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Treatment of domestic and agricultural water by natural lagoon system in arid areas, case of Oued Souf, Algeria

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Abstract

The rational management of water resources and the control of hydroagricultural techniques in the Oued Souf area are complex and crucial to a harmonious and sustainable development. The Oued Souf area is presently facing the problem of upwelling from groundwater, which is harmful to cultures and homes. In order to minimize this problem, several aerated lagoon treatment plants were set up; this technique allows an efficient control of pollution due especially to the upwelling phenomenon. The aim of this study is to provide information about the efficiency and the management of an aerated lagoon treatment system at two plants of the Oued Souf area, the Hassani Abdelkrim and the Reguiba plants. The obtained results show that the removal efficiency of organic load is significant (greater than 50%), thus indicating that aerated lagoon system is well suited to arid areas.

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Introduction

The degradation of water resources through the runoff of polluted water not only seriously damages the environment, but also leads to scarcity risks. It is therefore necessary to treat the wastewater before discharging it into the receiving environment. This pollution is caused by wastewater generated by our domestic activities, as well as various industrial and agricultural activities, which are essential to provide us with food and goods (UN World Water Development Report, 2017). Wastewater discharges increase as a result of industrialization and the higher standard of living of the population. The self-purification capacities are considered out of date, which encourages researchers to develop many techniques to treat these effluents (Vilagines, 2003).

In Africa, the gap between water availability and water demand is growing rapidly, especially in cities, where the urban population is expected to almost quadruple in 2037 (World Bank, 2012). This suggests that there will likely be a massive increase in wastewater from growing African cities. The setup of treatment systems downstream of sanitation constitutes one of the solutions or the only one capable of preserving the water resources. In addition to depollution of effluents, these equipments allow mobilizing a large amount of water reusable in many fields. According to the nature and the extent of pollution, different processes can be implemented in order to treat residual water in function of the properties of this latter and the desired treatment degree (ABHS, 2011; ANRH, 2009).

The biological processes and notably lagoon system are fairly efficient and cost-effective, since they only use the purifying power of microorganisms present in water, air oxygen, temperature and sunlight. (Cemagref, Sates, Ensp, Agence de l'eau, 1997).

Accordingly, the aim of this study is to present the wastewater treatment in the Oued Souf area, so we will discuss the findings of water quality at the outlet of the two aerated lagoon treatment plants investigated.

Material and methods

Geographical location

The Oued Souf area, also called Lower-Sahara because of the low altitude, is located south-east of Algeria in the center of a large synclinal basin. The Oued Souf province has a surface area of 44 586Km². It is located about 700Km south-east of Algiers and 350Km west of Gabès (Tunisia). It is limited to the north by the Biskra, the Khenchela and the Tébessa provinces, to the east by Tunisia, to the west by the Biskra and the Ouargla provinces and to the south by the Ouargla province. The Fig. 1 presents the geographical location of the study area.

