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# EFFECT OF POLYACRYLATE CONCENTRATION ON HOMOGENEOUS AND HETEROGENEOUS PRECIPITATION OF SCALE

**By Menzri Rayane, Ghizellaoui Samira* and Tlili Mohamed**

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## ABSTRACT

*Scaling is a common problem in domestic, commercial and industrial process where water is used. One of the most effective methods of controlling crystallization fouling is the addition of chemical inhibitors to potentially scaling waters. For reducing calcium carbonate scale formation different concentrations of polyacrylate (RPI2000) was added. The results show that this inhibitor is capable of inhibiting the formation of limestone deposit and inhibits the scale formed on the walls. Calcite growth rate is reduced and the inhibiting effect occurs at very low concentration. The precipitation ratio (τ) reached 0%, therefore a reduction of 24% compared to the raw water. This inhibitor extends the degassing phase. IR analyses demonstrated modifications in crystalline structure.*

Keywords:
Water, Inhibitor, Calcium carbonate, Polyacrylate, Calcite growth rate, IR.

## 1. INTRODUCTION

Several underground sources of water were exploited to satisfy the great need for fresh water. In the East of Algeria, the city of Constantine called for its water supply, the Hamma groundwater resource. The high content of hydrogen carbonate and calcium justify the very important scaling power; it contains 82 % by mass of these ions.

Scale deposit is a major concern in different facets of industrial processes and domestic installations. It can cause numerous technical and economic problems. According to S. N. Kazi (2012) [1], an additional cost is imposed by fouling of heat transfer equipment in industries (Table 1). Few studies have been undertaken to determine the fouling related costs in industry. Fouling costs can generally be divided into four major categories, such as: increased capital expenditure, energy costs, maintenance costs, cost of production loss and extra environmental management cost.

Various physical [2-3] and chemical methods [4-5] were used to prevent scaling. The physical methods were developed but the efficiency of these treatments is still a controversial question and it is not possible to get a clear explanation of the phenomenon. The most common and effective scale control method is the addition of small concentrations of inhibitors to the water [6-7-8-9].

In the present work, we investigated the effect of RIP2000 on the precipitation of $CaCO_3$ by the use of chemical anti-scaling method. The ratio between homogeneous and heterogeneous nucleation was determined. Formed scales were characterized by IR spectroscopy.

Table 1 Estimated fouling costs incurred in some countries.

| Country | Fouling costs US $ million | GNP (1984) US $ million | Fouling costs % of GNP |
|---|---|---|---|
| USA (1982) | 3860-7000<br>8000-10000 | 3634000 | 0.12-0.22<br>0.28-0.35 |
| Japan | 3062 | 1225000 | 0.25 |
| West Germany | 1533 | 613000 | 0.25 |
| UK (1978) | 700-930 | 285000 | 0.20-0.33 |
| Australia | 260 | 173000 | 0.15 |
| New Zealand | 35 | 23000 | 0.15 |
| Total Industrial World | 26850 | 13429000 | 0.20 |

## 2. MATERIALS AND METHODS

Calcium carbonate precipitation was provoked by degassing dissolved $CO_2$ by agitation. The RPI2000 was added at different concentrations in the solution at 30 °C, to optimize the effective concentration for the scaling prevention.

## 3. RESULTS AND DISCUSSION

### 3.1. $CO_2$ degasification by agitation

Figure 1 and Figure 2 show the changes of the homogeneous precipitation (%hm) and heterogeneous precipitation (%ht) for Hamma water without and with varying concentrations of RPI2000.

Such us:

-τ: the precipitation ratio. It was determined from the following equation:

$$\tau = \frac{TAC_0 - TAC_t}{TAC_0} * 100$$

Where: $TAC_0$ is the TAC at t = 0 min and $TAC_t$ is the TAC at the end of precipitation test.

-%hm: the percentage of the homogeneous precipitation.

-%ht: the percentage of the heterogeneous precipitation.

-$P_{CO2}$: $CO_2$ pressure in the solution.

Scale formation can occur through homogeneous and heterogeneous nucleation mechanisms.

We observe that the heterogeneous precipitation decreases and the homogeneous precipitation increases. We can conclude that 0.6 mg/L of RPI2000 is capable of inhibiting the formation of germs of calcium carbonate and inhibits the scale formed on the walls. Calcium carbonate forms in the bulk of solution instead of the walls.

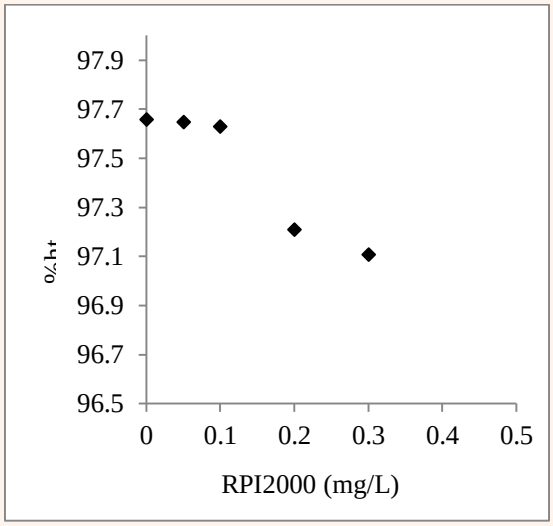


Figure 1: Variation of the %ht versus RPI2000 concentrations.

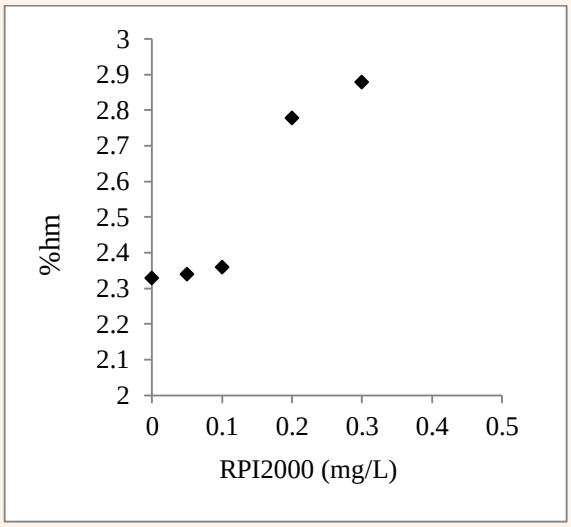


Figure 2: Variation of the %hm versus RPI2000 concentrations.

The crystalline growth rate was strongly affected. It decreases by ~14% in the presence of 0.6 mg/L of RPI2000 (Fig. 3).

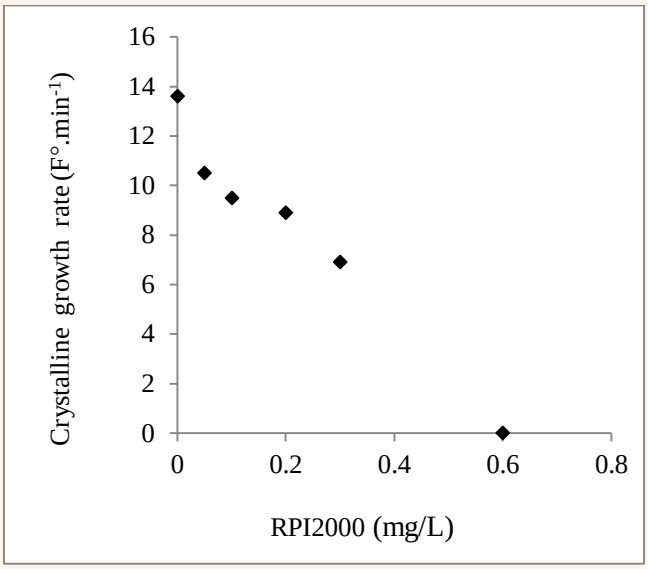


Figure 3: Variation of the crystalline growth rate versus RPI2000 concentrations.

The precipitation ratio (τ) reached 0%, therefore a reduction of 24% compared to the raw water (Fig. 4).

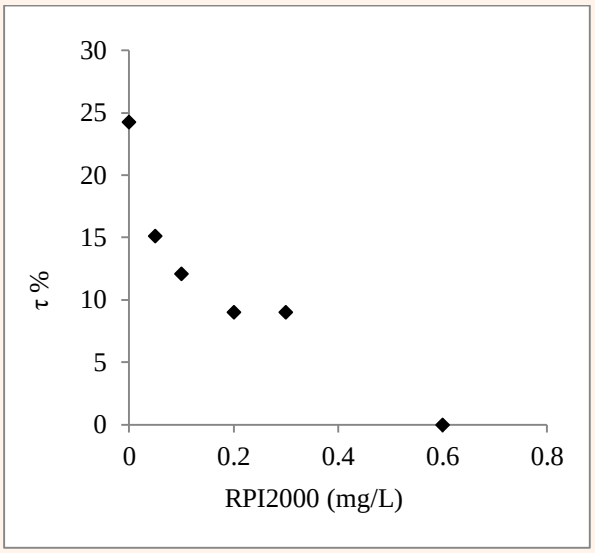


Figure 4: Variation of the precipitation ratio versus RPI2000 concentrations.

Figure 5 shows the $P_{CO2}$ variation as function of the added RPI2000 quantity at 30 °C. This inhibitor extends the degassing phase which retards the germination of $CaCO_3$ crystals.

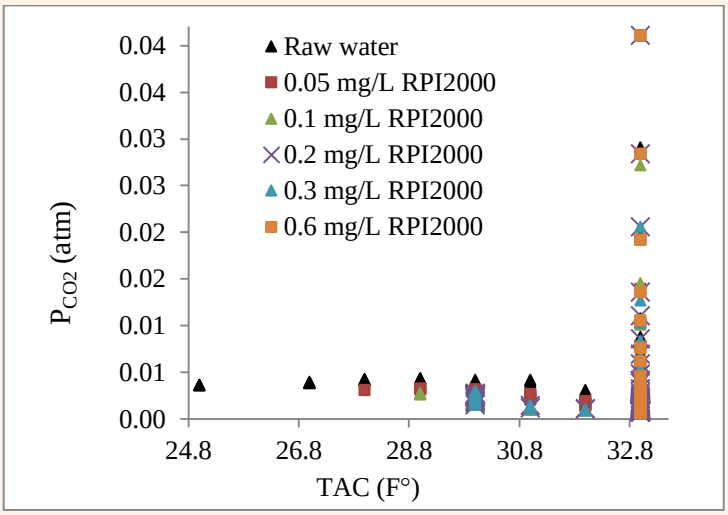


Figure 5: $P_{CO2}$ variation as function of the added RPI2000 quantity at 30 °C.

### 3.2. Interpretation of FTIR data

The Fourier transformed infrared (FTIR) spectrum of precipitated scale products in absence and presence of inhibitor is shown in Figure 6. For raw water, simultaneous occurrence of peaks at 711, 871 and 1417 $cm^{-1}$ confirmed the presence of calcite as was the most predominant crystalline form. The appearance of peaks at 850, 1082 and 1803 $cm^{-1}$ shows the presence of a small amount of magnesian calcite and aragonite.

For treated water, the appearance of new peaks were observed at 1160 and 1159 $cm^{-1}$ confirmed the presence of carbonate monohydrate, thus new peaks at 1533 and 1535 $cm^{-1}$ indicate the increase of aragonite. These values are compared with the data published by Eva Loste et al. [10] and Gopi et al. [11].

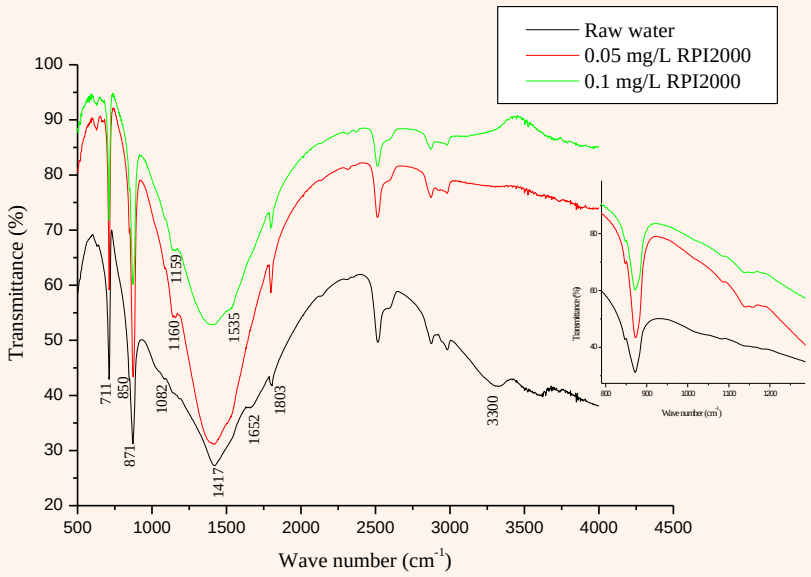


Figure 6: FTIR spectra of precipitated scale products in absence and presence of 0.05 mg/L and 0.1 mg/L of RPI2000

## 4. CONCLUSION

For reducing calcium carbonate scale formation different concentrations of polyacrylate (RPI2000) was added. The results show that this inhibitor is capable of inhibiting the formation of limestone deposit and inhibits the scale formed on the walls. The inhibiting effect occurs at very low concentration. The Fourier transformed infrared (FTIR) spectra of precipitated scale demonstrated modifications in crystalline structure.

## REFERENCES


1. S. N. Kazi (2012). Fouling and Fouling Mitigation on Heat Exchanger Surfaces, Heat Exchangers – Basics Design Applications, ISBN: 978-953-51-0278-6, InTech, Available from: http://www.intechopen.com/books/heat-exchangers-basics-design-applications/heat-exchanger-fouling-and-itsmitigation

2. F. Alimi, M. Tlili, C. Gabrielli, G. Maurin, M. Ben Amor (2006). Effect of a magnetic water treatment on homogeneous and heterogeneous precipitation of calcium carbonate. *Water Research*, 40, 1941-1950.

3. F. Alimi, M. Tlili, M. Ben Amor, G. Maurin, C. Gabrielli (2009). Influence of magnetic field on calcium carbonate precipitation in the presence of foreign ions. *Surface Engineering and Applied Electrochemistry*, 45 (1), 56-62.

4. G. Gauthier, Y. Chao, O. Horner, O. Alos-Ramos, F. Hui, J. Lédion, H. Perrot (2012). Application of the fast controlled precipitation method to assess the scale forming ability of raw river waters. *Desalination*, 299, 89-95.

5. D. Liu, W. Dong, F. Li, F. Hui, J. Lédion (2012). Comparative performance of polyepoxysuccinic acid and polyaspartic acid on scaling inhibition by static and rapid controlled precipitation methods. *Desalination*, 304, 1-10.

6. HY. Li, W. Ma, L. Wang, R. Liu, LS. Wei, Q. Wang (2006). Inhibition of calcium and magnesium-containing scale by a new antiscalant polymer in laboratory tests and a field trial. *Desalination*, 196, 237-247.

7. I. Atamanenko, A. Kryvoruchko, L. Yurlova, E. Tsapiuk (2002). Study of the $CaSO_4$ deposits in the presence of scale inhibitors. *Desalination*, 147, 257-262.

8. S. Ghizellaoui (2012). Partial elimination of the water hardness by using (lime, soda and sodium carbonate): representation of calcocarbonic balance curves. *Eur. j. water qual*, 43, 117-132.

9. R. Menzri, S. Ghizellaoui (2012). Chronoamperometry study of the inhibition of groundwater scaling deposits in Fourchi. *Energy Procedia*, 18, 1523-1532.

10. L. Eva, M.W. Rory, S. Ram, C.M. Fiona (2003). The role of magnesium in stabilising amorphous calcium carbonate and controlling calcite morphologies. *Journal of Crystal Growth*, 254, 206-218.

11. S.P. Gopi, V.K. Subramanian, K. Palanisamy (2013). Aragonite-calcite-vaterite: a temperature influenced sequential polymorphic transformation of $CaCO_3$ in the presence of DTPA. *Materials Research Bulletin*, 48, 1906-1912.

# CONTRIBUTION TO THE STUDY OF WATER TREATMENT BY ALGUE CHLORELLA PYRENOIDOSA

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## Abstract

The algue, photosynthetic microorganisms very widely used in various applications, one of which is the treatment of the waters. This work is to study the absorption of some elements by the Algue Chlorella Pyrenoidosa in the presence of heavy metals Cd, Pb, and Cr, in the purpose of the exploit for the treatment of the waters. The results allow to know how to include the Algue Chlorella Pyrenoidosa toward the toxic substances that may be found in their environment. And therefore the ability to be used in the field of water treatment. The results show us that the studied algue can be grown in media containing the one of these metals, toxic with a reduction of growth, as well as the presence of these metals to a negative effect on the absorption of phosphate and sulfate.

**Key words:** Absorption, Algue, Chlorella Pyrenoidosa, Growth, Water treatment

## 1. INTRODUCTION

The industrialization has led to an increase in the pollution of ecosystems by metal pollutants that can enter the food chain [01], The soils used for the production of food crops suffers from a decrease in productivity in areas polluted by toxic metals [02] and therefore, the accumulation of toxic metals such as Hg, Cd, Cr, and Zn by the man causes the growth and development of several anomalies [01].

The conventional technologies applied to eliminate heavy metals in particular to low concentrations are ineffective and / or expensive *[01].*To this effect, the development of' other more effective methods has become a necessity.

However, the treatment of wastewater is a very important process for human life. However, the treatment of wastewater is carried out not only to protect the health of the population and to

avoid contagious diseases, but also to protect the environment. Has the present, this last goal becomes more and more important and the techniques of treatment and purification stations are constantly evolving. The usual treatments have been supplemented by treatments that aim to eliminate the more possible of substances harmful to ecosystems *[03]*.

The alarming growth of pollution of waters by various materials, organic or not: pesticides, detergents, heavy metals and other toxic substances, represents a real danger to the flora and the aquatic fauna and cause serious problems for humanity *[04]*.

The analysis of the quality of the water is at the forefront of many interventions in the areas of environmental risk assessment or health. These concerns are reflected by an increase in the analytical needs and increasingly strict standards, particularly toward industrial discharges and urban areas in aquatic environments *[05]*. The algue are able to take the toxic heavy metals containing in the environment *[06] [07]*. They are used for the treatment of wastewater, however, some algue are able to absorb the ions of heavy metals such as zinc and cadmium of polluted waters *[08]*, In effect, the algue such as Chlorella, Scenedesmus and Spirulina are the most widely used for the elimination of nutrients *[01]*.

One of the most important properties of the Chlorella is its detoxifying force. It is scientifically proven that its cell wall has the remarkable ability to bind to toxins and eliminate the body. In addition the Chlorella purifies the body of heavy metals and radioactive elements. Thanks to this property, it had been used after the Second World War in Japan for recovery of the radioactive pollution *[09]*.

The ultimate goal of this study is to show the importance of algue in the field of treatment of waters; however, we will chose the Algue Chlorella Pyrenoidosa, in the main objective is to provide a solution to double benefits and who responds both to the two challenges majors: the protection of the environment by pollution control and the exploitation of the biomass of produced algue that biofuel, which contributes to energy security. In this article, we present the study of the effect of culture medium enriched by heavy metals on the growth of Algue Chlorella Pyrenoidosa and on the absorption of some elements of the culture medium by this algue.

## 2. MATERIALS AND METHODS

### 2.1. Method of culture

Cultures of *Chlorella Pyrenoidosa* continuously have been carried out in four systems of culture noted from T1 to T4, the culture medium used is that of Bold 1967 amended to 8.9 pH, the first is chosen as a reference, while the other systems (T2, T3 and T4) are enriched by the Cd, Pb, and Cr respectively at a concentration of 0.6 µg /L.

The cultures are exposed to an artificial light provided by four neon lamps and under a temperature of 25± 2°C. The aeration and agitation are insured by an arrival of air in continuing.

### 2.2. Analysis

The concentration in cells of a suspension is determined by measuring the absorbance at 680 nm of this last in use a UV spectrophotometer.

