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Evaluation of the Wastewater Quality Improvement by The Channel Located Downstream Of Kossodo Lagoons In Ouagadougou

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Abstract: The quality of treated wastewater coming from the Wastewater Treatment Plant (WWTP) by lagoons in Ouagadougou is not conform to national standard for discharge or for reuse in agriculture. The present study on the natural purifying capacity of the channel downstream of the WWTP aims to test the hypothesis that the quality of treated water running off through the gutter can significantly be improved for gardening. Then, the analyzes were done according French standards. So, the results between the output and a distance of 3 km along the channel indicate alkaline pH values slightly variable. Regarding carbon pollution, the Chemical Oxygen Demand (COD) average decreases from 1280 to 720 mg /l, while the average levels of Suspended Solids (SS) decreases from 343 to 300 mg /l. The nutrient contents such as orthophosphate and ammonia decrease with averages ranging from 9.18 and 6.05 mg /l for the former and 12 to 3.35 mg /l for the second whiletheconcentrationofnitratepassfrom2.91to6.37mg/l. Concerning microbiological pollution, faecal coliforms level increases from 3800 CFU /100 ml to 11300 CFU / 100 ml. In sum, there is a small auto scrubber power affected by factors as such as infiltration, high evaporation and anthropogenic activities near the channel.
Keywords: self-purification, channel, garden, pollution, nitrate.

• INTRODUCTION

According to the United Nations Environment Program (UNEP) report, by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity. Two-thirds of the world population could be living under water-stressed conditions. In Africa that will concern 25 countries [1]. In these conditions, the domestic or industrial wastewater are often reused in various activities. In most developing countries, the farming in city allows the urban supply of perishable leafy vegetables. The challenge is to ensure a food safety in a context of reuse of treated water in irrigation. This kind of water often presents high level of pollution [2]. It is estimated that about 10 per cent of the world population relies on food produced with contaminated wastewater [3]. Then wastewater reuse in agriculture can affect the health of users, consumers and it can be a source of the environment pollution if safe practices are not applied.

In Burkina Faso, sanitation and wastewater treatment are a luxury. The first treatment plant is operational since January 2004. Tis natural lagoons is situated in the industrial area of Kossodo and it receives domestic and industrial wastewater from the city. The treated water which is supposed to be without major risks for human health and environment is reused in gardening. A gardening site was built downstream of the WWTP on several hectares. The treated water is conducted by ditches to the agriculture area, and the excess of water runs off through a natural outlet towards the Massili River, located near Ouagadougou.

Today, most of the gardeners are abandoned the site and some of them have built new garden site located a little further (three or four km from the lagoon) along the channel, at Ana –Yélé. The gardeners still present near the lagoon produce only spinach, which are resistant to extreme salinity. So the present study interested to understand the environmental problem posed by effluent from the station.

The objective of this work is to study the self-purifying capacity of the soil downstream of the wastewater treatment plant of Kossodo, that can explain the new location of gardeners. Specifically, it aims to determine the physic, chemical and microbiological characteristics of treated wastewater at various points along the channel for the comparison purpose.

• MATERIAL AND METHODS

Description of Wastewater treatment plan (WWTP)

The fig. 1 shows a drawing of the WWTP of Kossodo. Note that the red part is not yet functional. These lagoons can receive 10.000 m^3/day of wastewater. It covers 20 hectares, and it is implemented since January 2004, with three levels of treatment including 3 kinds of ponds in serial. Three anaerobic ponds (in parallel), two facultative ponds (in parallel) and 3 maturation ponds (in serial). In the downstream of the WWTP, gardens were developed for reuse of treated water.

The Water and Sanitation National Office (ONEA) ensure the management of the WWTP and it ensure also the monitoring of the water quality and the condition of its reuse by the gardeners in respect of production measurements on the site.

Figure 1: The drawn map of the station (source: ONEA)

Methods of analysis

The samples were taken along the channel at 3 sites A, B and C each Monday during two months. The sampling sites are distributed as follows:

A: the exit of wastewater treatment plan (Fig. 2);

B: the exit of first gardening site arranged in the downstream of the station, 1000 m far from the exit of the WWTP;

C: upstream of the second gardening site located at 2000 m of the site B

The physical and chemical parameters such as temperature, electrical conductivity, hydrogen potential (pH) and dissolved oxygen were measured immediately after sampling. Faecal coliforms (FC) are analyzed the same day. The other parameters like the Chemical Oxygen Demand (COD), the Biochemical Oxygen Demand (BOD_5) or nitrates were analyzed during the following days, after the samples storing in a refrigerator at a temperature below 4 °C.