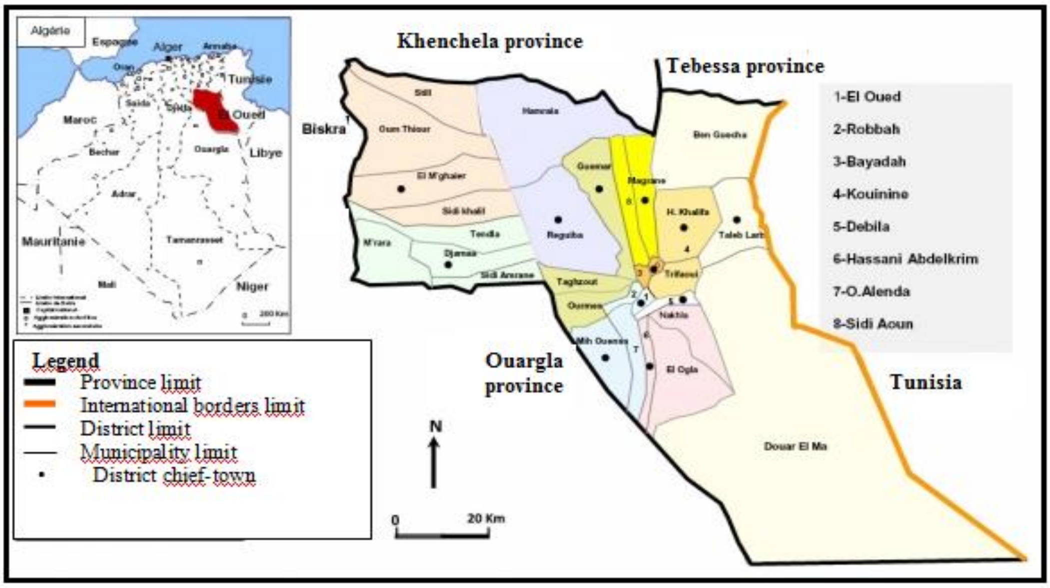

Fig. 1. Geographical location of the study area (DHW, Oued Souf).

Hydrogeology

In order to minimize the phenomenon of upwelling affecting the Oued Souf area, the state completed 112 wells and 40 piezometers in 1993 (Fig. 2), distributed over an area of 80km north-south and 40km east-west, so constituting a drainage network that drains groundwater into the two treatment plants being object of our study etude (Bouselsal and Kherici, 2014).

Fig. 2. Water wells (•) inventory map of the Souf valley groundwater (DHW, Oued Souf).

Hydraulic study

Origin of water entring treatment plants:

Pollution or contamination of groundwater can be defined as the degradation of this latter by the modification of its physical, chemical and biological properties by discharges of wastes, direct or indirect deposits of foreign bodies or undesirable matter, such as microorganisms, toxic substances and industrial wastes (Degrémont, 1989; Emilian, 2009).

Wastewater, regardless of its origins, is usually loaded with undesirable elements, which according to their amount and their composition, pose a real threat to receiving environments and to its users; it is the case of wastewater entering the two treatment plants being object of our study; this wastewater can be of domestic, industrial and especially agricultural origin (Bonnard and Gardel, 2001; 2003).

Domestic wastewater must be treated before being discharged to natural environment: streams, rivers and lakes. This treatment is made in treatment plants by bacteria that break down wastewater before being discharged; they convert this pollution into a byproduct called sludge, which can then be applied to farmland as fertilizers and organic matter (Biddlestone and Job, 1991).

Sanitation plan in the Oued Souf area

The proposed sanitation plan consists of a sewer system aimed at collecting wastewater of different agglomerations and conveying it into aerated lagoon treatment plants to purify them from matter harmful to public health and environment (Bouselsal and Kherici, 2014).

Once treated, a part of this water will be used for irrigation (Faby and Brissaud,1997) of farmland close to the plant, the other part will be discharged into a Chott zone located 70km north-west of the EL Oued city via a pipe fed by the different treatment plants. Sewage and treated water will be drained through a north-southern pipe into Chott Halloufa 70km north-west of the valley (Fig. 3).