The samples are performed in the morning in bottles sterilized 100 ml, and are then passed through a centrifugation step in order to filter the culture medium for the various analyzes, note that the samples are stored after the adding 0.5 ml of the nitric acid

## 3. RESULTS AND DISCUSSIONS

### 3.1. Growth of *Chlorella Pyrenoidosa* seaweed

The figure 1, presents the evolution of biomass of Algue Chlorella Pyrenoidosa Hcultivated in the different systems of study, whose reference is the one T1:

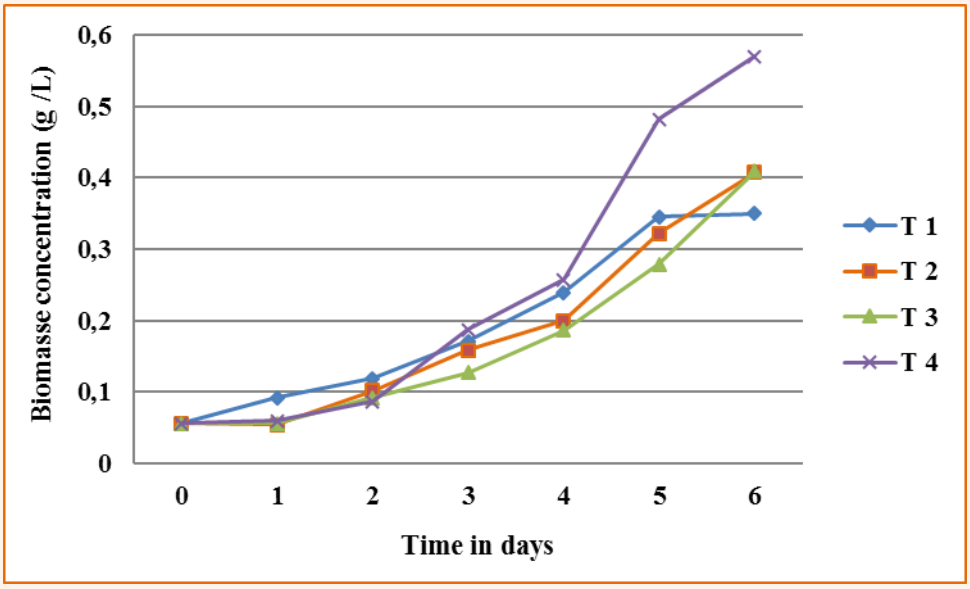


**Figure 1:** Evolution of biomass in cropping systems.

The analysis of the results of the figure 1 tells us that the pace of the graph is the same for all systems of cultures, with a low gap between all systems of T1 system until the T4 system.

It is very remarkable that, all the cultures of the systems go through a phase of adaptation during the first two days, then the growth of algue increases (exponential phase). However, the growth reached their maximum value during the 6th day for all systems, the greater value is recorded for the system T4, it is of the order of: 0.569 g/L. While the lowest value is recorded for the system T3, it is of the order of 0.2786 g/L. On the other hand, note that the T1 system between

in the stationary phase, from 6th days, whereas the growths in the systems: T2 and T3 remains to increase, during the 7th day, for the system 4 between in the stationary phase from days 7.

The analysis of these results, we show that the growth of the Algue Chlorella Pyrenoidosa is influenced by the different parameters dependent on the culture medium (presence of heavy metals). In which the study of the effect of the presence of heavy metals, it was made of the tests in the presence of three metals Cd, Pb, and Cr. According to the graphs in figure 1. We note that the presence of these metals generates a prolongation of the lag phase of the growth of the algue studied. However, it is observed that, overall for all three metals yields are lower than in test 1 that is chosen as the reference, for the first six days of the experience and vice versa during the 7th Days in Note that the enriched environments provides higher yield in biomass.

As regards the environment enriched by the leaded, allows for the growth of the strains grown 0.4088 g/L less than that enriched with chromium 0.5698 g/L, note that for the leaded (Figure 1) We note that it causes a remarkable reduction of the growth of the micoralgue *Chlorella pyrenoidosa* during the first six days of the experience, which in accordance with the results of Sindy Gagneux-Moreaux *[10]*, for cadmium, their presence in the culture medium creates a difficulty in the growth of strains, which complies with the results obtained by brand and all *[11];* Morelli and Scarano *[12]*, which have shown that the presence of cadmium causes the reduction of the rate of growth of algal populations, something which is noticed in our case during the first two days of culture. While, the superior performance to that of reference obtained between the 4th and 7th days of culture may be due to the increase in photosynthesis, which conform to the results of Thompson and Couture *[13]*.

**3. 2. Phosphate**

The concentrations in phosphates remained in the culture media for the systems studied are presented in the following figure:

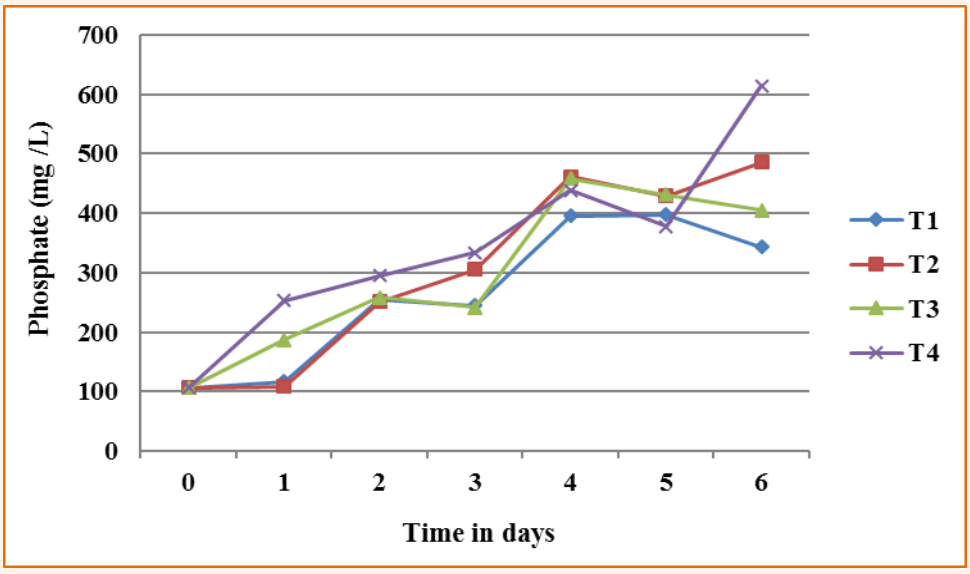


**Figure 2:** Variation of the concentration of phosphates in the culture medium

The analysis of the results of the figure 2, we note that the quantities of phosphate recorded in the days of experience in the systems of reference are weaker than those of other systems enriched with heavy metals, one finds that the presence of the heavy metals Cd, Pb and Cr to a negative effect on the growth of the Algue Chlorella Pyrenoidosa, However, these metals create a remarkable reduction of the consumption of phosphate by the algue studied. As well, that it is observed that the Cr is the more toxic for the Algue Chlorella Pyrenoidosa that the Cd and Pb, this last one is the least toxic.

### 3. 3. Sulfates

The concentrations in sulfates remained in the culture media for the systems studied are presented in the following figure:

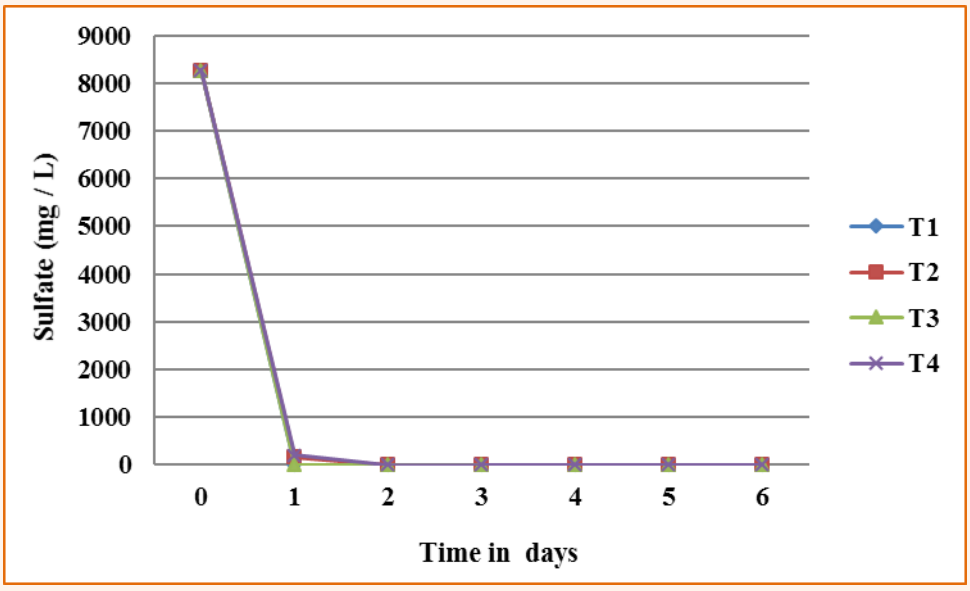

**Figure 3:** Variations in the concentration of sulfate in the culture medium

The analysis of the figure 2, shows us that there is a symmetry of the allure of the curves for all systems of culture, at the beginning of experience (Day 0) the concentration of sulfate is 8280 mg/L which presents a percentage of 100%, as soon as the first day of experience the strains of algue (*Chlorella*) grown to systems T1 and T3 have consumed the full (100%) of sulfate of culture medium. While the strains of other systems T2 and T4 have consumed: 98.06% and 97.58%, respectively, and then note the total consumption of sulfate from the second day. Of these results, it is concluded that the strains of *Chlorella* grow in the rich environments by the sulfate, as well as this consumption depends on the other culture conditions such as the presence of heavy metals, virtually a decrease in the consumption of sulfate is obtained in the case of system 4 in which the culture medium is enriched by Cr.

## 4. CONCLUSION

After this study, we have shown that the use of the Algue Chlorella Pyrenoidosa allows gradually absorb the existing elements in the water in the presence of toxic metals, this growth is variable from one medium to another, according to the metal in this medium, Note that these metals are harmful to human health and the environment, we can therefore consider that the treatment of the water by the algue is a modern method and easy, and the least expensive in this area, for it can be applied as an alternative for most machines and chemical products.

## REFERENCES


*01*. Seema Dwivedi, Bioremediation of Heavy Metal by Algue: Current and Future Perspective, *Journal of Advanced Laboratory Research in Biology*, Volume III, Issue III, July 2012, ISSN 0976-7614

*02*. Gosavi, K., Sammut, J., Gifford, S. and Jankowski, J., 2004. Macroalgal bio-monitors of trace metal contamination in acid sulfate soil aquaculture ponds. Sci. Total Environ., 324: 25-39.

*03. Solne MOULIN, David ROZEN-RECHELS, Milena STANKOVIC, Traitement des eaux uses, 2012-2013, p09*

04. *BELAHMADI Mohamed Seddik Oussama, Etude de la biodégradation du 2,4-*dichlorophénol par le microbiote des effluents dentrée et de sortie de la station d'épuration des eaux usées d*'ibn* Ziad ,16/01/2011, p 10

*05*. José Carlos DIAZ ROSADO, Étude et développement de la spectroscopie d'émission optique sur plasma induit par laser pour la réalisation d'analyses de terrain : application à l'analyse en ligne de métaux dans les liquides, 2012 – 2013, p 13

*06*. Megharaj M, Avudainayagam S, Naidu R, 2003 Toxicity of hexavalent chromium and its reduction by bacteria isolated from soil contaminated with tannery waste. Curr Microbiol 47:51-54.

*07*. Shamsuddoha A S M, Bulbul, A & IMAMUL HUQ S M. 2006. Accumulation of arsenic in green algue and its subse-quent transfer to the soil–plant system, Bangladesh J. Micro-biol., 22 (2): 148–151.

*08. http://www.fao.org/docrep/007/y5600f/y5600f07.htm, Situation mondiale des pêches et de l'aquaculture, consulter le : 16/05/2016*

*09. http://www.traitementdeseaux.fr/, le traitement des eaux, consulter le : 05/02/2016*

*10*. Sindy Gagneux-Moreaux, " Les métaux (Cd, Cu, Pb et Zn) dans la production des microalgues sur différents milieux de culture : biodisponibilité, bioaccumulation et impact physiologique", Thèse de doctorat, école doctorale chimie-biologie, 2006, PP. 27, 28, 29 et 31.

*11*. Brand L. E., Sunda W. G., Guillard R. R. L., 1986. Reduction of marine phytoplankton reproduction rates by copper and cadmium. *Journal of Experimental Marine Biology and Ecology,* 96, 225-250.

*12*. Morelli E., Scarano G., 2001. Synthesis and stability of phytochelatins induced by cadmium and lead in the marine diatom *Phaeodactylum tricornutum*. *Marine Environmental Research,*52, 383-395.

*13*. Thompson P.-A., Couture P., 1991. Short- and long-term changes in growth and biochemical composition of *Selenastrum capricornutum* populations exposed to cadmium. *Aquatic Toxicology,* 21, 135-144.

# FLOODS IN THE ARID ZONE: CASE OF WADI DEFFA'S BASIN IN SOUTH-WESTERN ALGERIA

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## Abstract

Rainfall events recorded in the last decade in arid areas have created deadly torrential floods. Climate change combined with entropy actions has increased surface runoff, causing considerable human and material damages. The arid areas Characterizing southern Algeria have few hydrometric information to quantify the phenomenon. It is in this specific context, based on sparse information we will approach the phenomenon by a suitable modeling. This work is used to quantify the flooding hazard by the hydrological approach modeling through the case of the wadi Deffa watershed that splits the town of El Bayadh by pressing the construction of intensity-duration-frequency curves. In the lack of flow data the modeling IDF curves was made for two groups of data: the annual maximum series (AMS) and partial duration series (PDS). After calculating the probability given rain and study the morphological properties of the basin, the transformation of the runoff at the outlet of the watershed goes through two levels. The first is the runoff production and the second is the transfer of this runoff through the basin, the lack of hydrometric measurements (real flows) necessary to look for models require no calibration, the SCS-CN model is retained for the production function and the SCS Unit hydrograph model, Clark Unit hydrograph for the transfer function. The second estimate is made by the method of synthetic hydrograph also called isochronous method. . The second allows the construction hydrographs flood of different frequencies. Its application requires three important parameters called climate exponent from a study of short duration rainfall, the maximum daily rainfall and flow deficit.

**Keywords:** floods, Watershed, wadi Deffa, IDF curves, rainfall-runoff modeling, SCS-CN, SCS Unit hydrograph, Clark Unit hydrograph, method of synthetic hydrograph.

# 1. INTRODUCTION

Floods are among the natural disasters that cause material loss and damage in the world. They are the best distributed risk in the planet. Moreover, their high frequency in some regions of the world, their dependence on climate change and the ever-increasing demographic pressure on the watercourses banks make these events more and more worrying and difficult to manage.

Several research axes have been developed in order to estimate streams flow, with the aim of quantifying this resource starting from its original origin: rain, until reaching the flow of a water course, water.

The present work is part of the modeling of rain transformation in flow, in arid zones, and in the absence of gauges.

We felt it necessary to introduce, through this study, different steps to answer properly the problematic of the outlet flow determination.

First, we will give a bibliographic overview on Intensity-Duration-Frequency (FDI) curves and finally a generality on hydrological modeling and their applications in arid zones, then a statistical study of the extreme rain events with the aim of elaboration the Intensity-Duration-Frequency (IDF) curves. Finally, we begin the hydrological modeling where we present the two methods used: the HEC-HMS model [1], and the isochrones method [5]**.** Finalized by an interpretation and discussion of the results obtained.

# 2. BIBLIOGRAPHICAL STUDY

Taking into account the analyzed models and the current state of available data, our choice is based on a hydrological model that deals with the flow modeling in arid and semi-arid regions. This is the HEC-HMS hydrological model [3].

Synthetic hydrograph method also called the isochrones method was taken to be able to compare the results and reach the goal by the most correct path. Our choice to simulate the basin behavior with these methods is justified by several criteria.

# 3. STATISTICAL STUDY OF EXTREME RAINFALL EVENTS

## 3.1. Modeling curves Intensity-Duration-Frequency

The determination of the IDF curves and their modeling are made for the series (ASM and PDS);

### 3.1.1. Study of (ASM)

The distribution function adopted for the calculation of the quantiles of the AMS series is the distribution according to the laws: Normal, Log Normal, GEV, exponential law and Gumbel. The quantiles are calculated for the return periods: 10,50, 100 years. Thus, the adequacy of these laws was verified by the Pearson test ($\chi^2$) for a significance level of 95%. [2]. The best fit was given by the Normal law.

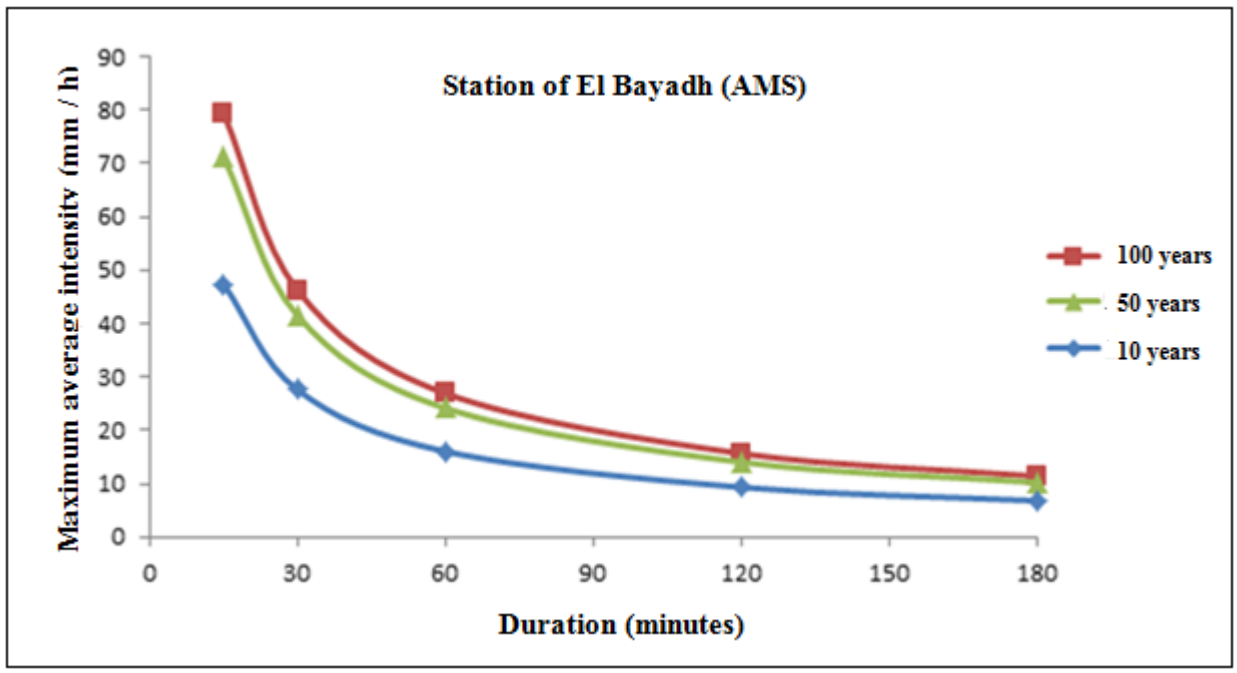


Fig.1. Curves Intensity- Duration- Frequency.

### 3.1.2. Study of (PDS)

#### a. Selection of threshold

For this study, several annual overruns average numbers are taken equal or more than 1.65, starting with $\lambda = 1.65$ [2], are retained, thus $\lambda = 2$. [6]. Other numbers of annual overruns will be considered, $\lambda = 3.5$[4], and $\lambda = 6$ [2];

Another threshold was chosen based on the series observation mean intensity $I_{moy}$ of the different storm events on all aggregation durations. The threshold was set at 5 mm / h.

As a result, 5 PDS were formed. The final choice of the PDS will be in function of its independence. The selected SDP must be the most adequate of the underlying probability distribution function.

### b. Study of independence of (PDS)

The simplest and most immediate way of assessing the independence of a series, adopted in many statistical hydrological literature, is to verify the autocorrelation function, for this study Spearman's nonparametric test was selected;

After verifying the independence of the 3 PDS with the annual overrun numbers ($\lambda = 1.65$, $\lambda = 2$ and $\lambda = 3.5$), the PDS retained must be the one that will better fit the probability distribution function (for All aggregation durations).

Multiple Cumulative Distribution Functions (CDFs) adopted for the calculation of the quantiles corresponding to the return periods: 10, 50, 100 years are: Normal, Log Normal, GEV, exponential law and Gumbel.

By applying the Pearson test ($\chi^2$), it appears that the normal Log law better adjusts the 3 series with the exception for the SDP ($\lambda = 1.65$) for the aggregation duration of 60 min and the SDP ($\lambda = 2$ ) For the aggregation time of 180 min, this means that the SDP ($\lambda = 1.65$ and $\lambda = 2$) adjustment to the normal Log has been rejected, and SDP ($\lambda = 3.5$) Although the Pearson test ($\chi^2$) is verified for a significance level of 95% for all aggregation durations. In conclusion, we can say that the partial time series that suits the construction of the IDF curves for the El Bayadh station is that of ($\lambda = 3.5$).

