2013)

Focus L-BAT assessment and final evaluation

From (figs. 12, 13 and 14), and table 4, evidence of the SBR technology as the best available technology against the different indicators has been demonstrated.

In the literature, among the various biological treatment processes, sequencing batch reactor (SBR) which is considered to be an improved version of activated sludge process, SBR operates in a pseudo batch mode with aeration and sludge settlement both occurring in the same tank. SBRs are operated in fill-react-settle-draw-idle period sequences. The major differences between SBR and conventional continuous-flow, activated sludge system is that the SBR tank carries out the functions of equalization, aeration, and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. Therefore, they are advocated as one of the best available techniques (BATs) for wastewater treatment because they are capable of removing organic carbon, nutrients, and suspended solids from wastewater in a single tank and also have low capital and operational costs (Wagner and Rosenwinkel, 2000).

According to table 4, the quantitative evaluation has come to the conclusion that SBR plant had 70% advantage over the two other plants and that the ASP technology had 45% less advantage compared to the SBR and 15% less advantage compared to the MBR.

Table 4 : Quantitative evaluation of ASP technology over the others

Criteria	ASP	SBR	MBR
-2	1	0	0
-1	2	1	3
0	2	1	1
+1	10	4	5
+2	5	14	11
TOTAL	20	20	20
Advantage per type of treatement	**25%**	**70 %**	**55%**
ASP advantage over the two other processes	- **45%**		- **15%**

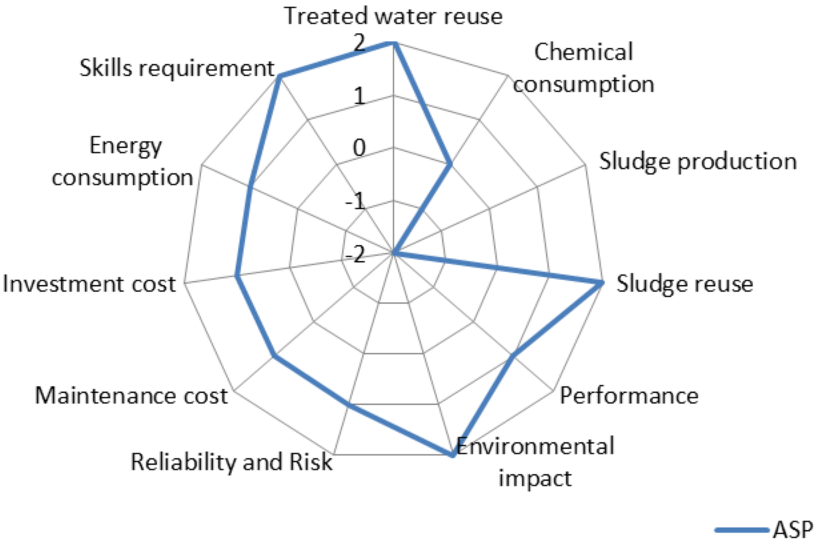

Figure 12 : ASP Profil based on BAT performance indicators

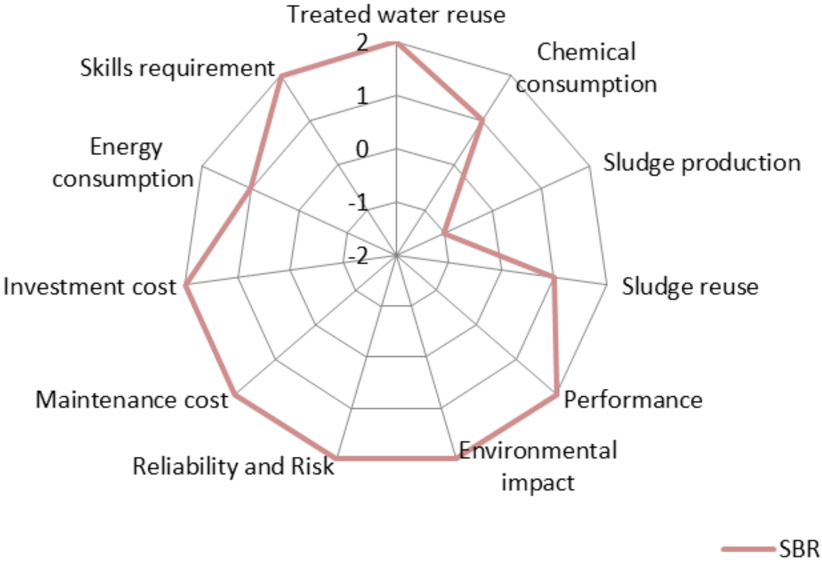

Figure 13 : SBR Profil based on BAT performance indicators

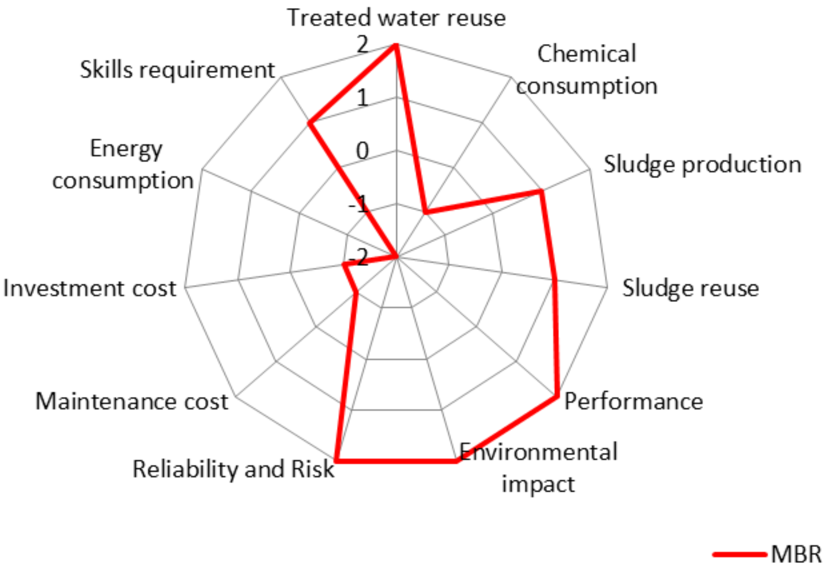

Figure 14 : MBR Profil based on BAT performance indicators

CONCLUSION

Either the MBR technology, ASP or the SBR technologies are giving satisfactory results: Flexibility (flexibility to the shock load), Convenience (convenience of operation and maintenance) and reliability (reliability of operation); However, SBR has the following advantages:

- All analytical parameters measured in SBR effluent were satisfying, as it produces high quality reclaimed effluent allowing to be reused in according to international Wastewater Reuse Standards.
- Also, SBR system requires only 40-60% of the space required for activated sludge system, therefore significantly reducing the concrete work and overall foot-print.

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