The Table 1 below provides the parameters and analytical methods used in this study. The fig. 2 and fig. 3 concern physical and chemical parameters measurement instruments *in situ* and in the laboratory.

Table 1: Methods used for analysis

Parameter	Units	Méthods
PH		AFNOR 90-008
Temperature	°C	AFNOR 90-008
Electrical Conductivity	µS/cm	AFNOR 90-008
COD	mg O_2/l	HACH DR/2400
Dissolved Oxygen	mg /l	AFNOR 90-008
BOD_5	mg O_2/l	OXYTOP/NF EN1899-2.
FC	UFC/100ml	By spreading on specific agar Chromocult for CF
Ammonium	mg /l	Photometer (Palintest)
Nitrate	mg /l	Photometer (Palintest)
Nitrite	mg/l	Photometer (Palintest)
Orthophosphate	mg/l	Photometer (Palintest)

Figure 2: Treated wastewater in the channel

Figure 3: Multimeter for physical measurement   Figure 4 : Photometer for Pollution measurement

• RESULTS AND DISCUSSION

Results

Table 2 provides a summary of the average of analyzes results of the treated water at different points in the channel during the period of November to December.

Table 2: Average values of the parameters analyzed

Sites Parameters		A	B	C
Temperature	°C	26,30	25,45	25,55
pH		8,55	8,55	8,54
Dissolved Oxygen	mg/l	2,88	4,16	3,87
Electrical Conductivity	µS/cm	1516	1544	1628
Suspended Solid (SS)	mg/l	329	343,34	301
COD	mg/l	1280	800	720
BOD_5	mg/l	250	210	200
Orthophosphate	mg/l	9,18	5,50	6,05
Ammonium	mg/l	12	9,25	3,35
Nitrate	mg/l	2,91	5,05	6,37
Nitrite	mg/l	0,48	1,35	2,03
Faecal Coliforms	UFC/100ml	12000	10000	7000

Discussion

3.2.1 The physical and chemical parameters

3.2.1.1Temperature and hydrogen potential

The average temperature along the channel is 25.5 °C (fig. 5). The microorganisms which ensure the wastewater purification in natural aquatic conditions, well grow around 37 °C. Indeed, the temperature increasing would promote the phenomenon of self-purification and this could influence the speed of suspended solid matter sedimentation[4].

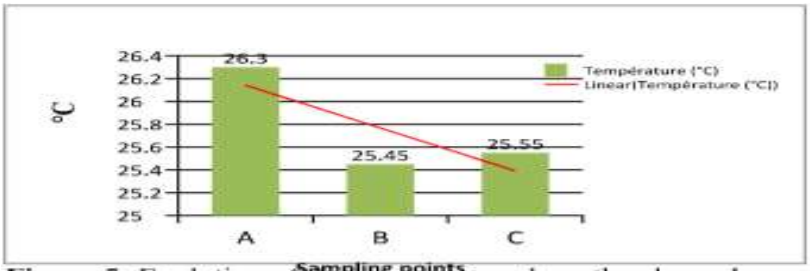

Figure 5: Evolution of the temperature along the channel

Along the channel the pH remains practically the same 8.54 and 8.55. Then, the treated water flowing in the channel is alkaline, but it is in accordance with the standard imposed by the national regulations concerning the discharge of wastewater in the nature, which is between 6.5 and 9.0. The pH has a big role in nutrient bioavailability and the activities of organisms living in the aquatic environment and in soil. In this case the alkaline pH may affect the bioavailability of nutrients and thus could be a limiting factor for good growth of bacteria in one part and it can affect the development of vegetables.

The alkalinity of the wastewater is due to the water generated by the brewery which provides major part of the effluent received by the lagoons. Indeed, this is all the more plausible than 2/3 of the water admitted to the WWTP come from a brewery whose activities generate waters rich in salts, sodium carbonate, calcium carbonate and magnesium carbonate because of the water softening and tank washing.