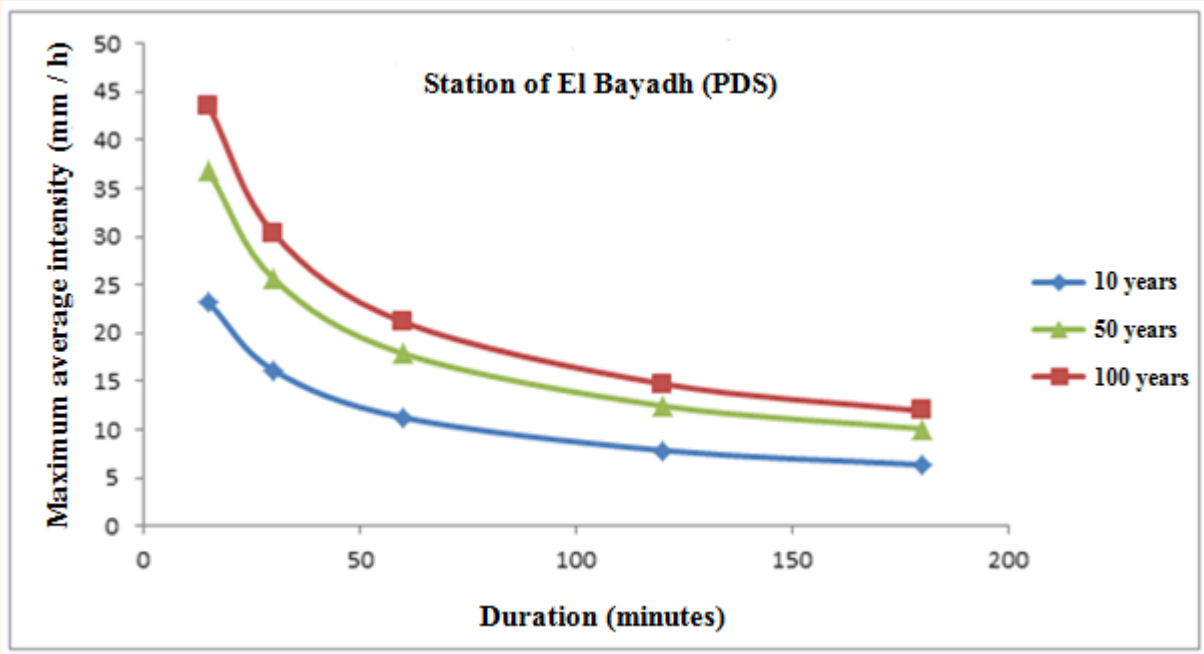


Fig.2. Curves Intensity- Duration- Frequency.

The mathematical modeling of the IDF curve made it possible to determine the climatic exponent of this station (b) by looking for a regressive model between the maximum mean intensity and the duration of the reference interval Δt (hours). The results obtained are summarized in Table I.

**Table 1.** IDF Models for Different Return Periods.

| Size of the series N=11, $R^2$=0.98 | |
|---|---|
| Return period (ans) | Model $i=a*t^{-b}$ ,t(min) i(mm/h) |
| 10 | $94.8\ t^{-0.52}$ |
| 50 | $150.47t^{-0.52}$ |
| 100 | $178.01\ t^{-0.52}$ |

### 3.2 Study of relationship rainfall-runoff modeling

The absence of hydrometric data leads to the search for models that not require any calibration, which can give satisfactory results. The models used are the HEC-HMS for the two methods: SCS (Soil Conservation Service) and CLARK as well as the isochrones method [5]. The results show that the two models of HEC-HMS and the isochrones method give satisfactory results and close, the flow rates of the centennial floods are respectively for the SCS, CLARK and the isochrones method: 364, 314 and 447 $m^3/s$.

Significant floods recorded during the event on October 1er, 2011 generated peak flows of approximately 450 m3 / s; The flow of this flood is close to the result obtained by the method of isochrones.

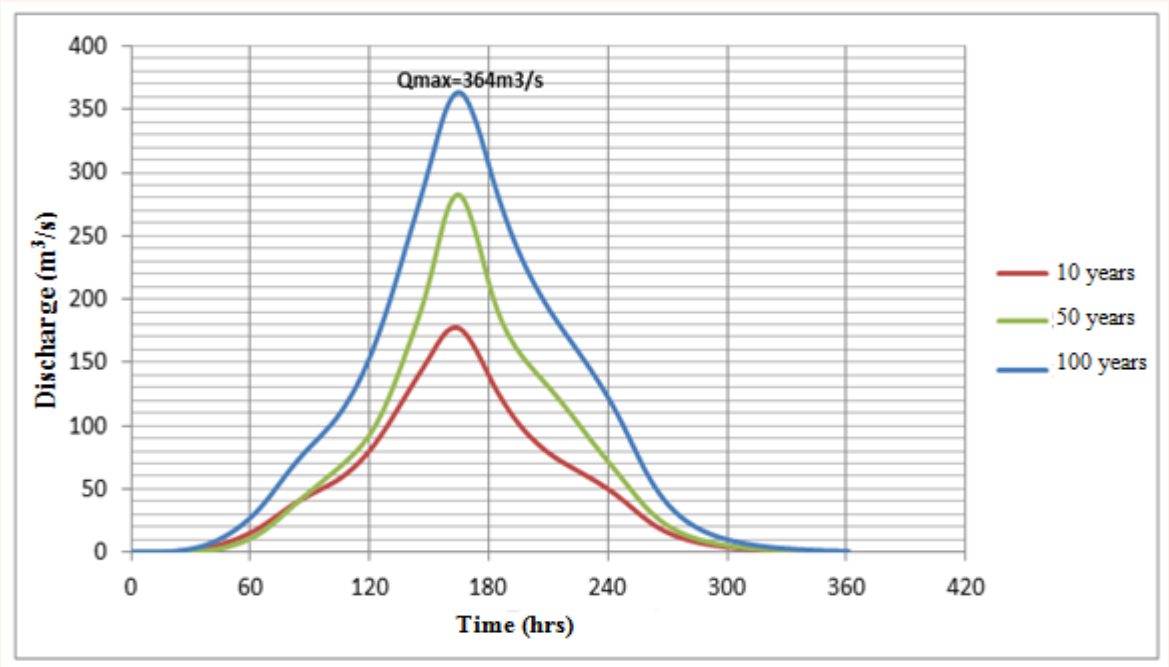


Fig.3.SCS synthetic hydrograph.

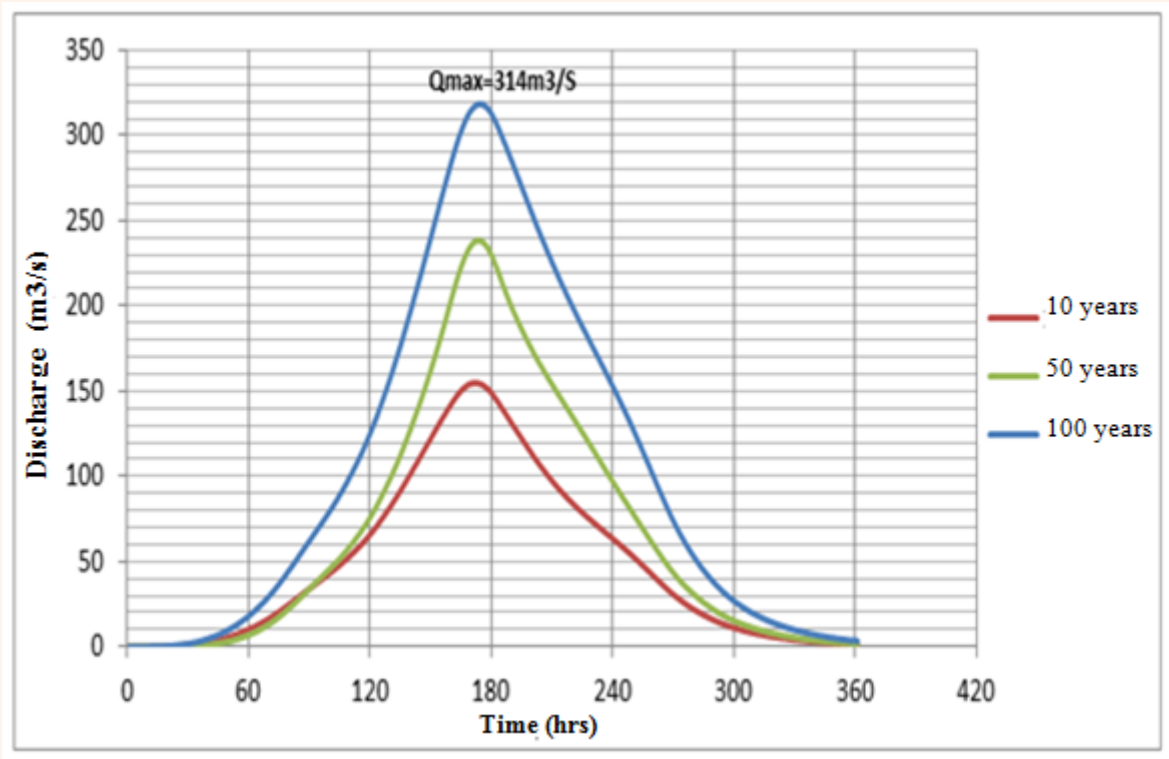


Fig.4. CLARCK synthetic hydrograph.

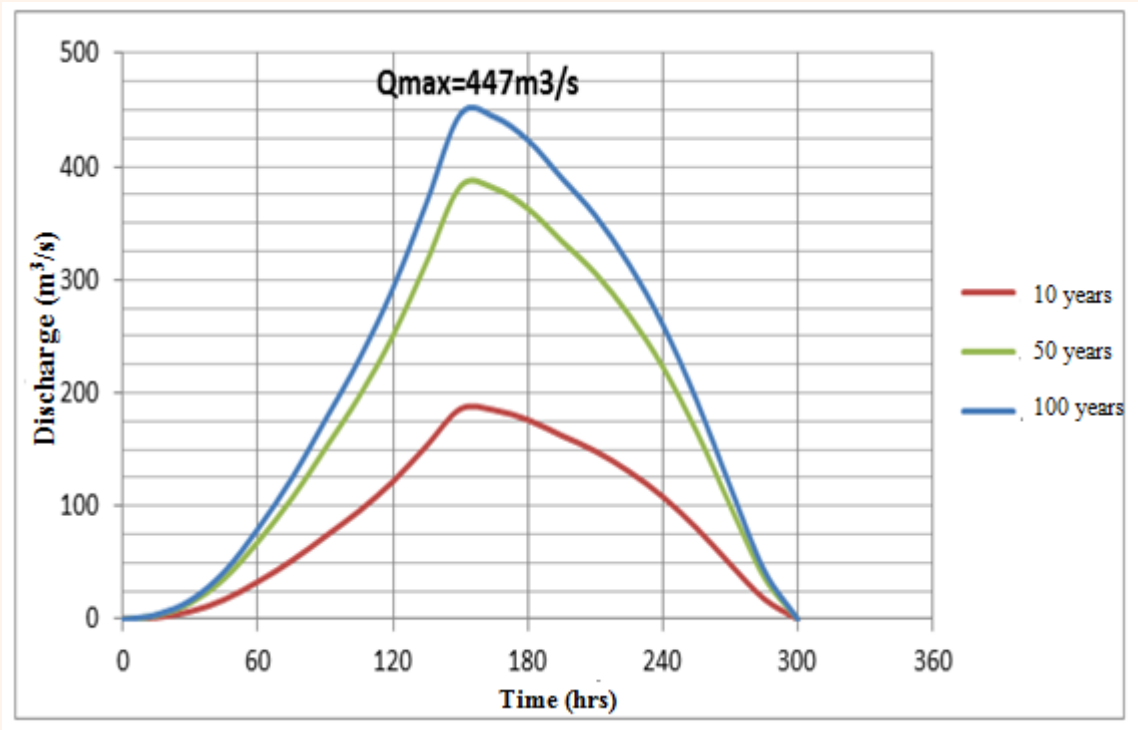


Fig.5. flood hydrograph obtained by the isochrones method.

## 4. CONCLUSION

For socio-economic reasons, the management of natural resources and risks becomes an important issue in modern society. On the hydrological level, it is then important to deepen knowledge both at the level of the floods and on the quantity of water that can be mobilized,

and in particular as a result of entropic impacts on the surface (urbanization, change of vegetation cover) Meteorological conditions (climatic variations). However, most catchment areas, even in developed countries, are not or very weakly instrumented, making estimation or prediction work very uncertain.

The estimation of flood flows suffers from numerous indeterminations. The lack of data partially explains this lack of knowledge. The human and material issues justify our care about sudden and violent floods with the flood damage are constantly increasing.

The present work leads us to think of carrying out other studies on the watershed: by the application other models and comparison the results obtained by these models with those obtained by HEC-HMS and the method of hydrograph Synthetic, on the one hand, and other: by the regionalization of the watershed, it can also open tracks of research on the IDF.

Finally, this paper may serve the decision-makers to manage the situation towards the risk violating flood at our study areas by application the method of isochrones.

## REFERENCES


1. **HEC-HMS (Hydrologic Engineering Center- Hydrologic Modelling System). (2000).**Technical Reference Manual.318p.

2. **Meylan, P ., Musy, A (1999).** Hydrologie fréquentielle. Editions HGA, Bucarest. Hongrie.

3. **SCS (Soil Conservation Service) (1986).** Technical Release 55: Urban Hydrology for Small Watersheds. USDA (U.S. Department of Agricul ture). June 1986.

4. **Svensson, C., Clarke,R.T., Jones, D.A (2007).** An experimental comaraison of methods for estimating rainfull intensity-duration-frequency relations from fragmentary records. J. hydrol.341,79-89.

5. **Touaibia, B (2004).** Manuel pratique d'hydrologie. Edition Madani frères. Blida. Algérie, 166p.

6. **Trefry, C. M., Watkins, D. W., Johnson, D (2005).** Regional rainfall frequency analysis for the State of Michigan. J. Hydrol. Engng **10**(6), 437–449.

# GEOSTATISTICAL STUDY OF THE AQUIFER SYSTEM WATERS COMPLEX TERMINAL IN THE VALLEY OF WADI RIGH-ARID AREA ALGERIA

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## Abstract

*Groundwater resources in the Wadi Righ valley are represented like the parts of the eastern basin of the Algerian Sahara superposed by two major aquifers: the Intercalary Continental (IC) and the Terminal Complex (TC). From a qualitative point of view, various studies have highlighted that the waters of this region showed excessive mineralization, including the waters of the terminal complex (EC Avg equal 5854.61 S / cm) .The present article is a statistical approach by two multi methods various complementary (ACP, CAH), applied to the analytical data of multilayered aquifer waters Terminal Complex of the Wadi Righ valley. The approach is to establish a correlation between the chemical composition of water and the lithological nature of different aquifer levels formations, and predict possible connection between groundwater's layers.The results show that the mineralization of water is from geological origin. They concern the composition of the layers that make up the complex terminal.*

**Keywords** Terminal Complex (CT); Mineralization; Statistical Approaches; CHA ;PCA; wadi Righ; Algeria.

## 1. INTRODUCTION

The Algerian Sahara is until now the subject of numerous several academic studies, scientific papers and technical reports. Among other theses studies were have focused mainly on geological and hydrogeological issues of their aquifers reconnaissance (Bel and Dermagne 1966; Busson 1971; Fabre, 1976; Cornet 1964; Bel and Cuche 1970; Castany 1982) aquifer system of the Northern Sahara. We denote that some investigations were various studies have also focused on the quality physicochemical and bacteriological sometimes, the waters of this aquifer system. They were able to estimate their potability and the ability for to irrigation, and therefore their impact influence on human health and the environment were identified. Thus studies suggest some treatments for proposals, suited to the quality parameters to be corrected, were performed (Achour 1990; Youcef and Achour 2001; Youcef 1998; Megdoud 2003; Djellouli et al 2005 and Bouchahm and Achour 2008).

The valley of Wadi Righ is located on a fossil bed (Wadi-Igharghar) which is a wide ditch subsidence in South-North direction with a longitudinal slope of 1 ‰ south El Goug to Chott Merouane north ˙Fig. 1'. The geological formations are mainly of aged of Quaternary they are

age and resulting from erosion of preexistent formation aged of continental Mio-Pliocene deposits (Bel and Cuche 1970; UNESCO 1972).

The climate of the region of Wadi Righ is of the hyper arid like the Saharan type, mild winters with a permanent drought therefore; where rainfall is low and erratic and hardly exceeding 60 mm / year over during 39 years. The average maximum temperatures is around 40 ° C, while the cumulative annual evaporation is (2400 mm / year) exceeds almost 40 times that of rainfall; (ONM, 2016).

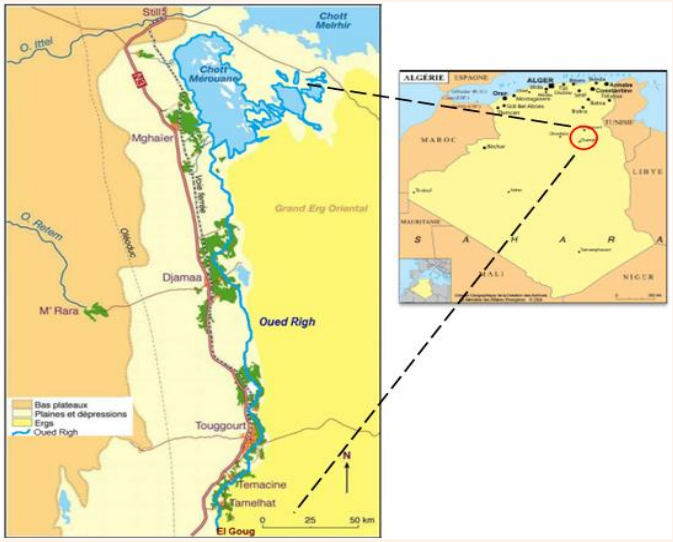


**Fig 1.** Physical framework (geographic division of the directorate of the archives of the ministry of foreign, 2004).

Three aquifers are distinguished: two layers of Mio-Pliocene age with a sandy lithology and a layer of Lower Eocene age représentés by limestone. The Mio-Pliocene is heterogeneous and it shows a variation of the thikness. It consists of sand and sandstone and sometimes limestone and clay, and evaporates with the dominance of clay formation in notably M'ghaier, Umm Thior. According to the hydrogeological cross-section of Terminal Complex ʿFig. 2ʾ, the findings show that the general flow direction follows the topographic model, i.e. from south to north.

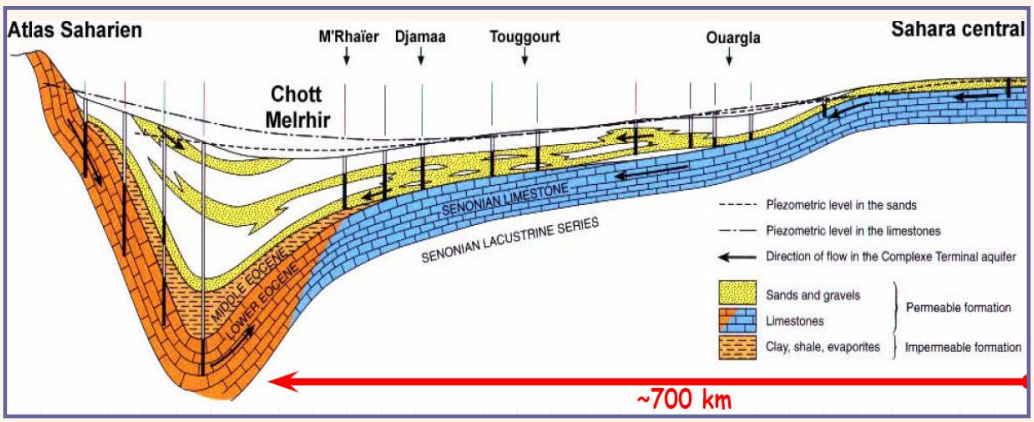


**Fig. 2** Cross-section the hydrogeology framework in the regionical cup in the web of highlighting the terminal complex in Algeria (UNESCO, 1972).

## 2. MATERIALS AND METHODS

Fifty-two samples (52) of water were sampled taken from the system of superimposed layers of Terminal Complex Bottom-up occurs (one layers of Eocene carbonate and two layers of Mio-Pliocene sands). The analytical data were tested and validated by the computer program AQ • QA, version Demo 1.1 (RockWare, Inc.Golden, Colorado, USA). Statistical analysis of data using ascending hierarchical classification (HCA) and main component analysis (ACP) was conducted by Statistica v6.1 (Stat Soft France, 2003) in a demo version (Saporta, 1990).