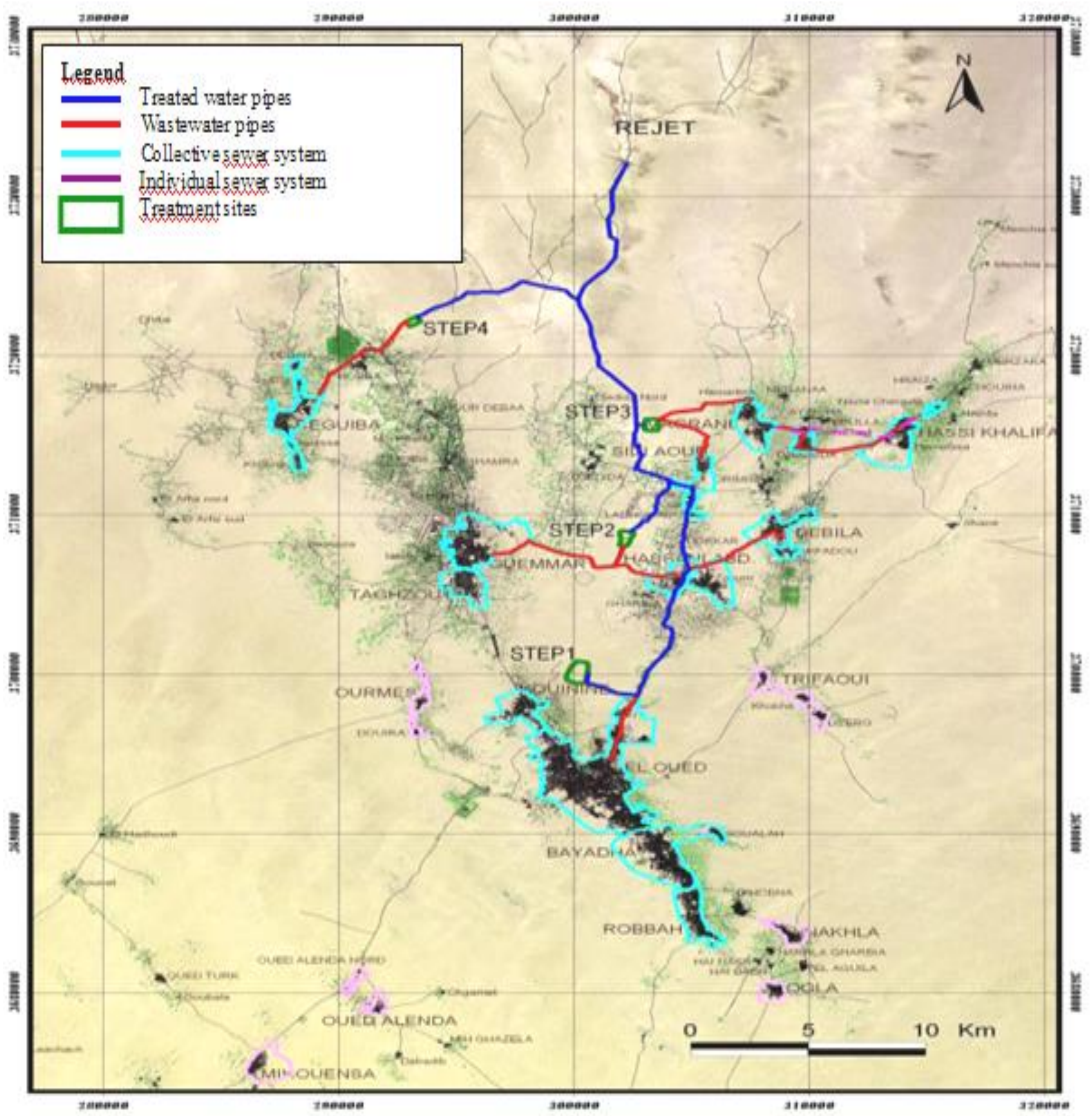

Fig. 3. Map of geographical location of the two studied plants.

Aerated lagoon method is a solution for wastewater treatment in arid areas like Oued Souf (Harrat *et al.*, 2013). For this reason, four treatment plants were completed in the area, the purpose of which is to stem pollution due especially to the upwelling phenomenon that is acute in this part of the country.

The following table shows the location of the plant in Oued Souf (Table 1).

In this framework, we studied two aerated lagoon treatment plants:

- Plant 2 of the Hassani Abdelkrim location.
- Plant 4 of the Réguiba location.

Table 1. Location of treatment plants in the Oued Souf area.

Plant code	Zone	Surface area of the plant (Hectare)	Capacity (Inhabitants)
Plant 01	Kouinine	50	246.000
Plant 02	Hassani Abdelkrim	40	80.000
Plant 03	Sidi Aoun	40	70.000
Plant 04	Réguiba	25	30.000

Experimental procedures

Sampling

The tests of our study were carried out on raw and treated water samples of the two plants over a period of 3 months (January, February and March of the year 2017). The samples were collected in well washed jerricans.

Samplings were performed at a depth of 15 to 30cm below surface water, avoiding air penetration. The samples were transported from the sampling point to the laboratory in a cool box kept at 4°C and then stored in the refrigerator. Before performing any analysis, it is essential to take all steps, such as homogenization at the time of dosage (Rodier *et al.*, 2009).

Methods

The different physicochemical parameters were determined by the techniques stated in Table 2.

Table 2. Devices and methods.