3.2.1.2 Conductivity

The average values of the conductivity recorded respectively for the three sites A, B and C are 1516, 1544 and 1628 µS /cm; they are relatively high and give an increasing curve (Fig. 6). These values still remain below the limit of 2700 µS/cm allowed by national standards about wastewater discharge into the natural environment. There is a strong overall mineralization, which increases the output of the WWTP to B and C. This trend to conductivity increased is related to reduction of the flows due to high evapotranspiration and water infiltration during the dry season. In addition, another factor that may contribute to this result is concerning the use of fertilizers on the garden sites. Indeed, the analyzes carried out in the rainy season (but far from a rainfall event) indicate a reverse trend; the conductivity decreases in the output of the WWTP to B and C l with a reduction up to 22% from the output to sampling point C.

Like the alkalinity, the high salinity of the effluent is due to the significant contribution of the brewery which produces the wastewater rich in minerals [5] [6]. The conductivity is an important parameter in the phenomenon of exchange by osmosis process that allows water to pass through the membranes that surround all living cells and which allows also the movement of water from lower concentration areas to the higher salt concentration areas. This high salinity could be toxic for crops [7]; a stress factor limits crops productivity due to the accumulation of certain ions, like Na^+. It may also be a degradation factor of the soil by increasing of sodium absorption ratio (SAR) [8].

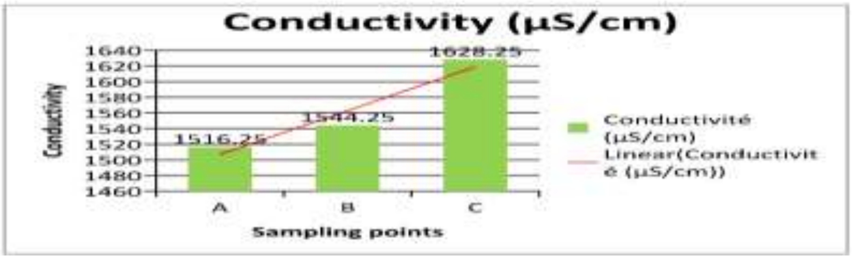

Figure 6: Evolution of the electrical conductivity

3.2.1.3 Dissolved oxygen

Dissolved oxygen quantities measured along the channel provided a relatively good amount at the exit of the station with the value of 2.88 mg /l on site A. Moreover, dissolved oxygen level at site B reached 4.16 mg /l and 3.87 mg /l at site C (Fig. 7). Only the amount of dissolved oxygen measured at the exit of the station is less than saturation level. Overall results reflect an acceptable oxygenation condition of the water along the gutter. This oxygenation is due to aeration which allows the atmospheric oxygen to dissolve in the water along the channel. The low oxygen content at the exit of the WWTP could be explained by the fact that the oxygen demand is high due to the activity of algae and bacteria in the lagoons [9]. The water discharged on the channel still needs a complementary treatment to conform it to national standards.

The good oxygenation of the water in the channel is a favorable factor for a good plant growth and for the microorganisms' activities that will make available the nutrients (nitrate, orthophosphate) for the vegetables.

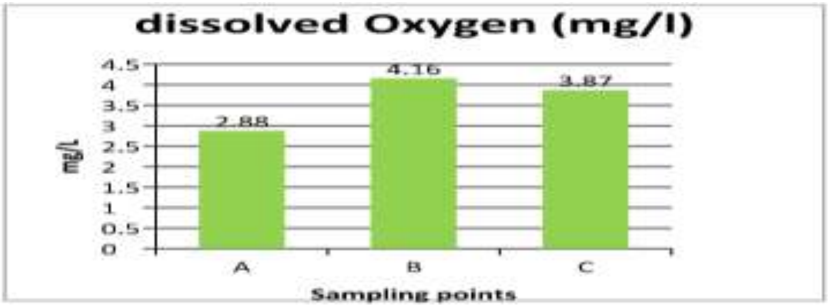

Figure 7: Evolution of dissolved oxygen

3.2.2. Organic pollution

3.2.2.1 Chemical Oxygen Demand (COD)

The national standard level is 150 mg /l for effluents coming from treatment by lagoons. The values of the COD obtained in this study are well above it. The COD parameter informs about chemical oxidizable matter (biodegradable and non-biodegradable). The fig. 8 shows a decrease of COD values along the channel, due to the oxidation of pollutants and also due to the settling of suspended solids matter.