## 3. RESULTS AND DISCUSSION

### 3.1.Correlation matrix

The examinations of the correlation matrix were performed on carried on 52 samples (Table 1). It shows that the most a significant correlations could be found between the electric conductivity and $Mg^{2+}$ (r = 0.9), $Na^{+}$ (r = 0.89), $Cl^{-}$ (r = 0.91) and $SO_4^{2-}$ (r = 0.81). Other significant correlations have been recorded as, between: $Mg^{2+}$ and $Na^{+}$ (r = 0.83), $Mg^{2+}$ and $Cl^{-}$ (r = 0.88), $Mg^{2+}$ and $SO_4^{2-}$ (r = 0.76), $Na^{+}$ and $K^{+}$ (r = 0.36), $Na^{+}$ and $Cl^{-}$ (r = 0.94), $Na^{+}$ and $SO_4^{2-}$ (r = 0.64) and between $Cl^{-}$ and $SO_4^{2-}$(r = 0.58).

### 3.2.Principal component analysis (PCA)

The distribution of the variance of factors axis shows that the first factor (F1) axis distinctly predominant over others. It alone accounts for represent 44.68% of total variance, according to the projection of variables in terms of on the F1F2 axes ʻFig.3ʼ. This last which represents a cumulative variance of 60.95%. It show: electrical conductivity with an association of , reflecting the mineralization, is in a considerable correlation with the most soluble and evaporate elements (Sulfate, magnesium and sodium chloride), this association is correlated positively well with the factor F1, and therefore, this axis it is regarded as exhibit the water mineralization factor. In addition, whereas the less soluble components, namely such as: potassium, nitrates, calcium and bicarbonate have low do not seem in good correlation with the factor F1.

Table 1 Correlation matrix of chemical elements from the web Complex Terminal aquifers (0.90 *: significant correlation).

| | PH | CE | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $SO^{2-}_4$ | $HCO^{-}_3$ | $NO^{-}_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | | | | | | | | | |
| CE | 0.05 | 1.00 | | | | | | | | |
| $Ca^{2+}$ | -0.06 | 0.07 | 1.00 | | | | | | | |
| $Mg^{2+}$ | 0.09 | 0.90* | -0.24 | 1.00 | | | | | | |
| $Na^{+}$ | -0.01 | 0.89* | -0.20 | 0.83* | 1.00 | | | | | |
| $K^{+}$ | -0.09 | 0.43 | 0.32 | 0.24 | 0.36 | 1.00 | | | | |
| $Cl^{-}$ | 0.01 | 0.91* | -0.23 | 0.88* | 0.94* | 0.37 | 1.00 | | | |
| $SO^{2-}_4$ | 0.09 | 0.81* | 0.28 | 0.76* | 0.64* | 0.23 | 0.58* | 1.00 | | |
| $HCO^{-}_3$ | -0.09 | -0.16 | 0.14 | -0.22 | -0.11 | 0.33 | -0.20 | -0.18 | 1.00 | |
| $NO^{-}_3$ | 0.27 | 0.06 | 0.10 | 0.08 | -0.07 | -0.05 | -0.11 | 0.20 | -0.13 | 1.00 |

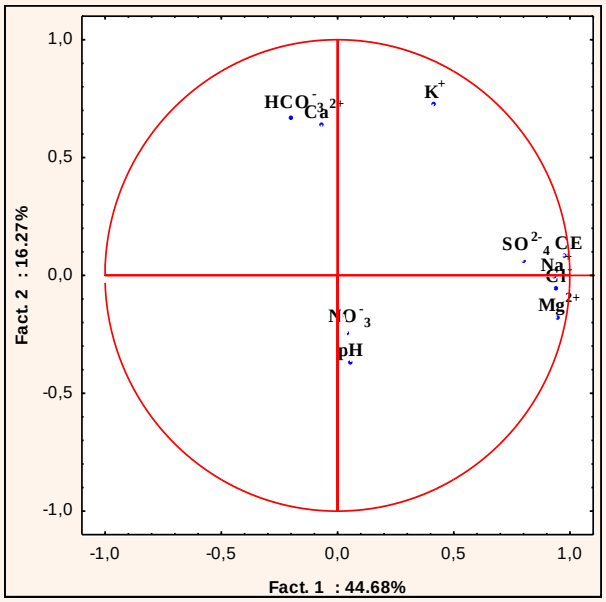


**Fig. 3** Results of the principal components analysis: varying projection of variables on the f1 versus f2 (complex terminal water) plan.

### 3.3.Hierarchical ascending Classification (CAH)

Dendrograms of variables and observations ˙Figs. 4(a) & (b)' show four classes: The first class: with indicates the mineralization pole that gathers the drillings wells (MPII6, MPII30, MPII13, MPII12, MPII22, EO3) characterized by strong electrical conductivities (6200µs / cm - 9030µs / cm).

The second class: indicates the evaporite pole ($Na^{+}$, $Cl^{-}$ and $SO_4^{-2}$) that gathers the drillings (OE1, EO4, MPII4, MPII19, MPI8, MPI4) characterized by high salinity (EC varies between 5500 and 6000µs / cm), the sodium chloride-facies, or sulfated sodium cause the dissolution of evaporate rocks and gypsum that characterizes the study area.

The third class: indicates the pole carbonate ($Ca^{+2}$ $Mg^{+2}$, $HCO^{-}_3$), which gathers the drillings (EO2, MPII18, MPII11, MPII13, EO5) facies characterized by the magnesium and sodium chloride-sulfated.

The fourth class: This class shows the pole pollution ($NO_3$, pH, $K^{+}$), includes the drilling of two plies of Miopliocène, most water points are located in areas characterized by agricultural activities with depths closest to the surface (60 to 170m).

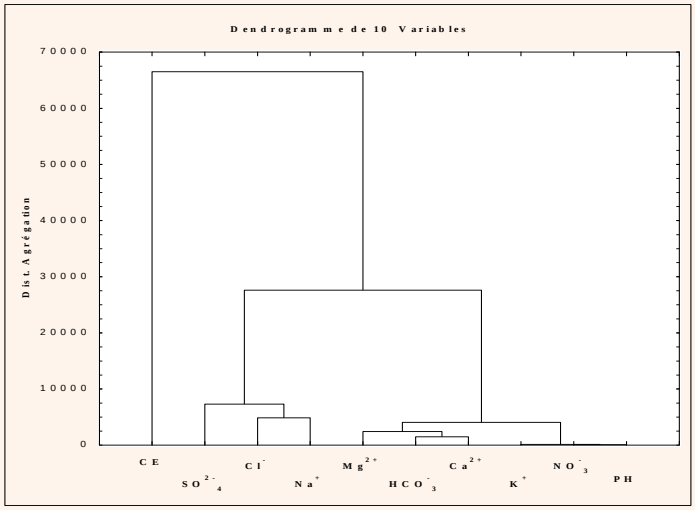


**Fig. 4(a)** Ascending hierarchical classification of variables.

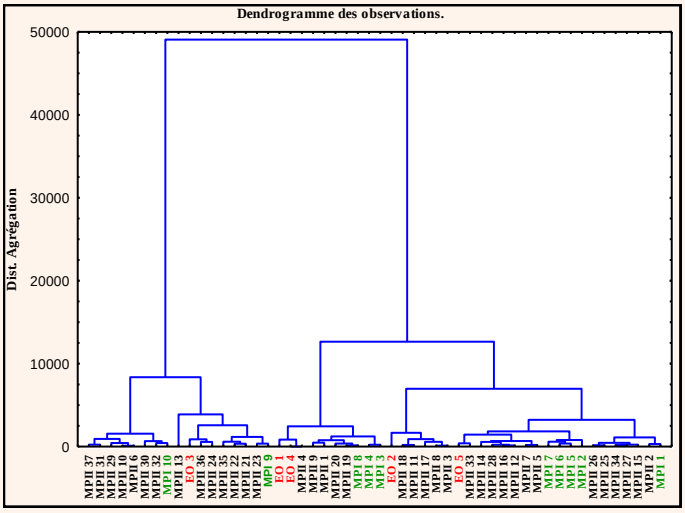


**Fig. 4(b)** Ascending hierarchical classification of individuals.

## 4. CONCLUSION

Our work is part of a study on the geochemical origin of the mineralization of the waters of the Terminal Complex in the region of the Wadi Righ in an arid area. The application statistical methods such us the principal component analysis with hierarchical clustering (two complementary methods) allowed us to demonstrate that the three aquifers groundwater levels making of the Complex Terminal according to their lithology are characterized by two (2) distinct poles, (1) namely; the carbonated pole ($Ca^{2+}$, $Mg^{2+}$ and $HCO^{-}_{3}$) on the sheet represent Eocene formation and the evaporatice pole ($Na^{+}$, $Cl^{-}$, and $SO^{2-}_{4}$) which has a correlative with the proxy to the two sheets of Miopliocène.

All in all according this study, we could conclude by stating that the mineralization and water salinity are of geological origin. It concerns the lithological composition of the layers that form the web from the Terminal Complex. This study approuved a communication between these superimposed layers is very apparent in the situation of drilling the second web Miopliocène (MPII18, MPII11, MPII13) in the class pole carbonated and drilling of the Eocene (OE 1) in

the class of evaporate pole.
Comparison of saturation indices obtained by geochemical modeling applied to 53 samples allowed us to obtain the following results: an under-saturation-gypsum, that is to say, dissolution of evaporate-minerals and a super-saturation for calcite.

## REFERENCES


1. ACHOUR, S., L. YOUCEF (2001). Excès des fluorures dans les eaux du Sahara septentrional oriental et possibilité de traitement. *EIN International*, No 6: 47-54.
2. Achour, S (1990). La qualité des eaux du Sahara septentrional en Algérie. Etude de l'excès de fluor tribune de l'eau, Cebedeau, 42 (542):53-57.
3. Aluja Banet T., A. Morineau (1998). *Analyse En Composantes Principales*. Cisia-Ceresta.
4. Bechiri, N.(2011) Evolution de la chimie des eaux de surface et souterraines dans le bassin versant du Nord-Est Seybouse. Thesis, University Badji Mokhtar, Algeria.
5. BEL, F, D. CUCHE (1970). *Etude des nappes du Complexe Terminal du bas Sahara; Données géologiques et hydrogéologiques pour la construction du modèle mathématique*. DHW, Ouargla.
6. Benzécri JP (1976). *L'Analyse Des Données*. Tome 1: *La Taxinomie*. Tome 2: *L'Analyse des Correspondances*. Dunod, Paris.
7. Benzécri, JP (1982). Construction d'une classification ascendante hiérarchique par la recherche en chaîne de voisins réciproques. Data Analysis notebooks, 7: 209-218
8. Benzécri, JP.,F. Benzécri (1985). Introduction à la classification ascendante hiérarchique d'après un exemple de données économiques. SocStat J of Paris, 1:14-34.
9. Bettahar ,A. (2013). Aspects qualitatifs des eaux de la région de Oued Righ – nappe Terminal Complex et Continental intercalaire-Sud-Est de. Thesis, University Kasdi Merbah, Algeria.
10. Bouchahm, N., S. Achour (2008). Hydrochimie des eaux souterraines de la région orientale du Sahara septentrional algérien – Identification d'un risque de fluorose endémique. La houille blanche J, No 02: 76-82.
11. Bouroche JM, G. Saporta (1980). *L'analyse Des Données* Coll « Que sais-je », No 1854 PUF, Paris.
12. BUSSON. G (1971). *Principes, Méthodes Et Résultats D'une Étude Stratigraphique Du Mésozoïque Saharien*. Edition Paris p 464.
13. Castany G. (1982). *Hydrogéologie, Principes & Méthodes*. Paris, Edition Dunod p237.
14. Confais, J. et JP. Nakache (2000). *Méthodes de classification*. Cisia-Ceresta.
15. Cornet, A (1964). Introduction à l'hydrogéologie Saharienne. Géorg. Phys. et Géol. Dyn 61:5–72.
16. Cornet,. A (1964). Introduction à l'hydrogéologie Saharienne. *Géorg. Phys. et Géol.* Dyn 61:5–72
17. Djellouli, H., M. Taleb, S. Harrache, Chettouh, D, et S. DJAROUD (2005). Qualité physico-chimique des eaux de boisson du Sud algérien : étude de l'excès en sels minéraux. *Cahiers Santé* vol. 15, n° 2
18. Fabre J. (1976). *Introduction A La Géologie Du Sahara d'Algérie Et Des Régions Voisines*. SNED, Alger p421.
19. Gilbert S. (1890). *Probabilités Et Analyse Statistique Des Données*. Paris, Edition Technip p243-257.
20. Guendouz, A., AS. Molla, WM. Edmunds ,K. Zouari,P. Shand et A. Mamou (2003). Hydrogeochimical and isotopic evolution of water in the Complex Terminal aquifer in the Algerian Sahara, hydrogeology J,11:483-495 DOI 10.1007/s10040-003-0263-7.
21. Handouzi ,M A. (2011). Evolution du chimisme du barrage Mexanna Nord-Est Algérien. Thesis, University Badji Mokhtar,Algeria.
22. Houari, IM. (2012). Contribution à l'étude de l'évolution géochimique de l'eau à partir de la table de Complexe Terminal du nord du. Thesis, University Kasdi Merbah, Algeria.
23. Lebart L, A. Morineau and M. Piron (1995). *Statistique Exploratoire Multidimensionnelle.* Dunod, Paris.
24. Lebart L, JP. Fenelon (1971). *Statistique Et Informatique Appliquées*. Dunod, Paris.
25. Lebart, L., A. Morineau, M. Piron (1995). *Statistique exploratoire multidimensionnelle*. Paris: Dunod.
26. Nezli, IE., S. Ashour (2009). Approche hydrogéochimique a l'étude de la fluoration des eaux de la nappe du Complexe Terminal de la basse vallée de l'Oued M'ya. Courrier du Savoir Scientifique et Technique No 09: 57-62.
27. Paix, P. (1956). Les nappes artésiennes de l'Oued. Thesis, Science Faculty, Algiers University.

28. Saporta G (1990). *Probabilités, Analyse Des Données Et Statistiques Probability*. Ed Technip, Paris p493.
29. Tabouche, N. Hydrogéochimie fluor dans les eaux souterraines du nord-est du Sahara algérien Si le Complexe Terminal nappe. Thesis, University Mohamed Khider, Algeria.
30. Tenenhaus M (1994). *Méthodes Statistiques En Gestion* .Dunod, Paris.
31. UNESCO (1972). Projet ERESS: *Etude des ressources en eau du Sahara septentrional*. Paris
32. YOUCEF, L. (1998). Etude des possibilités d'élimination du fluorure des eaux souterraines par précipitation chimique avec de la chaux. Thesis,University of Biskra, Algeria.
33. Zeghaba, N. (2011). Etude du chimisme des eaux souterraine et de surface de la basse vallée de l'Oued Saf-Saf Nord-Est. Thesis, University Badji Mokhtar, Algeria.

# HEXADECANOL MONOLAYERS EFFECTS ON THE QUALITY OF WATER SAMPLES (STUDY CASE OF OUARGLA LAKES)

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## Abstract

Monolayers are thin and invisible films of aliphatic alcohols. They are used to reduce evaporation of water plans with the aim of saving surface water resources. The present study consists of verifying monolayers effects of Hexadecanol applied to water samples of: (i) two lakes situated in department of Ouargla (south-east of Algeria)- lake of Lala Fatma (Megarine) and lake of B'Hour (Temacine)- and (ii) tap water; by verifying physical, chemical and bacteriological parameters of these samples with and without monolayers cover. Through analyzing results, we have realized that monolyers reduce evaporation but they increase the temperature since the monolyers do not reduce the amount of solar energy that water absorbs but decrease heating quantity lost. For the pH, the presence of the monolayers has no effect on the concentration of ions of hydrogen. For the electrical conductivity, it is high when there is no monolayer; and for the number of bacteria, it increases with the use of the monolayers. Therefore, under laboratory conditions, Hexadecanol monolayers reduce evaporation but effect physical, chemical and microbiological quality of water lakes.
***Key words:*** wetlands, monolayers, water quality, Temacine lake, Megarine lake.

## 1. INTRODUCTION

A **wetland** is an area that is inundated or saturated by surface water or groundwater with vegetation adapted for life under those soil conditions (for example, lakes, swamps, marshes) [1]. The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants,[2][3], adapted to the unique hydric soil. Wetlands play many roles in the environment, principally water

purification, flood control, carbon sink and shoreline stability. Wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal life [4]. The water found in wetlands can be freshwater, brackish, or saltwater [3]

In Algerian Sahara, wetlands (lakes) allow the greatest loss of water by evaporation, which affects water ecosystem. The current increase in the global temperature indicate that it is necessary to use techniques for reducing evaporation aiming at the conservation of water supplies.

It has been known for a long time that monomolecular films (called also Monolayers) of certain surfactants can retard water evaporation [5]. This seems to be the only viable technology for reducing the evaporative losses of water from open water [6]. For many years, important studies in field scale were carried out in order to identify the optimal substances and conditions for reducing water evaporation in Algeria [7].
Among the surfactants tested, biodegradable fatty alcohols of low toxicity presented the highest resistance to water evaporation, especially Hexadecanol.
The present paper consists in verifying the effect of Hexadecanol monolayers on water quality of Ouargla's lakes and consequently in aquatic environment by examining water samples collected from Megarine lake (called Lalla Fatma) and Temacine lake (called El B'hour).

## 2. SAMPLING AND MEASUREMENTS METHOD

Volumes of 5 L of water samples were collected from Lala Fatma (33°12'21.5" N, 6°05'54.2'' E) and El B'hour (33°00'53.5'' N, 6°01'24.3'' E) water plans using disposable plastic bottles, according to the procedures recommended by the Standard Methods [8]. The samples were kept in ice during transport to the laboratory, and all necessary material was previously prepared so that the experiments started immediately.

For each sample (specimen), we have used six beakers of 600 mL filled with 420 mL. The three first beakers of each sample were covered with Hexadecanol monolayers and the three other were not covered. In addition to samples (specimens), of two water plans, we have used tap water as control in order to have a good information about Hexadecanol monolayers effects on water quality.

Global physical chemical parameters (pH, water Temperature '$T_w$' and electric conductivity 'EC') were measured by multi-parameter (see table 1).

**Table1** Parameters and methods used in analysis

| *Parameters* | *Unites* | *Analysis methods* |
|---|---|---|
| pH | | Multi-parameter |
| $T_w$ | (°C) | Multi-parameter |
| EC | (ms/cm) | Volumetric method |

For bacteriological analysis, we have used plate count method and as growth medium Nutrient agar to observe the multiplication of bacteria [9].

## 3. RESULTS

Before monolayer deposition, we have analyzed the three water samples: tap water, Megarine lake water, and Temacine lake water. Results are shown in table 2

**Table 2.** Characteristics of water samples

| | *Megarine* | *Temacine* | *Tap water* |
|---|---|---|---|
| *$T_w$ (°C)* | 18.7 | 18.9 | 20.5 |
| *pH* | 8.55 | 8.61 | 8.37 |
| *EC (ms/cm)* | 25.3 | 15.46 | 2.2 |
| *Number of colonies* | 61 | 39 | 00 |

In the following figures, we show the variation of different parameters (physical, chemical and bacteriological parameters) in covered (Hexa) and uncovered (C) beakers of the three tested water samples.

### 3.1.Water Temperature (Tw)

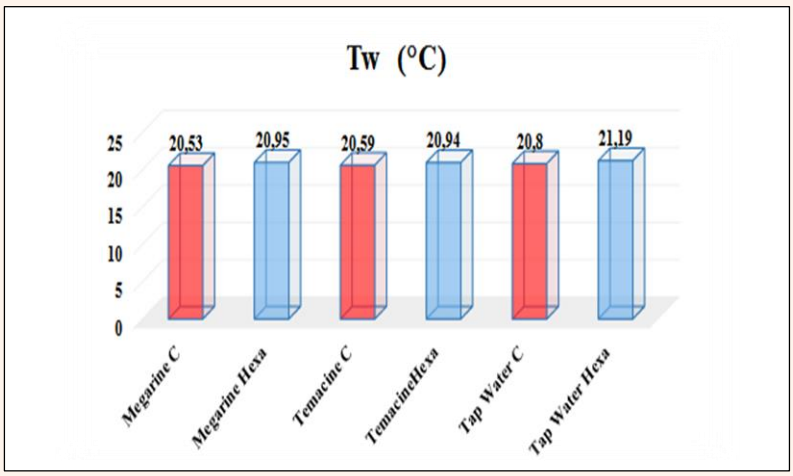


**Figure 1.** Water Temperature of covered and uncovered water samples.

It is well seen in figure 1 that water temperature in covered water is slightly higher than that measured in uncovered water for the three water samples which means that Hexadecanol monolayers contribute in rising water temperature. The highest water temperature was registered in the beaker with tap water covered by Hexadecanol monolayers.