Physicochemical parameters	Devices and methods
T°C, pH, dissolved O_2, conductivity	Multi-parameter type HANA
Turbidity	Turbidimeter (Turbe 550)
COD	Titrimeter LT200
BOD_5	Incubator
Heavy metals	Spectrophotometer DR/2800
Kjeldahl nitrogen	Kjeldahl method
Phosphorus compounds	Dosage after hydrolysis in acid medium

Results and discussion

The pollution assessment of raw wastewater is made on the basis of the determination of certain number of typical physicochemical parameters. The variation of major and overall parameters of wastewater of the Hassani Abdelkrim and the Reguiba cities during the period (January, February and March, 2017) is indicative of water quality received by the two plants. The results analysis of raw and treated water of the two treatment plants that are object of our study are summarized in the following tables 3 and 4:

Table 3. Results of average analysis of three months of raw wastewater and treated water of the plant 2 (Hassani Abdelkrim).

Parameter	Raw water	Treated water
pH	8.17	8.26
Temperature (C°)	11.81	12.83
BOD_5 (mgO_2/l)	66.16	28.66
COD (mgO_2/l)	422	103.66
SS (mg/l)	310.33	51.33
Concentration O_2 (mg/l)	4.76	7.16
Saturation O_2 (%)	32.07	74.98
Total nitrogenl TN (mg/l)	47	9.1
Total phosphorus TP (mg/l)	ND	ND
Total kjeldahl nitrogen (mg/l)	45.39	6.8
Turbidity (NTU)	95.39	25.64
Cadmium (mg/l)	105.33	31.66
Cyanide (mg/l)	0.258	0.048
Phenol (mg/l)	4.35	1.47
Lead Pb (mg/l)	44	19

Table 4. Results of average analysis of three months of raw wastewater and treated water of the plant 4 (Réguiba).

Parameter	Raw water	Treated water
pH	7,73	8,30
Temperature (C°)	19,47	14,54
BOD_5 (mgO_2/l)	383.88	27.77
COD (mgO_2/l)	637.96	100.78
SS (mg/l)	238.23	45.56
Conductivities (µs/cm)	6,67	6,47
Concentration O_2 (mg/l)	0,21	11.47
Saturation O_2 (%)	2.11	112.15
Total nitrogen TN (mg/l)	143	76
Total kjeldahl nitrogen (mg/l)	74,95	68,9
$N\text{-}NO_3^-$	8.75	2.03
$N\text{-}NH_4^+$	54.13	14.10
$N\text{-}NO_2^-$	3,78	3,24
$P\text{-}PO_4^{-3}$	7.77	4.45

pH

The pH plays a key role in the process of aerobic biological treatment, because biomass needs a pH approximate to neutrality to complete its purifying activity (Chaib A, 2004). The obtained results show a marginal fluctuation for the two treatment plants. The highest values can be explained by the bacterial activity; this shows that it remains slightly basic during all processes. Given that pH influences both the activity level, the bacteria growth and the solubility of compounds, it is essential to control it in the different steps of treatment, especially as bacteria are sensitive to its variation.

Temperature

Temperature has a dramatic impact on bacterial activity because each range of bacteria is adapted to a range of temperature (Brissaud *et al.*, 1989). We found a marginal fluctuation at the two treatment plants and for the two types of water; the average recorded at the plant 2 is of 11,81 and 12,83°C for raw wastewater and treated water, respectively. For the plant 4, the average temperature recorded is of 19,48 and 14,55°C. This temperature variation is not significant enough to pose problems to biological processes, but it is obvious that we could observe changes in nitrification.

BOD_5 and COD

The BOD_5 represents the biodegradable organic pollutant load. Thus, it provides a valuable indication to assess water quality and the degree of pollution; this test is recognized as very little accurate to assess natural water, but it is much used for monitoring the performance of treatment plants (Kone *et al.*, 2012). Additionally, the chemical oxygen demand (COD) and the oxydizable matter (MO = 1/3 DCO + 2/3 DBO_5) represent the parameters usually indirectly used to describe organic load of wastewater. The organic load recorded is more significant; it is of the order of 383, 89mg/l for raw water and 27, 77mg/l for treated water. The reduction rate is higher than 90%, thus indicating the good operation of the plant 4.