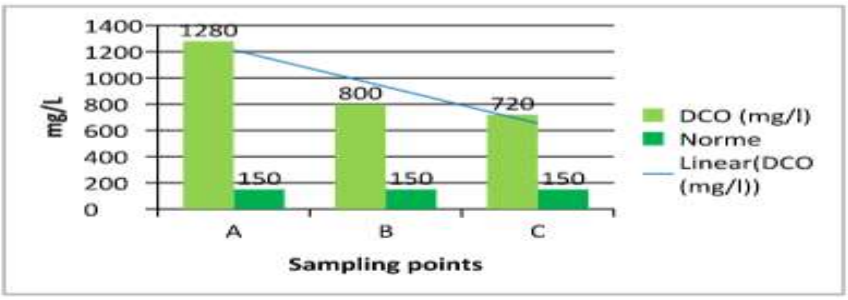

Figure 8: Evolution of COD in comparison with national standard

Biochemical Oxygen Demand (BOD) The different concentrations of BOD_5 measured during the study are decrease along the channel from A to C. But these values remain largely high compared to national standards which require less than 40 mg /l of O_2 for wastewater treated by lagoons process (Fig.9). The tendency of the curve shows that there is a slight removal of biodegradable organic matter all along the gutter. However, it is not enough to significantly reduce the residual organic biodegradable pollution. This low removal could be explained by the lack of purification bacteria even more so than in the lagoon process; the last shallow ponds ensure treated water disinfection before its discharge by removing bacteria due to the effects of sunshine UV rays. Moreover, it is also noted that the ratio COD / BOD_5 which is of the order of 5 indicates that the effluent discharged by the WWTP is not biodegradable. This confirms that the lagoons process has effectively eliminated the major part of the biodegradable pollutants [10].

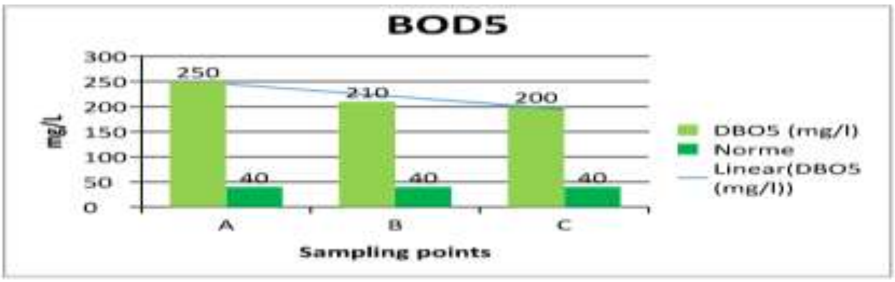

Figure 9: BOD_5 removal

Suspended solid removal

The Suspended Solid concentrations in the exit of WWTP are relatively high regarding the limit value allowed by the standard which is 150 mg /l for treated water coming from lagoons (fig.10). These high values are due to the presence of algae. In addition, the color of the effluent discharged during this period of year (November and December) was red like the fig. 2 illustrates it. The red water phenomenon observed is linked to the development of photosynthetic sulfur bacteria. These bacteria use the H_2S coming from the anaerobic process [11] for their growth. This is a malfunction of the lagoons probably related to climatic conditions with lower temperatures. Then, at another moment of the year green algae are mainly developed. The levels of suspended solids vary a little along the channel, with a slight increase at site B, probably related to gardening activities. Overall, there is high value of SS along the channel. The lack of decantation in the channel reflects the importance of the water flow velocity in link with the narrowness of the channel. Suspended solids are responsible of the clogging phenomenon of the sol or of the infiltration materials. The high concentrations of suspended solids noted could be the cause of gardens infertility by soil degradation due to clogging. In this conditions the soil becomes very compact and this makes difficult the infiltration of water. To corroborate this result, Philippe Bertrand Enoannomo with his study called "Influence of suspended solids on land irrigated by treated wastewater" related a similar results [12]. Concerning the case of lagoons of Kossodo, it is because of algae in one part and in other part because of the garden activities on different sites along the channel.