### 3.2.Hydrogen ions concentration (pH)

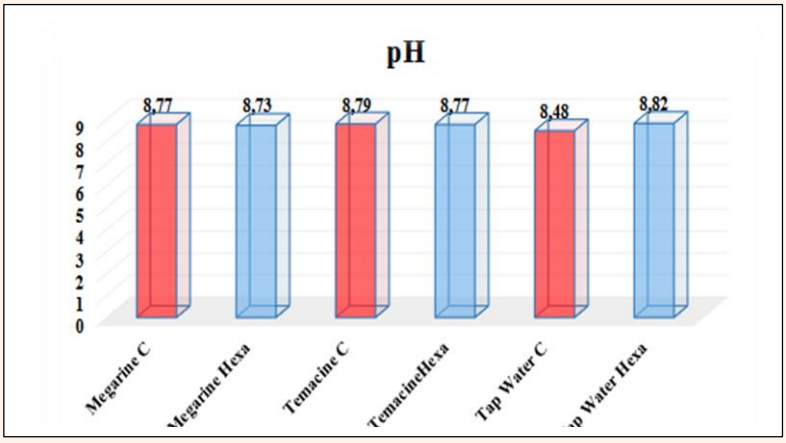


**Figure 2.** pH of covered and uncovered water samples.

Histograms of figure 2 show that pH, in the case of water samples of two lakes, is high in the uncovered water but for the case of tap water, it is high in the covered water. So, the presence of Hexadecanol monolayers on water has no effect on pH.

### 3.3.Electric conductivity (EC)

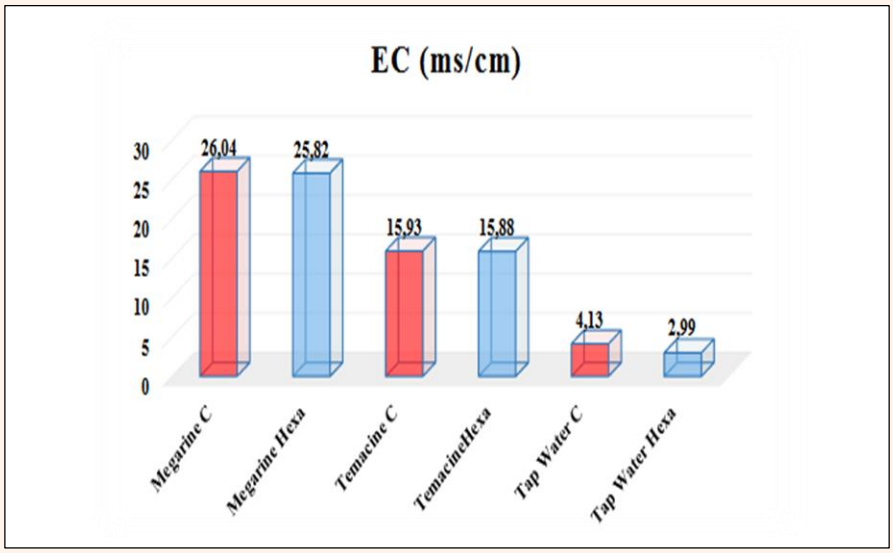


**Figure 3.** Electric conductivity of covered and uncovered water samples.

According to figure 3, the presence of Hexadecanol monolayers contributes in reducing electric conductivity. This reduction is important in the case of tap water and it is the lowest in the case of Megarine lake water.

### 3.4.Number of colonies

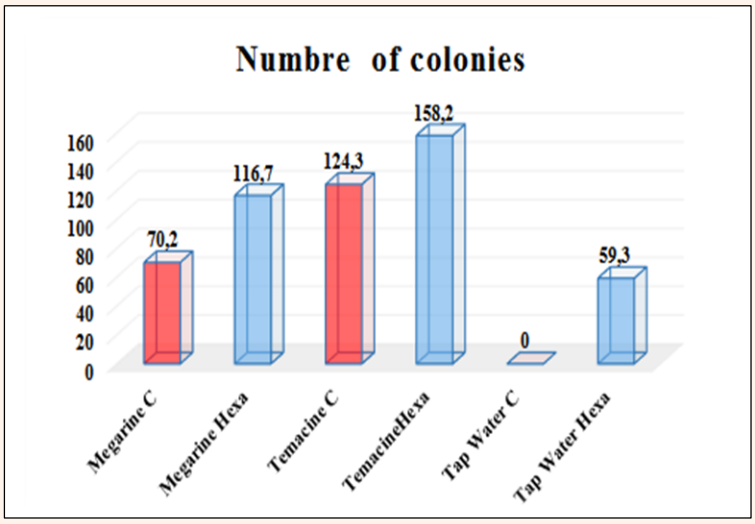


**Figure 4.** Number of colonies of covered and uncovered water samples.

Figure 4 shows that rate of colonies number multiplication is very important when water samples are covered by Hexadecanol monolayers. The rate of multiplication is important in the case of tap water sample

## 4. DISCUSSION

The presence of Hexadecanol monolayers contributes to the evaporation reduction of water plans, and it effects physical, chemical and bacteriological quality.

Changes in water temperature affect aquatic life. Temperature determines which organisms will thrive and which will diminish in numbers and size. For each organism, there is a thermal death point. The formation of a condensed monolayer on the water surface reduces the cooling effect associated with evaporative loss and capillary waves. Experimentally, the impact of a condensed monolayer in retarding evaporative loss is proportional to the rise in temperature of the water surface [10, 11]. That is why water temperature, in our experiments, increases. Several authors have expressed concern that the increase in water temperature associated with the application of a condensed monolayer may adversely affect water quality by reducing the dissolved oxygen concentration [12] and by increasing the risk of algal blooms [13].

For the pH, we notice that monolayers of Hexadecanol have no effect on the pH of the water of both studied lakes and tap water. This result goes with what have found SAGGAI and al. [11] and WIXSON [14] in their experiments.

For electric conductivity, which is proportional with salinity, it is noticed well that in beakers with monolayers, this conductivity is low compared with that registered in beakers without monolayers. This is explained by the small quantity of water lost in beakers with monolayers and it is the same remarks made by WIXSON [14]. The difference of the conductivity between both lakes is explained by the difference of type

of lake: Temacine lake is of type mesohaline that his salinity varies between 3 g/l and 16 g/ l; and the lake Megarine is of type polyhaline, which his salinity varies between 18 g/ l and 30 g/l.

The presence monolayers also causes an increase of the number of bacteria in the water. This result goes with those of Silvey [15] and Ludzack and Ettinger [16] , who reported that the presence of monolayers contributes on multiplication of bacteries. According to LUDZACK and ETTINGER [16] and CHANG et al. [17] the monolayer is biodegradable and can be assimilated by bacteria in the water as food, which explains their high rate of colonies number multiplication in water amples covered by monolayer compared to those uncovered.

## 5. CONCLUSION

Evaporation reduction by monolayers of Hexadecanol is a technique that has proved its efficacy in Algerian arid conditions. The application of this technique on water surface of two lakes of Ouargla department has shown that in addition to the evaporation reduction, monolayers of Hexadecanol affect physical, chemical and bacteriological characteristics of lakes water and consequently aquatic beings. The application of monolayers on water surface of lakes rises the water temperature and reduce the electric conductivity but it does not affect water pH. For bacteriological part, the presence of monolayers contribute in rising the rate of bacteria multiplication in water.

Based on the findings in this study, further studies are needed to verify the effect of this water, after application of monolayers of Hexadecanol, on aquatic beings (plants, fishes, animals, etc….) and assessing what actions need to be taken.

## ACKNOWLEDGMENT

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## REFERENCES

[1] "Department of Environmental Protection State of Florida Glossary". State of Florida. Retrieved 2011-09-25.
[2] S. Butler, “Macquarie Concise Dictionary”, Sydney, Australia: Macquarie Dictionary Publishers Ltd, 2010.
[3] "Official page of the Ramsar Convention", [Retrieved 2011-09-25].
[4] "Ramsar Convention Ecosystem Services Benefit Factsheets", [Retrieved 2011-09-25].
[5] G.T. Barnes, “Review: The potential for monolayers to reduce the evaporation from large water storages”, Agricultural Water Management”, vol. 95, 2008, pp.339-353.
[6] V.K. LaMer, and T.W. Healy, “Evaporation of water. Its retardation by monolayers”, Science, vol.148, 1965, pp. 36–42.
[7] S. Saggai, “Réduction de l’évaporation des plans d’eau : l’expérience algérienne”, Editions universitaires européennes, Allemagne, p. 76, 2016.

[8] L.S. Clesceri, A. E. Greenberg, and A. D. Eaton, “Standard Methods for the Examination of Water and Wastewater”, 20th EPA, AWWA, WPCF., American Public Health Association: Washington D.C,. p. 1220, 1998.
[9] F. Rejsek, “Analyse des eaux : aspects réglementaires et techniques”, CRDP d’Aquataine, Bordeaux, p. 360, 2002.
[10] N.L Jarvis, C.O. Timmons, W.A. Zisman, “The effect of monomolecular films on the surface temperature of water”, In: La Mer, V.K. (Ed.), Retardation of Evaporation by Monolayers: Transport Processes, Academic Press, New York, 1962, pp. 41–58.
[11] S. Saggaî, M. M. Saggaî, and N. Hancock; “Laboratory study of the effect of hexadecanol monolayer on the aquatic fauna (case of Tilapia nilotica), Revue des BioRessources, vol. 3(2), 2013, pp. 1-7.
[12] B. Parker, and G. Barsom, “Biological and chemical significance of surface microlayers in aquatic ecosystems” bioscience, vol. 20, 1970, pp. 87-93.
[13] D. McJannet, F. Cook, J. Knight, and S. Burn, “Evaporation Reduction by Monolayers: Overview, Modelling and Effectiveness”, Urban Water Security Research Alliance Technical Report No. 6, Australia, p. 25, 2008.
[14] B.G Wixson, “Studies on the ecological impacts of evaporation retardation monolayers”, Technical Report No. 6, Texas Water Resources Institute, Texas A & M University, USA, p. 101, 1966.
[15] J. K. G. Silvey, 1960 “Physical, chemical and biological effects of hexadecanol on Lake Hefner, 1958”, J. Amer. Water Works Assoc, vol. 52(6), 1960, pp. 791-802.
[16] F. J. Ludzack, and M. B. Ettinger, 1957 “Biological oxidation of hexadecanol under laboratory conditions”, J. Amer. Water Works Assoc., vol. 49(7), 1957, pp. 849-858.
[17] S.L. Chang, M.A. McClanahan, and P.W. Kabler, “Effect of bacterial decomposition of hexadecanol and octadecanol in monolayer films on the suppression of evaporation loss of water”, In: La Mer, V.K. (Ed.), Retardation of Evaporation by Monolayers: Transport Processes. Academic Press, New York,1962, pp. 119–131.

# DEFINITION OF THE LOCATION EROSION CONTROL MEASURES ON THE SLOPES OF AGRICULTURAL FIELDS

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## ABSTRACT

Anti-erosion measures are defined for the agricultural fields territory on the base of the evaluation of water velocity for surface runoff during storm rainfalls. The results have allowed to select the form and location of engineering protection which provides the reduction of soil erosion to the minimum.

**Keywords:** rain surface runoff, of runoff, soil erosion; erosion control measures. water velocity

## INTRODUCTION

The intensity of water soil erosion on farmland has take because of the disruption of sustainable water regime in the process of soil use. The elimination of the erosion conditions we can achieve by reducing the concentration of water flows and slowing down surface runoff or by drainage of some amount of water to the hydrographic network.

Many researchers have studied the process of slope water erosion [1,2 and others] and obtained the numerical characteristics of this process and its determining factors. It is obviously that intensity soil destruction dependents on surface slope water velocity and slope characteristics. The surface slope water velocity dependents on next more important factors:

- the intensity of rainfall,
- gradient of slope,
- length of slope,
- the size of the catchment area,
- Kind soil of slope,
- kind of agricultural crops,

Also the erosion process dependents on the kind and frequency of tillage, vegetation and some of other factors.

Characteristic of critical water velocity in respect to surface flow on the slope has essential particular importance. We will be name such critical velocity as the velocity of surface water flow ($v_x$) at which water begins erosion. At water velocities less than a critical value, separation of aggregates (and hence erosion) will not arise, and vice versa.

Accordingly, the paper is dedicated to analysis of practice experience in respect to the projecting of anti-erosion measures for agricultural fields territory.

The next problems were decided in the frames of the research:

1) evaluation of the flow velocity on the typical slopes of the agricultural fields;

2) the choice of erosion control measures

3) evaluation of the concrete characteristics in respect to chosen erosion control measures

## OBJECT OF RESEARCH

Objects for research were agricultural fields Kursk region which belongs to the Black soil zone of Russia. Significant intensity of water erosion process takes place here due to:

- high the intensity of rainfall;
- structure of topsoil;
- significant gradients of the slopes.

Consequently, the annual soil losses are very high, and soil fertility and its value are very high too.

## MATERIALS AND RESEARCH.

According to researches of C. E. Mirtskhoulava [1] etc virtually erosion occurs when the ratio is reached:

$$v_x \approx 1{,}15 v_{don} \qquad (1)$$

Here:

$v_x$ - bottom velocity of drain slope,

$v_{don.}$ - critical bottom velocity at which water begins erosion.

The velocity flow slope determines the force particles, aggregates of individual soil during their separation, and transport capacity of the flow. Prediction of the velocity is applied a number of methods and formulas [1,2 and others]. The most famous formula of them is the formula of C. E. Mirtskhoulava:

$$V_{don} = 1{,}25\sqrt{\frac{2m}{2{,}6\rho_0 n}}\left[g(\rho_z - \rho_0)d + 1{,}25C_y^H K\right] \qquad (2)$$

where: d – average size of aggregates of the soil, m;

*m* – coefficient, taking into account the influence of various factors on the erosion process;

$C^H_y$ – regulatory fatigue breaking strength of soils, PA;

K – coefficient of uniformity of cohesive soils, characterizing the probability of deviations of the characteristics from their mean values in an unfavorable direction compared to the normative;

n - is the load factor considering the eroding capacity of flow under the influence of the pulsatile velocity;

$\rho_z$ – soil density, kg/m3.

However the formula (2) don't take to consideration important parameter of slope length, which accounting by formula of V. N. Goncharov . This formula has next view:

$$V_x = 22{,}2 \cdot (I - K)^{0{,}30} \cdot x^{0{,}30} \cdot i^{0{,}35} \cdot n_0^{\,0{,}3} \cdot m^{0{,}7}, \text{ m/s} \qquad (3)$$

where

I – rainfall intensity, mm/s;

x – slope length, m;

*i* – the gradient of the surface slope;

$n_0$ – the coefficient of roughness;

K – rainfall intensity required for infiltration, m/s;

m – the coefficient characterizing looseness of the soil.

We transform the formula (3) by taking the following assumptions: $(I - K) = \delta I$,

where:

δ – coefficient of runoff, then $\delta n_0$ - coefficient of capacity of slope runoff.

Hence, the formula (3) will look as follows:

$$V_x = 22{,}2 \cdot (\delta n_0)^{0,3} I^{0,30} \cdot x^{0,30} \cdot i^{0,35} \cdot m^{0,7}, \text{ m/s} \qquad (4)$$

Probability of exceeding of daily rainfall intensity X [mm] is taken not very small because slope water erosion is not perceived by catastrophic evince. So annual probability of exceeding of rainfall intensity for normative calculations was taken 0,25 (25%). Analysis of dynamic changes of storm rainfall [3-5 and others] has showed that depth of storm rainfall has increased due to total changes of climatic characteristics and because of landscape changes which impact at the climatic processes of concrete region. It was confirmed in respect to the study region according to data observation of storm rainfalls for nearest meteorological station -"Kamennaiay Step ". Two series of data observations for the storm rainfall were analyzed: 1) period 1930-1960 years; 2) period 1963-1995 years (the periods were provided with reliable daily observations).

The empirical probabilities of exceeding of storm rainfall depth were determined for every series according to Weibull formula and their numerical values are represented on the fig. 1. Here we can see that 32 points of second period exceed corresponding points of first period and just 1 case has inverse position. Such fact confirms hypothesis about increasing storm precipitations in respect to last decades [3-5].

So a value of daily storm rainfall had taken according to probability of exceeding (P = 25%) - 36 mm. However, usually a duration of the most storm rainfall not exceeds 1 hour during day. Therefore, value of intensity of precipitation for the 1 hour for following calculations has been taken M=36 mm per hour.

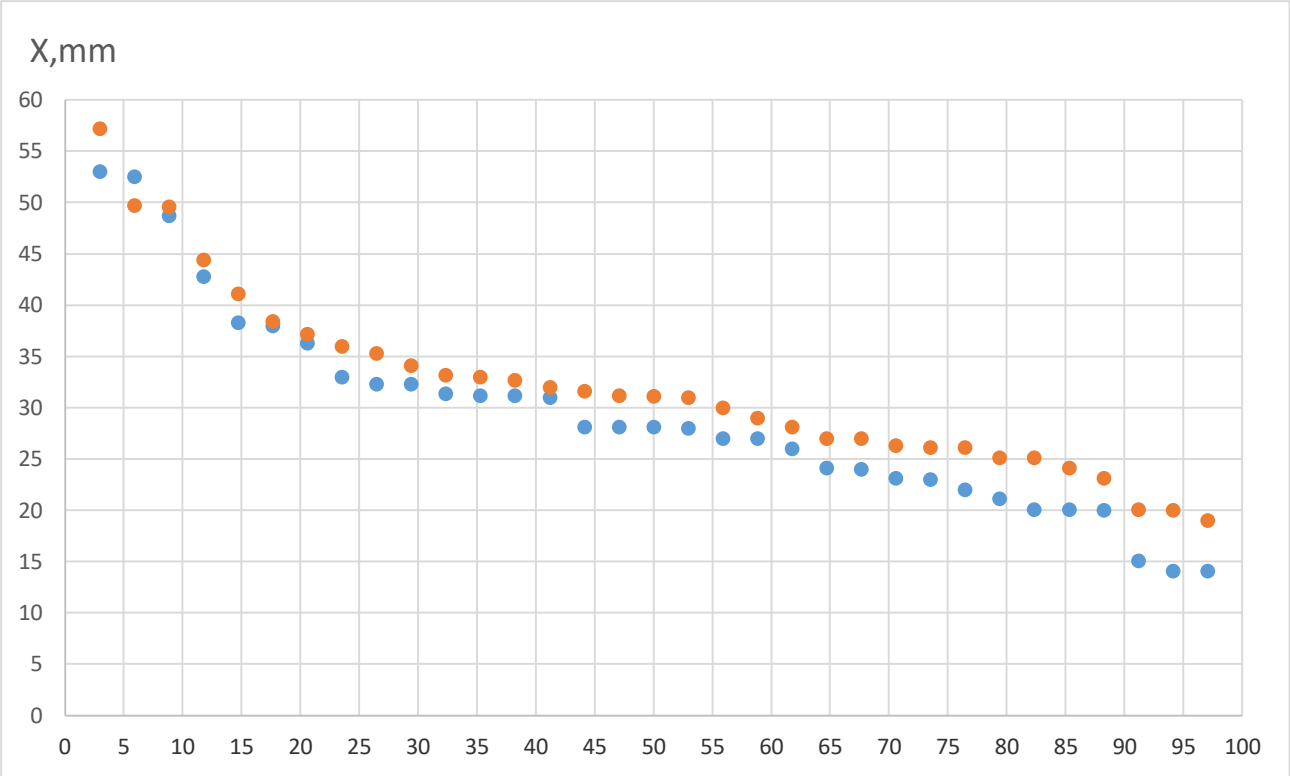


Fig.1. Empirical probabilities of exceeding of storm rainfall depth

Accordingly, value of storm rain intensity was calculated in respect to I [mm/s].

$$I = \frac{M \cdot 0{,}001}{60}, \text{ mm/s} \qquad (5)$$

M – intensity of precipitation for the 1 hour.

Four typical catchment characteristic slopes of crop rotations were analyzed in this study relative to gradient and length of slope. The results are shown in table 1.

Results of table 1 in respect to the bottom velocity of slope runoff are from to 0,18 to 0,26 m/s. Such values exceed bottom velocity of drain slope, which is 0,10 m/s for the research region [1]. So, the velocity achieved of eroding power and the erosion of the topsoil occurs. It is assumed that erosion does not occur on surface of the slope if velocity of surface runoff less 0,1 m/s. The characteristic slopes of crop rotations are presented in figures 2 and 3, where we can see active length (Distance, m) and gradients, which influence the flow velocity on slope.