The COD values are significant for the two treatment plants; the mean values of treated water are 103,6 (MO = 1/3 DCO + 2/3 DBO_5) 7 mg/l and 100,78mg/l for the plant 2 and 4, respectively, thus meeting the discharge standards (125 mg/l). However, several organic molecules present in residual water are not or only very slowly biodegradable. In this case we observe: COD > BOD.

Given that BOD measured after 5 days (BOD_5) accounts only for a part of the total BOD, so the use of the COD/BOD_5 ratio allows gaining a realistic insight into the biodegradability of an effluent. In the case of an urban residual water containing most of biodegradable organic compounds, we consider that BOD accounts for about 80 to 90% of COD and COD/BOD_5 ratio is generally comprised between 1,5 and 2,5.

For the industrial effluents containing a notable fraction of non-biodegradable compounds, we could consider, according to the COD/BOD_5 ratio, that the biodegradability is more or less favorable for a biological treatment, given that the following rules are generally adopted (Rodier *et al.*, 2009; Degrémont, 1989):

- COD/BOD_5 < 3 readily biodegradable effluent
- 3 < COD/BOD_5 < 5 moderately biodegradable effluent
- COD/BOD_5 > 5 hardly biodegradable or even non-biodegradable effluent

This biodegradability index (COD/BOD_5) also proved very useful for monitoring the performance of biological treatment; the ratio increases, especially as the biological treatment is more sophisticated (Marsalek *et al.*, 2002).

The two studied plants represent a biodegradability ratio between 3 and 5, thereby indicating that organic matter received by the two treatment plants is moderately biodegradable Table 5.

Table 5. Biodegradability ratio of the OM at the two plants.

Plant	COD/BOD_5 ratio
Plant 02	3.61
Plant 04	3.62

Suspended solids (SS) and turbidity

Suspended solids (SS) represent all insoluble mineral and organic particles, floating or suspended, contained in wastewater. They are mostly biodegradable (Rodier *et al.*, 2009). Turbidity results from the dispersion and the absorption of light by the particles of suspended solids. Suspended solids and turbidity record more or less significant values for the plant 2. We can observe that (SS) and turbidity follow the same trend and that the removal of the two parameters by settling is dramatic, but remains always above the discharge standards (40mg/l).

Dissolved oxygen and percentage of oxygen saturation

The presence of dissolved oxygen in wastewater is mainly determined by the oxidation and the degradation of pollutants and finally by air-water exchange (Degrémont, 1989). It is obvious that raw wastewater entering the two plants originates from domestic use of water; it is marked by its richness in organic matter (Bouselsal and Kherici, 2014); there is not any notable oxygen input into this plant. This explains the low contents of dissolved oxygen, observed at the inlet of each plant.

Wastewater undergoes an extensive treatment at lagoons for reducing organic load by bacteria, so more air oxygen. Waste water oxygenation occurs progressively by means of turbines providing more oxygen input, thereby proving the increase in dissolved oxygen and the saturation percentage at the two plants.

Nitrogenous matter

Nitrogen is an essential constituent of living matter, but its presence in large amounts in wastewater requires a careful monitoring (Vaillant, 1974).

Wastewater nitrogen exists in organic and inorganic form. The inorganic forms are immediately available for the crop, whereas the organic forms must be mineralized by microorganisms. Wastewater nitrogen exists in ammoniacal form NH_4^+ (Degrémont, 1989). In order to remove nitrogen pollution, a long biological treatment is needed, where lagoons are alternatively aerated and then deprived of oxygen. Initially, nitrifying bacteria will oxidize ammonium into nitrates (NO_3^-), then denitrifying bacteria follow on to reduce (in the absence of aeration) nitrates into non-pollutant atmospheric nitrogen (N_2). Finally, 90% of nitrogen is removed (Rodier *et al.*, 2009).