Figure 10: Evolution of suspended solid

3.2.3. Nutrients

3.2.3.1 Orthophosphate

The fig. 11 shows the evolution of orthophosphate concentrations along the channel. It decreases progressively. However, the values remain relatively high compared to the national standard (5 mg/l). The considerable decrease observed at the site B may be due to good uptake of orthophosphate by living microscopic plant in the gutter. But the slight increase in C may be due to gardening activities on the new site.

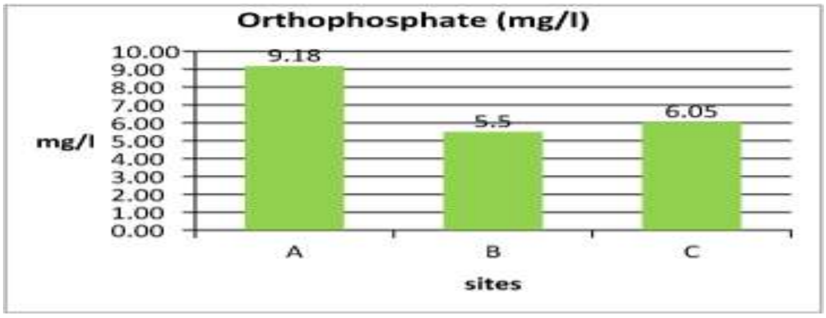

Figure 11: Evolution of orthophosphate concentration

3.2.3.2 Ammonia

The fig. 12 shows that the concentrations of ammonium ions decrease along the channel. However, very high concentrations were registered along the channel compared to the national standard which is 1 mg /l. The removal of ammonium along the channel is due to aerobic degradation processes. The concentrations of NH_4^+ at the exit of the station indicate that the treatment by the WWTP is not still sufficient to eliminate ammonium. The good elimination of ammonium along the channel is due certainly to the phenomenon of nitrification according to the balance equation (1). (1)

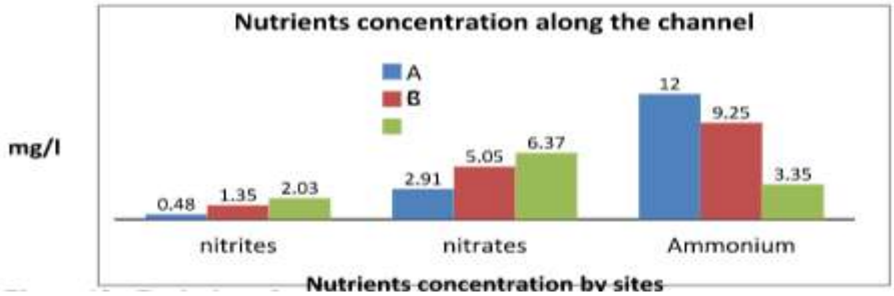

Figure 12: Evolution of nutrients

3.2.3.3 Nitrite

At the exit of the treatment plant, nitrate concentration is less than 1mg /l, which is the limit of standard about the discharges of wastewater in nature. But along the channel the concentrations increase progressively and become higher than the standard (Fig.12). The values obtained for nitrite provide an increasing curve. During the nitrogen cycle, the ammonium is firstly converted to nitrite and then nitrite to nitrate, by nitromonas and Nitrobacter bacteria. This stage of the cycle could explain the increase of the concentration of nitrites although they are a transitional stage between the ammonium and nitrate.

The high concentration of ammonium at the exit of the WWTP explains the high level of nitrification. It means that the channel environment is oxidizing. This is also the proof that the nitrification process is not completed within the lagoons. The nutrients and treated water can be used in gardening if essentials standards are observed.

3.2.3.4 The nitrate ions (NO_3)

The evolution of nitrate concentration presents as follows: an increase in the Site A to Site C and a decrease in site B at the outlet of the channel (Fig. 13). The Nitrate concentrations registered are lower than the national standards, but it increases. This trend to increasing of nitrate amount could be explained by the phenomenon of nitrification which transforms ammonium to nitrate thanks to bacteria in two steeps. (*Nitrosomonas* bacteria and the *Nitrobacters* bacteria, according to equation (2): (2)

At the exit of the station, the concentration of ammonium reaches 12 mg /l. The ammonium is transformed to nitrate according the equation (2) above; that is why when the amount of ammonium decreases, the amount of nitrate increases (fig. 13). In adapted conditions, the nitrate can be converted to nitrogen gas (N_2) by denitrification process due to the activities of *pseudomonas* bacteria according to equation (3), or it can be assimilated by plants and algae. **(3)**

Given the low nitrate concentrations observed along the channel, the treated water discharged by the lagoons don't present at major risk of eutrophication actually.