Table1. The values of the bottom velocity (m/s) of slope runoff in dependence on gradient (i) and distance slope (X).

| Catchment 1 | | | Catchment 2 | | | Catchment 3 | | | Catchment 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| X,m | i | $V_x$ | X,m | i | $V_x$ | X,m | i | $V_x$ | X,m | i | $V_x$ |
| 100 | 0,01 | 0,18 | 100 | 0,015 | 0,21 | 130 | 0,031 | 0,29 | 140 | 0,022 | 0,26 |
| 340 | 0,012 | 0,27 | 620 | 0,008 | 0,28 | 170 | 0,016 | 0,25 | 150 | 0,026 | 0,28 |
| 460 | 0,009 | 0,23 | 940 | 0,003 | 0,22 | 250 | 0,015 | 0,27 | 190 | 0,021 | 0,28 |
| 700 | 0,006 | 0,26 | 1100 | 0,004 | 0,26 | 320 | 0,012 | 0,26 | 730 | 0,006 | 0,27 |
| | | | | | | 580 | 0,008 | 0,24 | 820 | 0,005 | 0,25 |

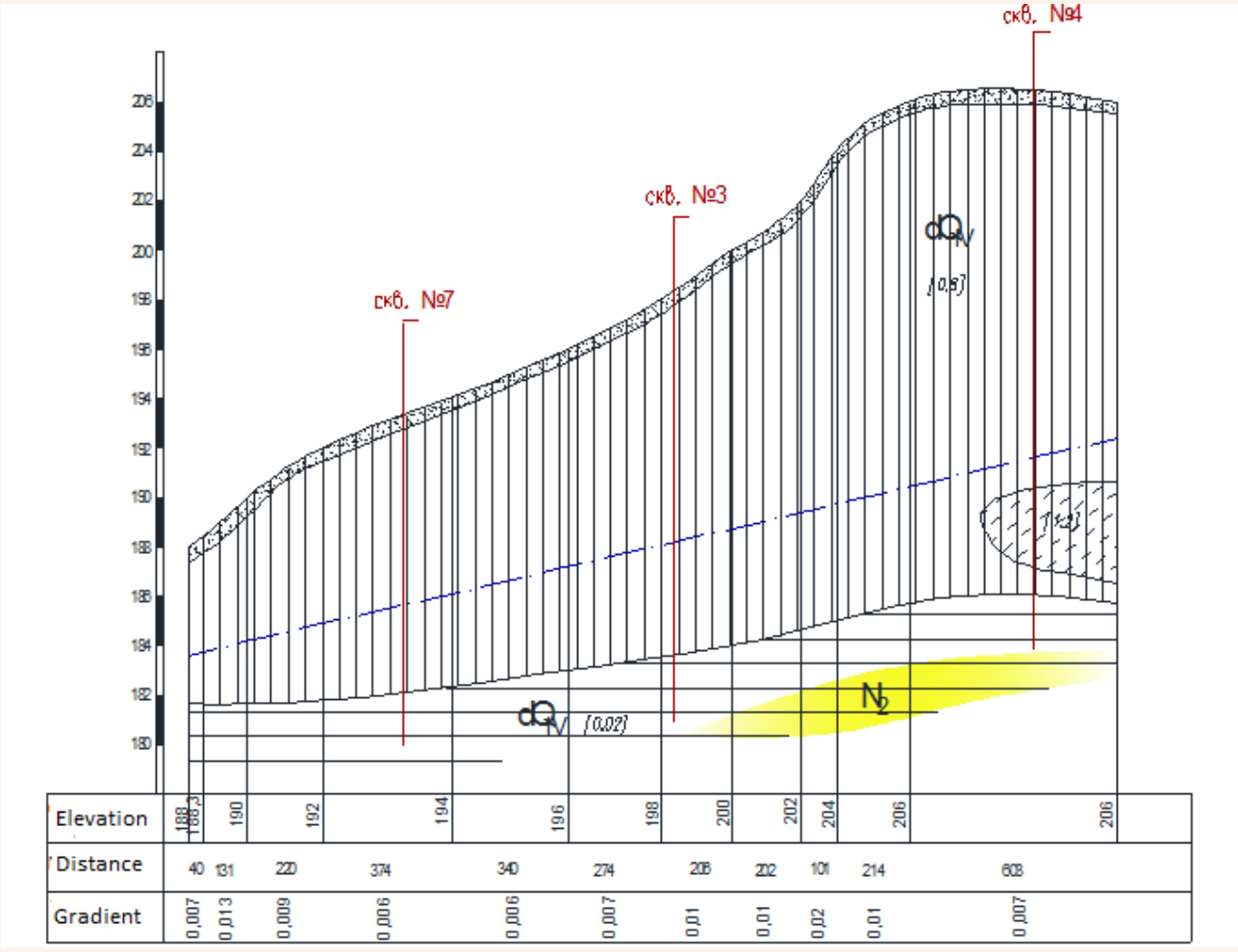


Fig. 2. Longitudinal profile along the slope 1.

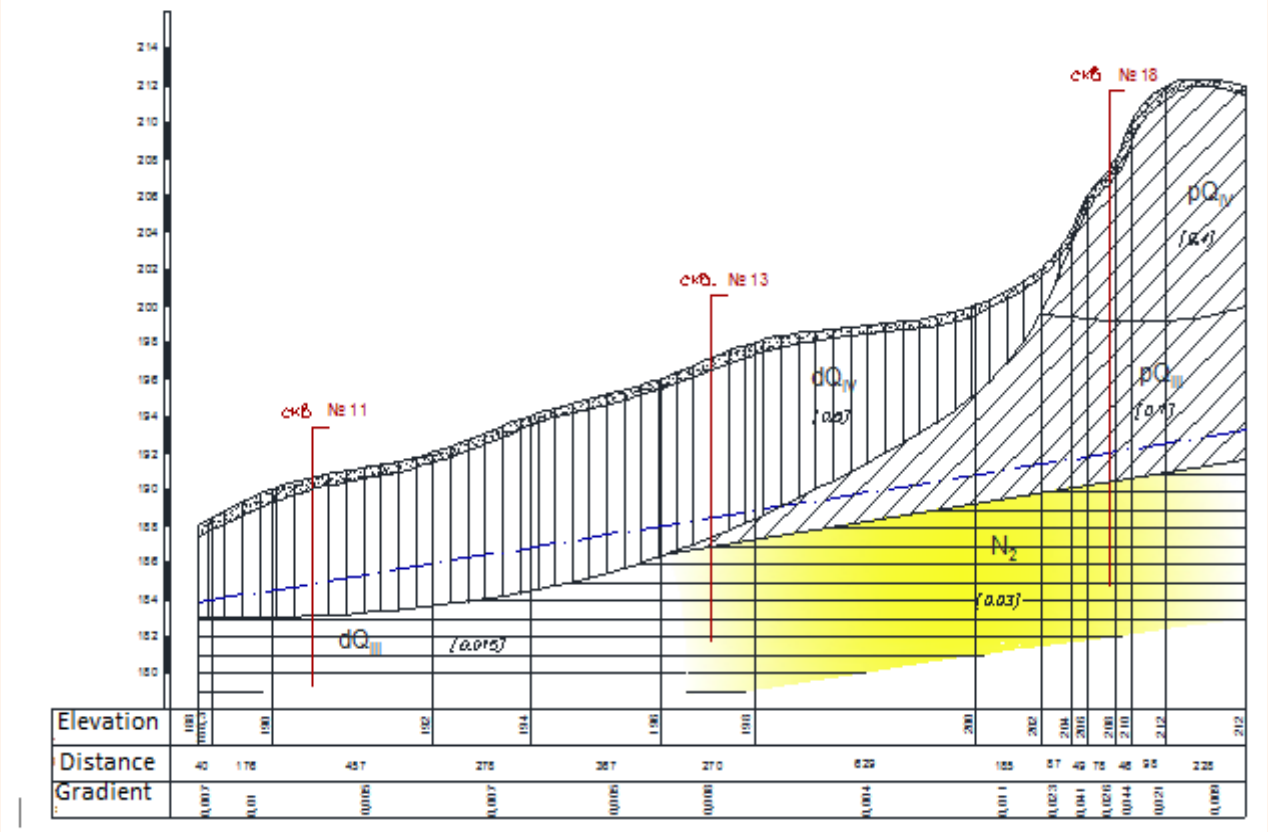


Fig. 3. Longitudinal profile along the slope 1.

So, the cultivation of crops is possible with the use of intensive erosion control measures only. Recommended anti-erosion measures must be chosen from those which best resist water erosion and rainfall floods and are beneficial respect to economic point of view. Effect of agronomic and agroforestry activities manifests itself in a few years only. A quick anti-action to surface runoff and cessation of erosion can take place just by erosion control with help of waterworks. Therefore, the earthen shafts were chosen for regulation of surface water flow to stop erosion on the slopes and growth of existing gullies.

The constructions consist of a shafts and trapezoidal notches (the small ditch from which the soil was taken for the embankment of the shaft). Shafts are placed on the terrain contours, they have a small variable height and gentle slopes. Then we can reduce the velocity of runoff of surface waters and provide water drainage into a special drainage canal. Locations of erosion control shafts were determined on the base of analysis of the velocity flow along slopes (formula 4), they are represented by red lines on figure 4.

Fig. 4. Scheme of location of earthen shafts on the plan of crop rotations.

Map legend of Fig. 4.

— - earthen shafts; - pasture; - fodder crop rotation; - vegetables;

- Orchard; - haymaking; - houses; - roads;

- watershed boundary; - isohypses; - drainage canal.

## CONCLUSIONS.

The offered methodical approach and use of formulas (4) allows to estimate the bottom velocity of surface runoff on the slopes of agricultural fields during rainfall floods. The analysis of such velocity on specific slopes provides an opportunity to plan an engineering protection which helps to decrease soil erosion to minimum.

## REFERENCES.

1. Mirtskhulava C.E. Water the soil erosion (movement, weather). – Tbilisi: Metsniereba, 2000, P. 264. (Rus);

2. Goncharov V.N. Dynamics of channel flows. Leningrad, 1962, P.374. (Rus);

3. V. Ilinich, E. Akulova, V. Belchihina and K. Ponomarchuk. Estimation of Statistical Characteristics for Storm Precipitation with Long-term Data to Assess Climate Change. Journal of Climate Change, Vol. 2, No. 2 (2016), pp. 83–87. DOI 10.3233/JCC-160019.

4. V.V. Ilinich, T.D. Larina. Evaluation of changes storm Precipitation during century for the modeling of floods. In the book: Sustainable Hydraulics in the Era of Global Change – Erpicum et al. (Eds.) © 2016 Taylor & Francis Group, London, ISBN 978-1-138-02977-4, p. 928 – 934.

5. Belchikhina V.V., Ilinich V.V., Asaulyak I.F., Belolubtsev A.I. SIMULATION OF THE PRECIPITATION SCENARIOS ON THE RIVER CATCHMENT WITH CONSIDERATION OF THE CLIMATIC CHANGES. 12th International Conference on Hydroinformatics (HIC 2016) - Smart Water for the Future. Procedia Engineering, Volume 154, 2016, p. 665-669/

# THEORETICAL FOUNDATION BY ESTIMATION OF MIGRATION OF TECHNOGENIC IMPURITIES IN THE SYSTEM "ATMOSPHERE-LITHOSPHERE "

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## ABSTRACT.

Methodological approaches are offered for simulation of migration of technogenic impurities in the system "atmosphere-lithosphere". The methods are based on natural and hydrodynamic modeling. Processes of distribution and accumulation of technogenic impurities are considered at the example of the Ivankovo reservoir bacine.

**Keywords**: modeling, pollutant migration, technogenic impurities, water flow, bottom sediments.

## INTRODUCTION.

Analysis of the processes of anthropogenic pollution of the natural environment is one of the greatest scientific problems which currently studied only partially. In particular, it is concern to the flow of man-made impurities. The danger of air pollution is not only in contact with clean air. The pollution by harmful substances is dangerous for the subsequent change of Earth's climate system. Figure 1 represents a global atmospheric industrial pollution.

The seriousness of environmental problems related to air pollution in the territory of the Russian Federation is illustrated by the following statistical data [1]:

· the maximum permissible concentration of air pollution is exceeded by 5 times - in the 151st city of Russia;

· the maximum permissible concentration is exceeded 10 times - in 87 cities.

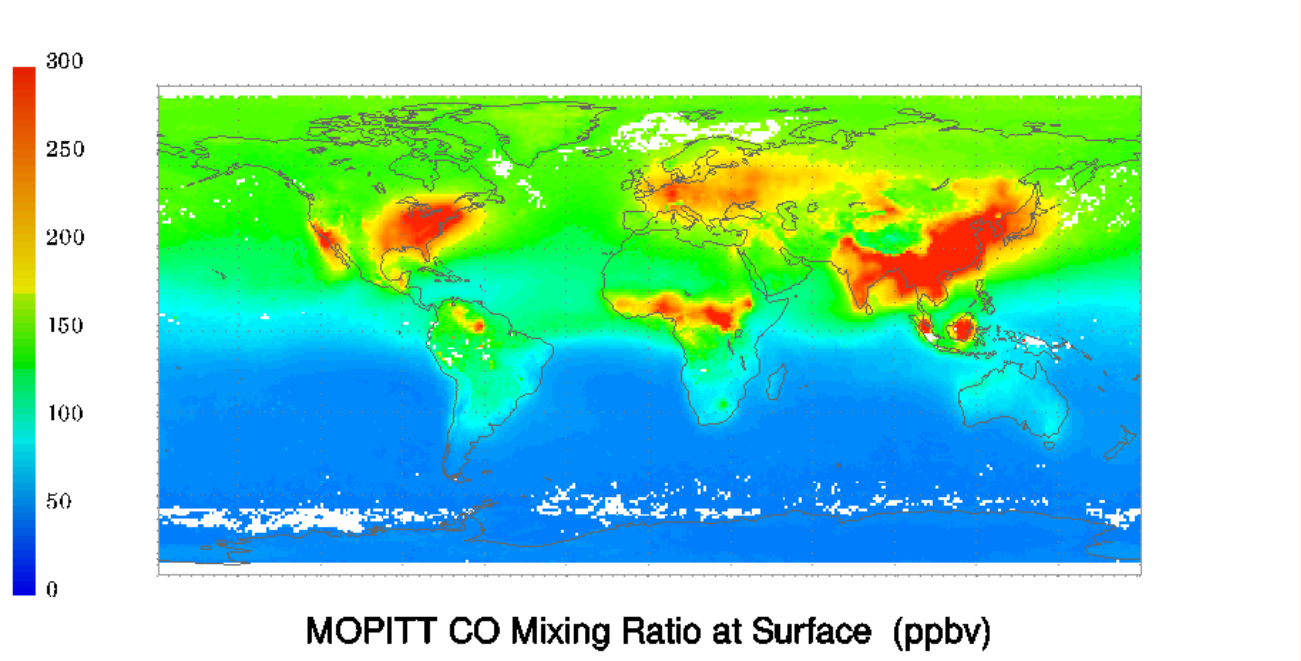


Fig.1. Pollution of the atmosphere with carbon dioxide, was from outer space (according to NACA).

## OBJECT OF RESEARCH.

Moscow region is Russian leader in respect to harmful substances into the atmosphere. Here, the total emissions of harmful ingredients into the atmosphere reaches sometime 1,2 ton/hectare per year. Landfill industrial solid waste (LISW) gives significant share of environmental pollution. Non-waste technology not yet found in the country wide application. Disposal of waste in the natural environment is almost the only method used in practice [2].

Diagnostic assessment of pollution of natural objects was done in respect to the landfill industrial solid waste in Konakovo city (fig/1) which is located on the catchment of the Ivankovo water reservoir. The is first significant water reservoir along stream of the Volga river from her source. The reservoir is one of the main sources of drinking water supply of Moscow.

Long-term observations are collecting now at landfill with near the water reservoir in the vicinity of the waste dump g. Konakovo which is located on the shore of the reservoir.

The diagnosis of recycling is understood as a scientific description of potential adverse consequences of the disposal of materials of production and consumption. [3].

The evaluation is conducted using the methods of field simulation by means of instrumental observations in separate points with the subsequent spatial averaging.

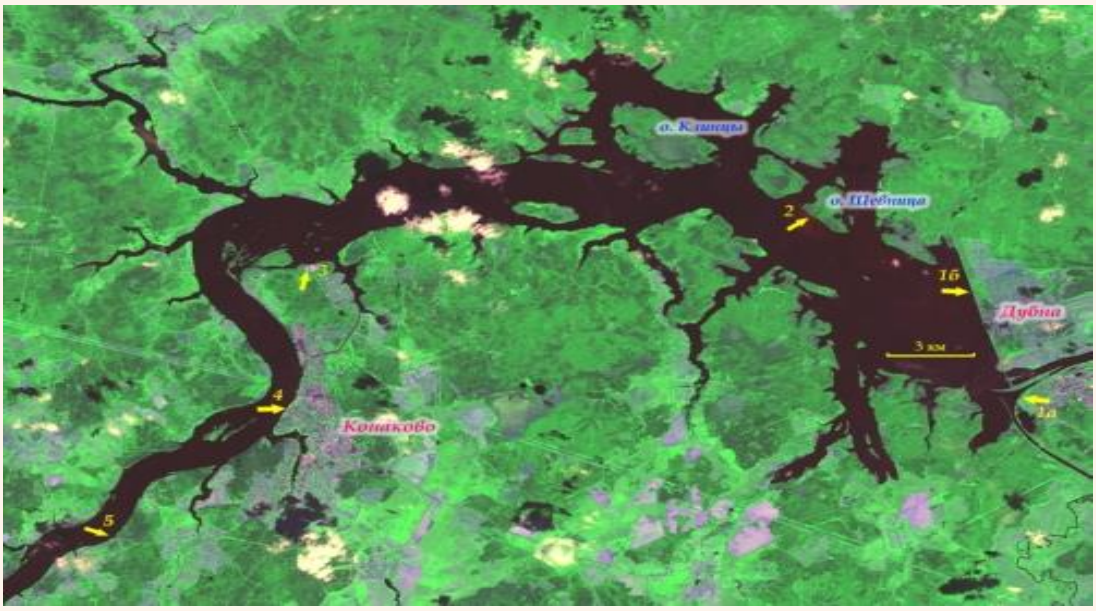


Fig.2. Satellite photo of the catchment Ivankovo reservoir.

So, the main goal of the research is to study the process of accumulation of technogenic impurities in environmental objects.

Specific problems are:

- Experimental and theoretical studies of advection of diffusion of technogenic impurities
- Investigations of the process of interaction of flows at the boundaries of the lithosphere
- Development of theoretical algorithms of the process.

## MATERIALS AND RESEARCH.

Expeditionary researches involved measurements of migration of pollutants in soils, groundwater and air in respect to two rays from a dump (azimuth of 255 and 330 degrees). They included 9 wells to a depth of 3 m, which penetrated aquifers. The distance between the holes was set equal to 100 m. Repeatability in respect to the wind directions and their velocities were researched too. Samples of every well (from the aeration zone rocks) were selected for estimation of humidity, mechanical composition of rocks and content of the basic chemical elements: chlorine, sulfates, nitrates, phosphates, potassium. Samples of ground water were taken from the wells too.

Elevations of earth surface were determined according to orientation (rays) of wells for total characteristics of place relief.

Chemical samples and monitoring data showed that the most stable pollutants are chlorine and sulfate ions. Water in the nearby well contains high concentrations of chlorine (45,6 - 60,0 mg/l) and sulfate ion (13,0 - 97,0 mg/l) in winter and summer in respect to azimuth of ray 255º. Another ray with an azimuth 330º - high content of chlorine and sulphate is fixed at a distance of up to 300 m, but to a lesser extent. Main results are represented in table 1.

Table 1. The concentration of chlorine and sulphate for 2 rays from garbage dump.

| Azimuth of ray | 255º | | 330º | |
|---|---|---|---|---|
| Distance | 500 m | | 300m | |
| Ingredients | chlorine | sulphate | chlorine | sulphate |
| Concentration (*mg/l*) | 60 | 97 | 10 | 14 |

Samples content in the groundwater of heavy metals were processed with help of the mass spectrometer ICP-MS 7500.

Manganese, iron, barium and sodium were found in the water at a distance of 50 m from the landfill. The concentrations of heavy metals exceed maximum permissible concentrations for drinking water by 2 and even by 10 times.

It is established that the landfill affects at the air of the surrounding areas.

Two employees were poisoned choking gases emanating from the smoldering garbage during working near the landfill. So, the aerosol deposition to the surface of the reservoir may occur due to the spread of polluted air on the wind rose.