According to the obtained results, the concentration variation of ammoniacal nitrogen at the two plants is caused by the degradation of ammonium concentration as a result of aerated lagoon biological treatment that allows reducing NH_4^+ pollution load. Nitrates are the final step of oxidation of organic nitrogen in water. Nitrifying bacteria (nitrobacter) oxidize nitrites into nitrates. This reaction, called nitratation, is also accompanied by oxygen consumption. We also observe an increase in NO_3^-; this can be explained by the oxidation of NH_4^+ into NO_3^-.

Phosphorus compounds

According to the illustrated results, we can see that the phosphorus compounds undergo a sharp decrease during settling especially of suspended solids. *Heavy metals (Cd , Cn, Ph ,Pb):* The heavy metals contents in wastewater of the Oued Souf area are probably due to discharges of grease, oils and greywater coming from car wash, directly contaminated and not having undergone treatment. The decrease in these metals in treated water is actually due to adsorption on SS then to settling.

Treatment efficiencies:

The efficiencies computed on the fluxes of organic matter by the formula below are significant (Fazio, 2001), indicating the good treatment efficiencies of lagoon system suited to this area.

$$R\% = \frac{C_o - C_f}{C_o} \times 100$$

Where,

- R (%): removal efficiency
- C_o: initial concentration of pollutant (raw water)
- C_f: final concentration of pollutant (treated water)

The following Figs. show the treatment efficiencies of the two plants studied (Fig. 4 and 5)**:**

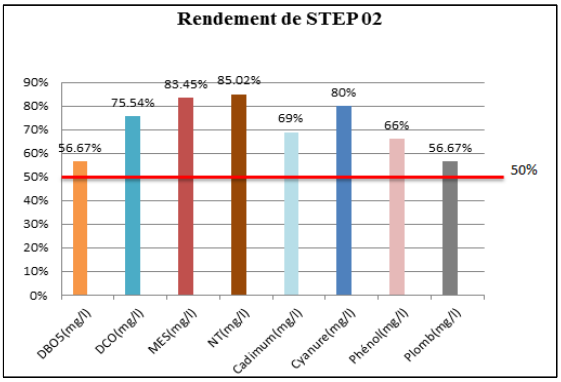

Fig. 4. Removal efficiency of plant 2 (Hassani Abdelkrim).

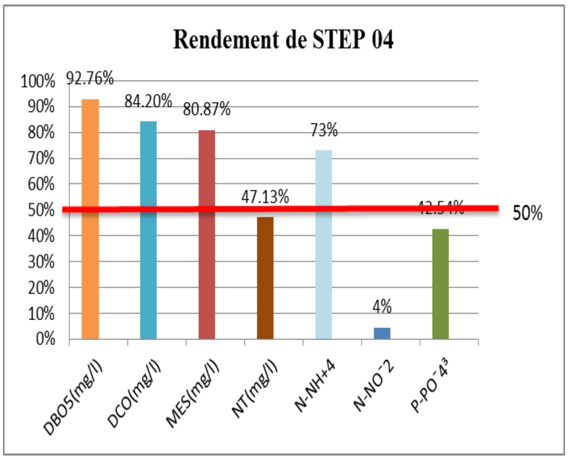

Fig. 5. Removal efficiency of plant 4 (Reguiba).

Conclusion

The results that we found, concerning domestic wastewater treatment of the El Oued city by aerated lagoon extensive processes at the Reguiba and the Hassani Abdelkrim plants allowed us to determine the physicochemical and biological properties of raw wastewater and treated water on the one hand, and to check the treatment efficiency and the suitability of the two plants for an arid area on the other hand. The results obtained for the physicochemical and organic parameters of the raw wastewater and treated water of the two investigated plants, and for the same period (January, February and March 2017) show more or less high concentrations (Interministerial Order, 2012).

The removal efficiency of organic load is significant for the two plants and exceeds 50%, thus indicating that aerated lagoon system is well suited to an arid area. Generally, and on the basis of the results, we can say that the Reguiba plant is the most efficient with a removal efficiency greater than 80%, and that organic load present in water of the Hassani Abdelkrim plant is far from being of domestic origin (COD/BOD5>3). The contents of heavy metals existing at the plant 2 highlight the industrial origin of a part of water. In terms of efficiency, we can say that the two plants provide an adequate treatment and that most water discharged to receiving environment after treatment complies with WHO standards.

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