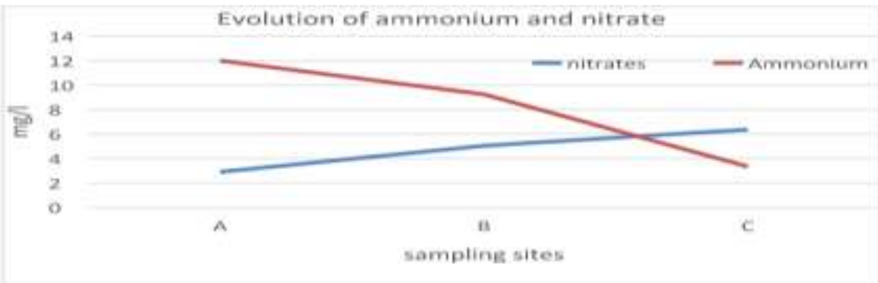

Figure 13: Correlation between ammonium and nitrate

The fig. 13 shows a curve of decreasing of the ammonium concentrations and an increasing curve for concentrations of nitrate. Before site C the concentration of nitrate ions becomes higher than ammonium concentration.

The ammonia level in treated water discharged after WWTP mean it need a complementary treatment, to be conform with the standards. These values indicate a need to consider an improvement in water quality before discharge this by adding additional basins or a filtration process.

- **Pathogens**

There are several kinds of organisms in wastewater (bacteria, virus, parasites) and some of them can be the sources of diseases like cholera or typhoid fever. It is difficult to try to identify all of them and it is useful to check the presence of bacteria, indicator of fecal pollution like fecal coliform. Its level can indicate sanitary risk due to the reuse of treated water [13] [14].

The analyzes of water samples taken from the site A yielded high amounts of coliform bacteria in the waters of the exit of the station**.** However, these concentrations are higher at C, after a long flow in the channel (fig.14).The increased bacterial load could be explained by contamination due to the use of compost as a fertilizer in the plots but also by the proximity of dumps garbage used as a place of defecation of residents near the channel[13]. It may be due to the fact that the river serves as a drinking trough for animals with a high probability of depositing their excrement in this environment. In any case, there is a very important new contamination along the channel due to human activities.

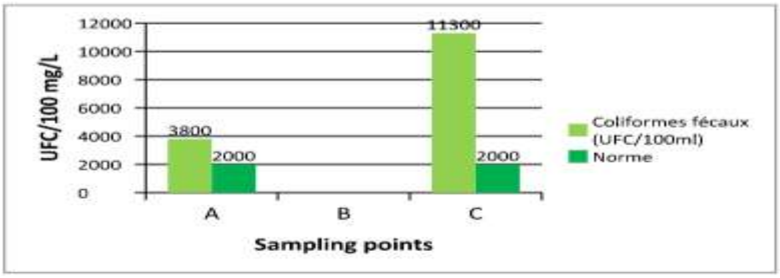

Figure 14: Evolution of faecal coliforms concentrations

• CONCLUSION

The characterization of treated water flowing into the channel revealed high concentrations of COD, BOD_5, MES, orthophosphate, ammonia, nitrite, faecal coliforms, and high values of conductivity at the exit of the station. This shows that the purification performance of the station is not sufficient regarding the national standards concerning wastewater discharge. The channel allowed a complementary treatment of water that improves his quality from exit to the second site of garden.es the quality of water; However, the self-purification does not allow to achieve the quality targets imposed by national standards concerning COD, BOD_5, ammonium, MES and CF. The pH and nitrate levels are conformed to national and international releases. The study also found a pretty good oxygenation of the water along the gutter. The low level of self-purification is due firstly to the high evaporation and infiltration that reduce the water flow. That increases different parameters level in effluent. It is also important to notice the pressure of human activities on the quality water resources, particularly concerning some parameters such as TSS and fecal coliforms, which presented a very significant increase. In conclusion, the channel has a natural purifying power, but that is affected by the surrounding human activities.

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