The possibility of accumulation of pollutants in bottom sediments due to the arrival of aerosols is the main hypothesis for the hydrodynamic model. The methods of research are based on the experience of studies of the process by different researchers [4-7].

Estimation of the accumulation of aerosol deposition in the reservoir can be described by hydrodynamic models. Scheme of the such model is represented on the fig. 3. The X-axis is directed along the current of water reservoir and the Z axis is oriented in the direction from the bottom to its surface. The streams of conservative admixture are represented with respect to the cross section of the water body.

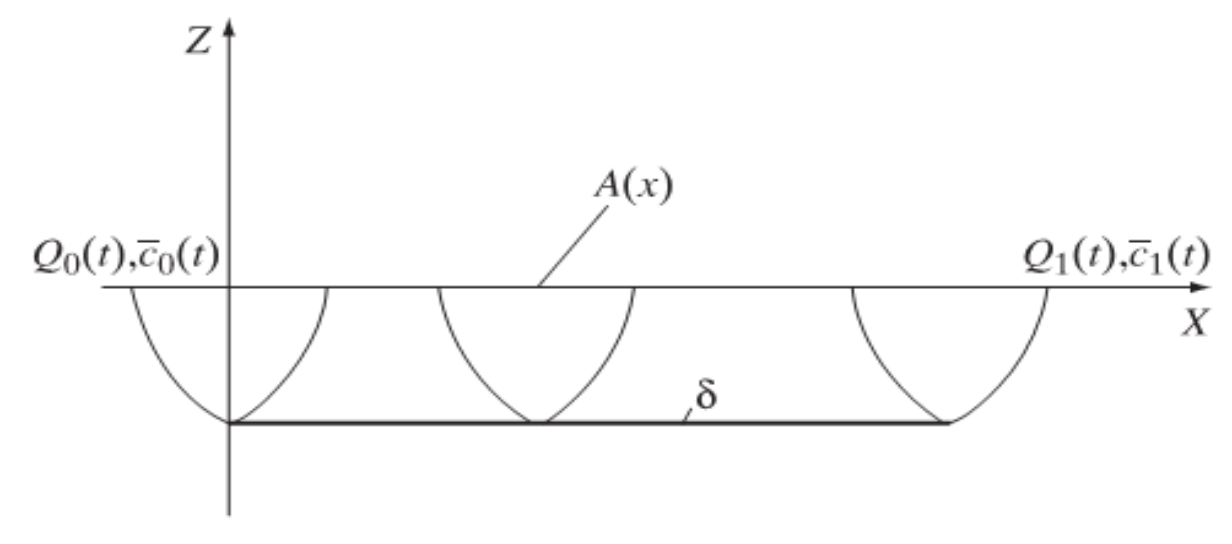


Fig.3. Scheme of the transverse-vertical section of the reservoir.

The physical and mathematical formulation of problems is based on the following equations.

*Water balance equation*

$$Q_0 = Q_1,$$

here: $Q_0$, $Q_1$ – water discharges respect to the cross section.

Scheme of the model supposes equal numerical values of water discharges in frames of water balance equation in respect to input and output cross sections:

*Equation for balance of ingredients in the water is represented by next view*:

$$Q_0(t)\bar{c}_0(t) + Sq_A(t) = Q_1(t)\bar{c}_1(t) + q_B(t)S\ ,$$

S - square water area, $m^2$;

$q_A$ , $q_B$ - the transport of suspended ingredients from the atmosphere to the bottom, kg / $m^2$ s.

*The convective-diffusion equation of conservation for average of the impurity concentration in the open flow has next view*:

$$\frac{\partial}{\partial t}(A\bar{c}) + \frac{\partial}{\partial x}(Au\bar{c}) = \frac{\partial}{\partial x}\left(AK_x\ \frac{\partial \bar{c}}{\partial x}\right) + (q_A - q_B)B,$$

here:

*B width of water reservoir, m;*

*$K_x$ - horizontal turbulent diffusion coefficient, $m^2/s$;*

u – flow velocity, m/s;

Obviously, of greatest interest is the flux of impurities on the bottom of techno-genic sediments:

$$q_B = \alpha \overline{c},$$

here:

$\overline{c}$ - the average concentration of particles respect to cross section A(x) of the reservoir;

α is the parameter of the settling velocity (fall diameter).

Accordingly, distribution of the average concentration of the weighed ingredients is calculated for water reservoir:

$$\overline{c} = \frac{q_A}{\alpha} + D_1 \exp(\lambda_1 x) + D_2 \exp(\lambda_2 x),$$

where:

$$\lambda_{1,2} = \left( Q \pm \sqrt{Q^2 + \frac{4\alpha K_x}{h}} \right) (2AK_x)^{-1},$$

$D_1, D_2$ - constants of integration,

*h* – depth of water reservoir.

Dynamics of aerosol accumulation of sediments in the reservoir during time is determined with help of equation:

$$\delta(t,x) = \int_0^t n \frac{q_B(x,t)}{\rho_b} dt$$

for $\delta_{t=0} = 0$

$\rho_b$ - density of suspended ingredients,

*n* – parameter porosity of sediments.

## CONCLUSIONS.

The presented theoretical justification of the accumulation of aerosol admixtures in the bottom sediments of a water body is used for practical purposes in the conditions of the Ivankovo reservoir.

## REFERENCES.

1. Izrael Израэль Y.A. Problems of anthropogenic ecology. Scientific aspects of Russia's environmental problems // Proceedings of the All-Russian Conference. Volume 1. M., 2001. - 624 p.(Rus).

2. Vavilin V.A. and others. Landfill as an excitable environment // Nature - №5, 2003. - P. 54-60. (Rus).

3.Ahmetieva N.P. Lapina E.E., Putirskiy V.E. Study of the influence of the landfill of Konakovo on the quality of natural waters. Industrial and municipal waste in the Tver region: environmental and technological aspects // Inform. Bulletin .- Tver: TSTU - No. 13, 2006. - P. 23-27.4. Brechovskich V., Putirskiy V. Investigation of the hydrodynamic interaction between river and sea water. Pros. Of Int. Conf. “Civil Engineering and Environment”. Vilnius, 1994, p.44. (Rus).

5. Eistma D. Suspended matter in the aquatic environment: Springer-Verlag, Berlin, 1993, 315 p.

6. Kueper B.N., Wealthall G.P., Smith J.W.N., Leharne S.A., Lerner D.N. An illustrated handbook of DNAPL transport and fate in the subsurface. Anvironment Agency R D Publication No. 133, Bristol, 2003. 64p.

7. Simons T.J. Verification of numerical models of lake Ontario. J. of the Phys. Oceanogr. 1976, v.6, p. 372-378.

# PREDICTION A DISCHARGE HYDROGRAPH DUE TO DAM FAILURE BY A TWO-DIMENSIONAL SHALLOW FLOW MODEL

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## ABSTRACT:

*The paper is dedicated to study of problem of dam break simulation, which must be used for estimation of life safety. Finite Volume Method (FVM) is applied to solve two Dimensional Shallow Water Equations (2D SWE) on structured mesh. Flux difference splitting method is utilized to* construct numerical solvers of SWE. *Besides, semi implicit method is used to solve the friction source term. The effectiveness and robustness of the above scheme is verified by some reference tests to handle the main challenges involved in the numerical simulation, such as: capturing discontinuities in the flow field without spurious oscillations, satisfying C-property and robust tracking of wet/dry fronts. A well-known test case Malpasset (France) and a case study of Thuong Tien reservoir - Hoa Binh province (Vietnam) are implemented to simulate flood hydrographs of dam collapsed scenarios.*

**Keywords**: Finite Volume Method; Flux difference Splitting Method; Discharge hydrograph

## 1. INTRODUCTION

Construction dams and reservoirs with several purposes, such as: hydroelectric production, water storage for consumption or irrigation, flood mitigation, etc. has been an important issue of water resources management in many countries. Along these benefits, however, dams pose serious flooding risks for downstream area if they collapse. The real case studies, such as: Gleno, Italy (1923); Malpasset, France (1959), etc. caused many dead and catastrophic consequences are remarkable examples when dam collapsed. Thus, the estimation of the flood wave due to the breaking of a dam, for instant: outflow hydrograph, maximum water depth, flood arrival time is an important requirement to build an early-warning tool for downstream area. Especially, breach hydrograph is considered as a necessary input data to compute flood propagation to downstream valley. In this paper, the most applicable numerical method, Finite Volume Method (FVM) is implemented to simulate it.

FVM is considered as the most applied numerical strategy to simulate most complicated shallow water flow phenomena, for instant: transcritical and supercritical flows; discontinuous type flow or moving wet/dry front, etc. The effectiveness

and robustness of the presented scheme are demonstrated by comparing numerical results with analytical solutions of the reference test cases, indicating good application aspects. Then, a well-known test case Malpasset (France) is applied to obtain outflow hydrograph and flooding map and a case study of Thuong Tien reservoir - Hoa Binh province (Vietnam) are implemented to simulate flood hydrographs of dam break scenarios.

## 2. NUMERICAL MODEL

### 2.1. Governing mathematical scheme.

The conservation form of 2D SWE can be written as [5]:

$$\frac{\partial \mathbf{U}}{\partial t}+\frac{\partial \mathbf{K}(\mathbf{U})}{\partial x}+\frac{\partial \mathbf{H}(\mathbf{U})}{\partial y}=\mathbf{S}_1(\mathbf{U})-\mathbf{S}_2(\mathbf{U}) \tag{1}$$

In (1), **U** is the vector of conserved variables; **K** and **H** are flux vectors. $h$ is flow depth, $u$ and $v$ are the velocity components in $x$ and $y$ directions.

$$\mathbf{U}=\begin{bmatrix} h \\ hu \\ hv \end{bmatrix};\ \mathbf{K}(\mathbf{U})=\begin{bmatrix} hu \\ hu^2+0.5gh^2 \\ huv \end{bmatrix};\ \mathbf{H}(\mathbf{U})=\begin{bmatrix} hv \\ huv \\ hv^2+0.5gh^2 \end{bmatrix} \tag{2}$$

and $\mathbf{S_1}$ is bed slope term and $\mathbf{S}_2$ friction term:

$$\mathbf{S}_1(\mathbf{U})=\begin{bmatrix} 0 \\ ghS_{0x} \\ ghS_{0y} \end{bmatrix};\ \mathbf{S}_2(\mathbf{U})=\begin{bmatrix} 0 \\ ghS_{fx} \\ ghS_{fy} \end{bmatrix}, \tag{3}$$

in which $S_{0x}$, $S_{0y}$, $S_{fx}$, $S_{fy}$ are bed slopes and friction slopes along the same directions; $g$ is the acceleration due to gravity.

$$S_{0x}=-\frac{\partial z_b}{\partial x};\ S_{0y}=-\frac{\partial z_b}{\partial y};\ S_{fx}=\frac{n^2u\sqrt{u^2+v^2}}{h^{4/3}};\ S_{fy}=\frac{n^2v\sqrt{u^2+v^2}}{h^{4/3}} \tag{4}$$

where $z_b$ is bottom elevation; $n$ is Manning roughness coefficient.

### 2.2. Numerical scheme

The flow variables are updated to a new time step by the Eq. 5, based on Godunov type:

$$\mathbf{U}_{i,j}^{n+1} = \mathbf{U}_{i,j}^{n} - \frac{\Delta t}{\Delta x}\left[\mathbf{K}_{i+1/2,j} - \mathbf{K}_{i-1/2,j}\right] - \frac{\Delta t}{\Delta y}\left[\mathbf{H}_{i,j+1/2} - \mathbf{H}_{i,j-1/2}\right] + \Delta t\mathbf{S}_{1i,j} - \Delta t\mathbf{S}_{2i,j} \tag{5}$$

where superscripts denote time levels; subscripts *i* and *j* are space indices along *x* and *y* directions; $\Delta t$, $\Delta x$, $\Delta y$ are time step and space sizes of the computational cell.

Flux Difference Splitting method is proposed by [6], which construct numerical solvers of SWE. The discretisation is performed so that retains an exact balance between flux gradients and source terms; Roe scheme is selected for approximation flux terms.

Taking into account the flux vector **K** in *x* direction and its Jacobian matrix **A**, two matrices **M** and $\mathbf{M}^{-1}$ can be constructed with the property to diagonalize the Jacobian **A**:

$$\mathbf{A} = \mathbf{M}\Lambda\,\mathbf{M}^{-1} \tag{6}$$

Where $\Lambda$ is a diagonal matrix with eigenvalues of matrix **A** in the main diagonal:

$$\Lambda = \begin{pmatrix} u-c & 0 & 0 \\ 0 & u & 0 \\ 0 & 0 & u+c \end{pmatrix} \tag{7}$$

The matrix **M** has the form:

$$\mathbf{M} = \begin{pmatrix} 1 & 0 & 1 \\ u-c & 0 & u+c \\ v & c & v \end{pmatrix} \tag{8}$$

Matrix $\Lambda$ is split into $\Lambda^{+}$ and $\Lambda^{-}$ so that $\Lambda = \Lambda^{+} + \Lambda^{-}$, where $\Lambda^{\pm} = \left(\Lambda \pm |\Lambda|\right)/2$ , we can rewrite the Jacobian matrix **A** as:

$$\mathbf{A} = \mathbf{M}\left(\Lambda^{+} + \Lambda^{-}\right)\mathbf{M}^{-1} \tag{9}$$

The above expression is basis of *Flux Difference Splitting Method.*

The numerical flux in *x* direction, for example, can be evaluated as:

$$\mathbf{H}_k^* = \frac{1}{2}\left[(\mathbf{H})_R + (\mathbf{H})_L - \left|\tilde{\mathbf{A}}\right|(\mathbf{U}_R - \mathbf{U}_L)\right] \tag{10}$$

The approximate Jacobian matrix $\tilde{\mathbf{A}}$ is not directly used in the actual method. Instead, the difference in the vector **U** across the grid edge is decomposed on the matrix eigenvectors basis. Considering the *x* direction:

$$\Delta\mathbf{U} = \mathbf{U}_R - \mathbf{U}_L = \sum_{m=1}^{3} \alpha^m \tilde{\mathbf{R}}^m \tag{11}$$

$$\left|\tilde{\mathbf{A}}\right|(\mathbf{U}_R - \mathbf{U}_L) = \sum_{m=1}^{3} \left|\tilde{\lambda}^m\right| \alpha^m \tilde{\mathbf{R}}^m \tag{12}$$

Where expression of coefficients $\alpha^m$ are:

$$\begin{cases} \alpha^{1,3} = \dfrac{h_R - h_L}{2} \pm \dfrac{1}{2\tilde{c}}\left[\left((hu)_R - (hu)_L\right) - \tilde{u}(h_R - h_L)\right] \\ \alpha^2 = \dfrac{1}{\tilde{c}}\left[\left((hv)_R - (hv)_L - \tilde{v}(h_R - h_L)\right)\right] \end{cases} \tag{13}$$

*R* and *L* denote the right and the left states at the right cell and left cell, respectively. As suggested by [7], $\tilde{\mathbf{A}}$ represents the approximate Jacobian of the normal flux **A** but is evaluated at an average states.

Both right eigenvector $\tilde{\mathbf{R}}$ and eigenvalue $\tilde{\lambda}$ are estimated by average values of water depth (*h*), velocities (*u*,*v*) and celerity (*c*), these values can be obtained as:

$$\tilde{u} = \frac{\sqrt{h_R}u_R + \sqrt{h_L}u_L}{\sqrt{h_R} + \sqrt{h_L}};\ \tilde{v} = \frac{\sqrt{h_R}v_R + \sqrt{h_L}v_L}{\sqrt{h_R} + \sqrt{h_L}};\ \tilde{c} = \sqrt{\frac{g}{2}(h_R + h_L)} \tag{14}$$

The eigenvalues $\tilde{\lambda}$ have to satisfy the following *entropy condition*:

$$\text{If} \quad \left|\tilde{\lambda}^{1,3}\right| < \varepsilon^{1,3} \rightarrow \left|\tilde{\lambda}^{1,3}\right| = \varepsilon^{1,3},$$

where

$$\varepsilon^{1,3} = \max\left(0, \tilde{\lambda}^{1,3} - \lambda_L^{1,3}, \lambda_R^{1,3} - \tilde{\lambda}^{1,3}\right) \tag{16}$$

In order to retain an exact balance between the flux gradients, the discretisation approach should be adopted to model the bottom variations by the same way with flux term when this is appropriate, source term $\widetilde{\mathbf{S}}_1$ should be decomposed into inward and outward contributions in the same way of flux term:

$$\widetilde{\mathbf{S}}_{1k}^{\pm} = \widetilde{\mathbf{M}}(\mathbf{I} \pm \left|\widetilde{\mathbf{\Lambda}}\right|\widetilde{\mathbf{\Lambda}}^{-1})\widetilde{\mathbf{M}}^{-1}\widetilde{\mathbf{S}}_{1k} \text{ with } k \text{ is } x \text{ or } y \text{ direction.} \tag{17}$$

Rewriting bed slope term:

$$\widetilde{\mathbf{S}}_1 = \widetilde{\mathbf{S}}_{1x} + \widetilde{\mathbf{S}}_{1y} = \begin{bmatrix} 0 \\ g\tilde{h}S_{0x} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ g\tilde{h}S_{0y} \end{bmatrix} \tag{18}$$

where

$$S_{0x} = -\frac{\Delta z_{bx}}{\Delta x};\ S_{0y} = -\frac{\Delta z_{by}}{\Delta y} \tag{19}$$

and $\Delta z_{bx} = \left(z_{bR} - z_{bL}\right)_x;\ \Delta z_{by} = \left(z_{bR} - z_{bL}\right)_y$ with $\tilde{h} = \frac{1}{2}\left(h_R + h_L\right)$

In *x* direction:

$$\widetilde{\mathbf{S}}_{1x} = \widetilde{\mathbf{S}}_{1x}^{+} + \widetilde{\mathbf{S}}_{1x}^{-}$$

$$= -\frac{1}{4\tilde{c}} g\tilde{h}\frac{\Delta z_{bx}}{\Delta x}\left\{\begin{bmatrix} sign(\tilde{u}+\tilde{c}) - sign(\tilde{u}-\tilde{c}) \\ 2\tilde{c} + |\tilde{u}+\tilde{c}| - |\tilde{u}-\tilde{c}| \\ \tilde{v}\left[sign(\tilde{u}+\tilde{c}) - sign(\tilde{u}-\tilde{c})\right] \end{bmatrix} + \begin{bmatrix} -sign(\tilde{u}+\tilde{c}) + sign(\tilde{u}-\tilde{c}) \\ 2\tilde{c} - |\tilde{u}+\tilde{c}| + |\tilde{u}-\tilde{c}| \\ \tilde{v}\left[-sign(\tilde{u}+\tilde{c}) + sign(\tilde{u}-\tilde{c})\right] \end{bmatrix}\right\} \tag{20}$$

Similarly, in *y* direction:

$$\widetilde{\mathbf{S}}_{1y} = \widetilde{\mathbf{S}}_{1y}^{+} + \widetilde{\mathbf{S}}_{1y}^{-}$$

$$= -\frac{1}{4\tilde{c}} g\tilde{h} \frac{\Delta z_{by}}{\Delta y} \left\{ \begin{bmatrix} sign(\tilde{v}+\tilde{c}) - sign(\tilde{v}-\tilde{c}) \\ \tilde{u}\left[sign(\tilde{v}+\tilde{c}) - sign(\tilde{v}-\tilde{c})\right] \\ 2\tilde{c} + |\tilde{v}+\tilde{c}| - |\tilde{v}-\tilde{c}| \end{bmatrix} + \begin{bmatrix} -sign(\tilde{v}+\tilde{c}) + sign(\tilde{v}-\tilde{c}) \\ \tilde{u}\left[-sign(\tilde{v}+\tilde{c}) + sign(\tilde{v}-\tilde{c})\right] \\ 2\tilde{c} - |\tilde{v}+\tilde{c}| + |\tilde{v}-\tilde{c}| \end{bmatrix} \right\} \quad (21)$$

Hence, the final numerical solution obtained by this scheme is represented:

$$\mathbf{U}_i^{n+1} = \mathbf{U}_i^n - \frac{\Delta t}{\Delta x}\left(\mathbf{K}_{i+1/2,j} - \mathbf{K}_{i-1/2,j}\right) - \frac{\Delta t}{\Delta y}\left(\mathbf{H}_{i,j+1/2} - \mathbf{H}_{i,j-1/2}\right)$$
$$+ \Delta t(\mathbf{S}^+_{1x(i+1/2,j)} + \mathbf{S}^-_{1x(i-1/2,j)}) + \Delta t(\mathbf{S}^+_{1y(i,j+1/2)} + \mathbf{S}^-_{1y(i,j-1/2)}) - \Delta t \cdot \mathbf{S}_2 \quad (22)$$

To avoid unphysical solution, friction terms should be discretized by semi-implicit scheme, as follow by Eq. 23:

$$S^*_{fx} = 0.5(ghS_{fx})^n + 0.5(ghS_{fx})^{n+1}$$
$$S^*_{fy} = 0.5(ghS_{fy})^n + 0.5(ghS_{fy})^{n+1} \quad (23)$$

The stability condition for the numerical scheme governed by the Courant–Fredrichs–Lewy (CFL) criterion. For Cartesian grids, the time step $\Delta t$ is controlled by Eq. 24:

$$\Delta t = Cr\left[\max\left(\frac{|\tilde{u}| + \sqrt{g\tilde{h}}}{\Delta x} + \frac{|\tilde{v}| + \sqrt{g\tilde{h}}}{\Delta y}\right)\right]^{-1} \quad (24)$$

where $Cr$ is the Courant number specified in the range $0<Cr\leq 1.0$.

Roe method does not yield the correct flux at a boundary between a wet and dry cell, [4]. According to [3], a proper way to deal with this problem is used the technique of local redefinition of the bottom level difference at the interface to fulfil the mass conservation equation.

## 3. VALIDATION

### 3.1. Preservation of still water surface

C-property is considered as one of the most important requirements that the numerical scheme should be satisfied. According to [2], for hydrostatic condition water

elevation remains constant and discharge value equals zero during computational time. An interesting test is described in [9] to verify well balancing property of proposed schemes. The computational domain is 50*m* long. Reflecting condition is imposed at both upstream and downstream ends.

The bottom elevation is defined by the following expression:

$$z_b(x) = \begin{cases} -0.0513\,x + 4 & \text{if} \quad 0 \le x \le 15m \\ -0.0762\,x^2 + 3.2108\,x - 27.766 & \text{if} \quad 15m \le x \le 29m, \\ 0.4824\,x - 14.472 & \text{otherwise} \end{cases} \tag{25}$$

Two cases for initial water elevation are considered: Case 1: H = 10*m*, bottom is fully submerged accordingly to Singh's work; Case 2: H = 5*m*, bed is partly submerged. A uniform grid size $\Delta x = 0.5m$ is used for the simulation.

The results shown in Fig. 1 were obtained by the proposed scheme. The numerical solution of water elevation remains at 10*m* and 5.0*m* and unit discharge is exactly equal to $0.0 m^2/s$ during the computational time. Thus, the presented models satisfy exact C-property.

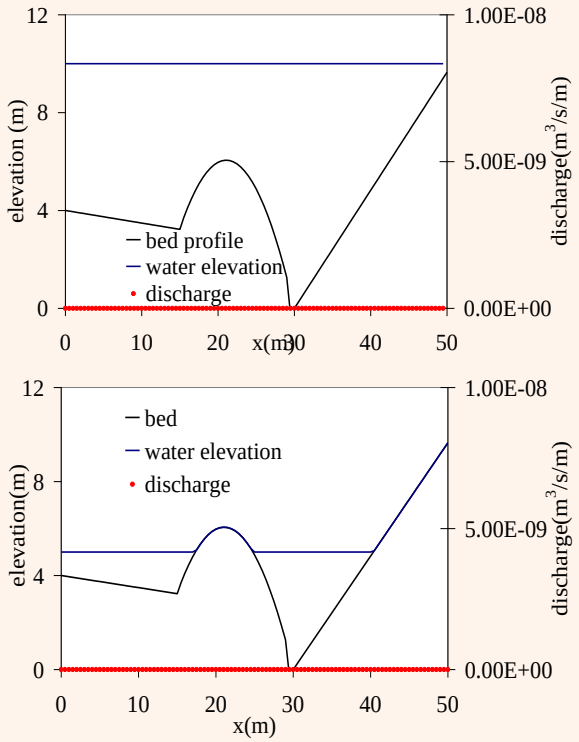



**Figure 1:** *Still water.*

### 3.2. Evolution of shorelines over a frictional parabolic topography

This interesting test allows verifying the behavior of the numerical model in dealing with bed slope and friction source terms as well as wetting and drying. The domain topography is defined by:

$$z_b(x) = h_0 (x/a)^2 ,$$

(26)

In which $h_0$ and $a$ are constants. The analytical solution is originally presented by [8] and later by [10] depending on a bed friction parameter $\tau$ and $a$ hump amplitude parameter $p = \sqrt{8gh_0/a^2}$ . In this case, friction term is calculated by the equation: $S_f = -\tau \cdot h \cdot u$ .

The numerical simulation is performed on a domain 10000$m$ long. No boundary conditions are necessary because the flow never reaches the boundaries. For the case with $\tau < p$, the initial conditions of water elevation and velocity are imposed by a set of equations in Eq. 27:

$$\eta(x,0) = \max\left( z_b(x);\ \ h_0 + \frac{a^2 B^2 e^{-\tau t}}{8g^2 h_0}\left(\tau^2/4 - s^2\right) - \frac{B^2 e^{-\tau t}}{4g} - \frac{e^{-\tau t/2}}{g}(Bs)x \right)$$
$$u(x,0) = 0$$

(27)

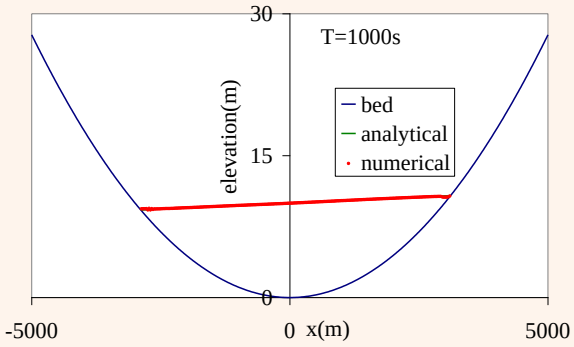
And the analytical time history of the water surface elevation is:

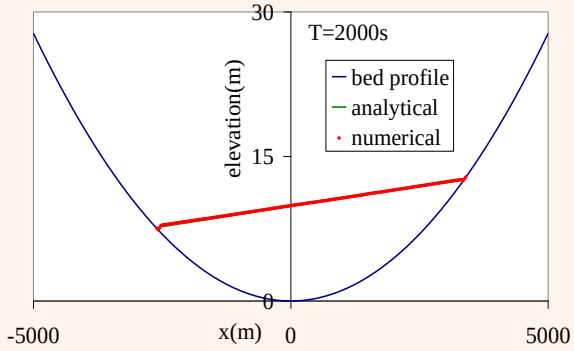
$$\eta(x,t) = h_0 + \frac{a^2 B^2 e^{-\tau t}}{8g^2 h_0}\left(-s\tau \sin 2st + \left(\tau^2/4 - s^2\right)\cos 2st\right) - \frac{B^2 e^{-\tau t}}{4g} - \frac{e^{-\tau t/2}}{g}\left(Bs\cos st + \frac{\tau B}{2}\sin st\right)x$$

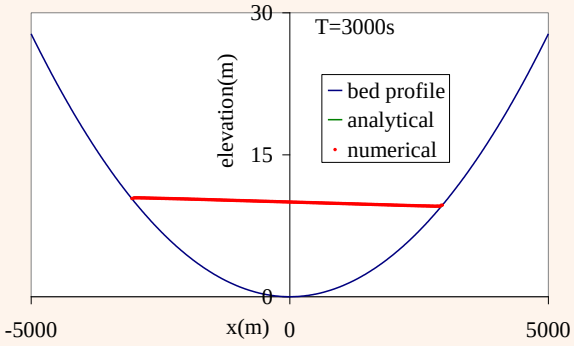
(28)

where parameter $B$ is a constant and $s = \sqrt{p^2 - \tau^2}/2.$

The relevant coefficients are selected as: $a$ = 3000$m$, $h_0$ = 10$m$, $\tau$ = 0.001s$^{-1}$ and $B$ = 5$m/s$. Numerical time simulation of 6000$s$ is taken the same as [10].


30
T=1000s
elevation(m)
bed
analytical
numerical
15
0
-5000
0 x(m)
5000


30
T=2000s
elevation(m)
bed profile
analytical
numerical
15
0
-5000
x(m)
0
5000


30
T=3000s
elevation(m)
bed profile
analytical
numerical
15
0
-5000
x(m)
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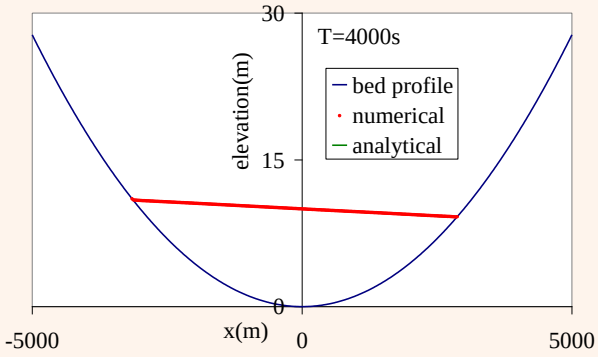
5000


30
T=4000s
elevation(m)
bed profile
numerical
analytical
15
0
-5000
x(m)
0
5000

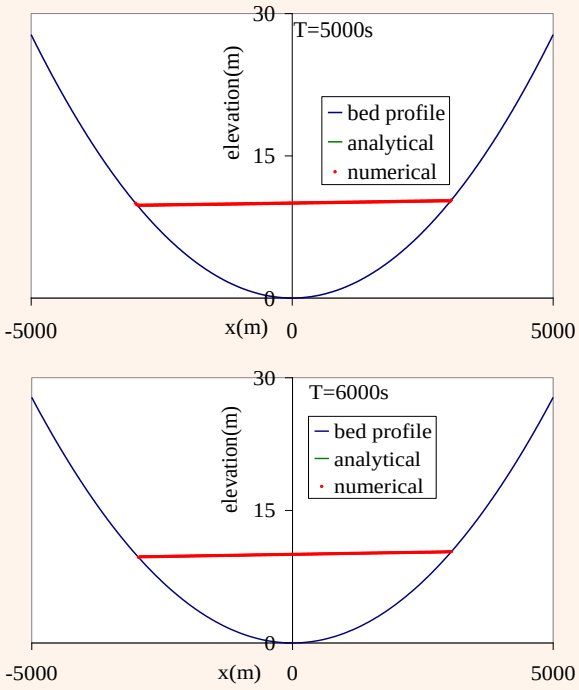



**Figure 2:** *Sloshing motions in a vessel with parabolic bottom topography.*

Fig. 2 shows the predicted water surface elevation obtained by Roe scheme at difference output times on a uniform grid with 400 cells. Excellent agreement is observed between numerical predictions and analytical solutions. The wet/dry interfaces are correctly reproduced, thus validating the well-balanced wetting and drying algorithm.

## 4. APPLICATION

### 4.1. Malpasset test case.

In order to validate the capability of the presented model in simulating dam break flows referring to field-scale case studies, the well-known test case of Malpasset (France) is taken as a reference test. Actually, observed data as well as experimental results obtained by physical modeling are available for this dam break event. Malpasset case study, had a 66.5$m$ high arch dam with a crest length of 233$m$ and the maximum reservoir capacity of $55\times10^{6}m^{3}$. The dam failure occurred during the night of 2$^{nd}$ December 1959 because of heavy rain in the preceding days. A total of 433 casualties were reported.

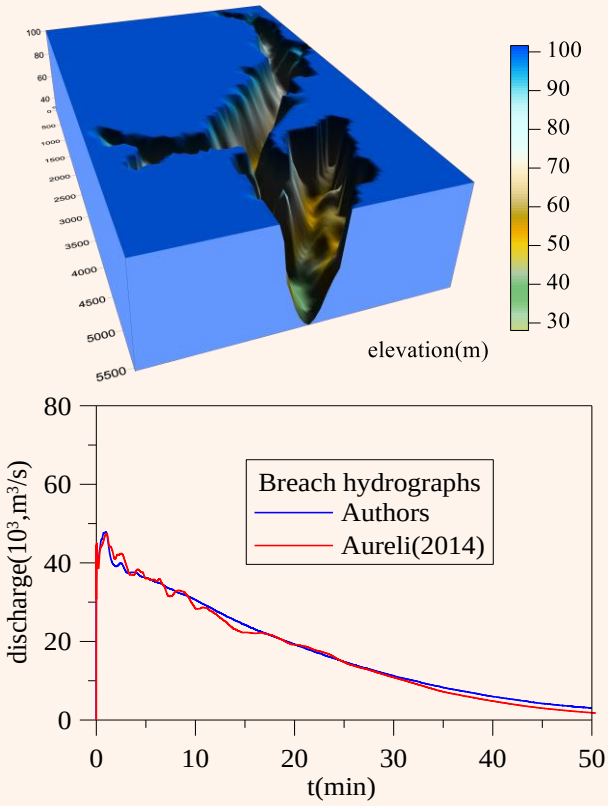



**Figure 3.** *a) Bed geometry of Malpasset reservoir; b) Breach hydrograph of total dam break.*

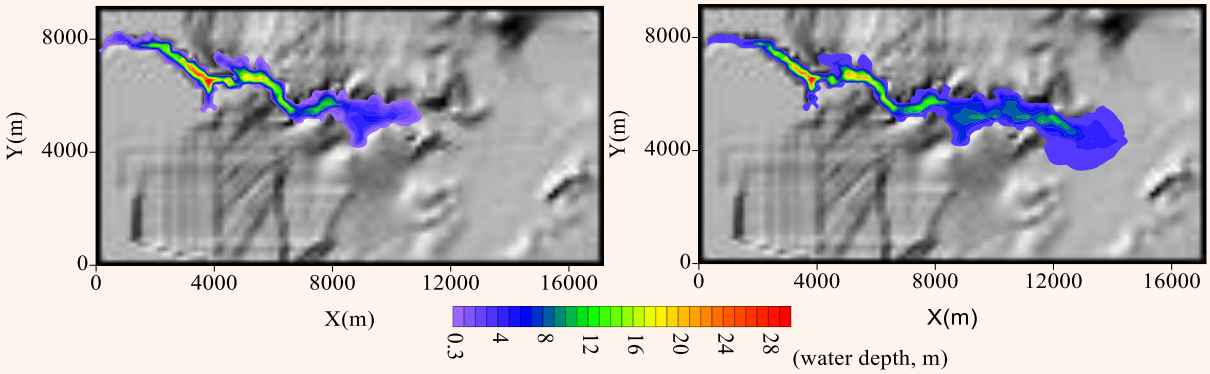



**Figure 4.** *Predicted inundation maps at different times: 1200s and 2280s.*

The numerical model was applied to compute the discharge hydrograph at dam site, allowing a comparison with the result published by [1]. For this purpose, a computational domain of regular grid size $10m \times 10m$ was used (Fig. 3a). A close agreement between predicted solution of breach hydrograph simulated by the proposed scheme and the numerical result in Aureli's work can be observed. On the other hand, the peak discharge predicted by the numerical model is about $48000 m^3/s$ and is fairly close to the estimation of $45000 m^3/s$ assumed by the CADAM workgroup. Also, the flooding maps at t=1200*s* and t=2280*s* are generated by this present scheme (Fig. 4).

### 4.2. Thuong Tien dam break scenario

Thuong Tien reservoir constructed by Vietnam Hydraulic Engineering Consultants Corporation Company (HEC) is located in Boi River in Kim Boi district – Hoa Binh province (Fig. 5a). Its responsibility is to irrigate 1300ha of agricultural area and supply water to 20000 inhabitants. Thus, it plays an important role on the economical development of this province. However, the total storage capacity of Thuong Tien reservoir of $13.31\times10^6 m^3$ can cause potential catastrophic consequences for downstream area if its dam collapses. Therefore, simulating dam break flood propagation should be considered to build early warning scenarios for downstream area if reservoir's dam breaks.

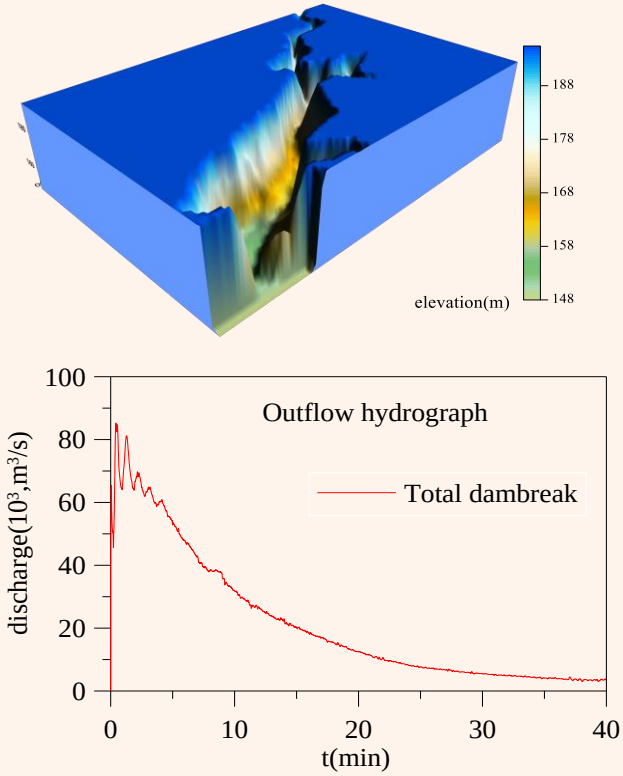



**Figure 5.** *a) Bed geometry of Thuong Tien reservoir; b) Breach hydrograph of total dam break scenario.*

In this work, the most dangerous hypotheses are set up: extreme water elevation at reservoir is +194.22*m*. Water depth at downstream is set to equal zero and the total dam collapses instantaneously.

According to (Fig. 5b), the peak of discharge is around $85000 m^3/s$ and emptying time is around 40 minutes in case of total dam break scenario. This hydrograph can be used as input data for hydraulic simulation of flood propagation to downstream area if its geometry is available. Since then, alternative early warning scenarios can be built which ensure life safety if the damage of dam occurs.

## 5. CONCLUSIONS

The estimation hydraulic characteristic such as outflow hydrograph, flooding map, etc. is necessary for constructing early warning scenarios for downstream area if dam of reservoir breaks. In this work, FVM is selected to generated a model to deal with this purpose. By two tests presented in this paper, the scheme demonstrated to behave satisfactorily with respect to their effectiveness and robustness in simulating free surface flows on complex topographies. A real case study of Malpasset (France) is simulated to obtain outflow hydrograph and flooding map. The numerical solutions are quite close with others in different works. Then, Thuong Tien reservoir (Vietnam) is utilized to generate the breach hydrographs of total dam collapse. In further study, if geometry of its downstream is available, the flooding map will be generated.

## REFERENCES


[1] F. Aureli; A. Maranzoni; P. Migosa (2014). A semi-analytical method for predicting the outflow hydrograph due to dam-break in natural valleys. Advances in Water Resources,.63, 38-44.

[2] A. Bermudez and M.E. Vaquez (1994). Upwind methods for hyperbolic conservation laws with source term. *Computers Fluids*, 23(8), 1049-1071.

[3] P. Brufau; M.E. Vaquez Cendon; P. Garica–Navarro (2002). A numerical model for flooding and drying of irregular domains. *Int. J. Numer. Meth. Fluids*. 39, 247 – 275 (DOI: 10.1002/fld.285).

[4] S.F. Bradford and B. Sander (2002). Finite Volume Model for Shallow Water Flooding of Arbitrary Topography. *Journal of Hydraulic Engineering (ASCE).* 128**(**3), 289- 298.

[5] J.A Cunge, F.M Holly, A. Verwey (1980). Practical aspects of computational river hydraulics. *London: Pitman Publishing Limited*.

[6] M.E. Hubbard and P. Garcia Navarro (2000). Flux difference splitting and the balancing of source terms and flux gradients. *Journal of Computational Physics,*. 165, 89–125.

[7] P.L. Roe. (1981). Approximate Riemann Solvers, parameter vectors and difference schemes. *Journal of Computational Physics*, 43, 357-372.

[8] J. Sampson; A. Easton; M. Singh (2006). Moving boundary shallow water flow above bottom topography. *ANZIAM (EMAC2005),*. 47, C373-C387.

[9] J. Singh; M.S. Altinakar; Yan Ding (2011). Two dimensional numerical modelling of dam break flows over natural terrain using a central explicit scheme. *Advances in Water Resources*, 34, 1366-1375

[10] L. Song, J. Zhou, Q. Li, X. Yang, Y. Zhang (2010). An unstructured finite volume model for dam-break floods with wet/dry fronts over complex topography. *Int. J. Numer. Meth. Fluids*, 67, 960-980.