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An analysis of Organic Matter form waste water by mathematical model of Laplace Transform

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Abstract:

This paper presents major accomplishment of research over all past years in the field of Bio- Mathematics. In this paper we analyzed waste water of different sites and described a mathematical relation between organic matter and salinity by interpolation with Laplace Transform.

Kew Words: Heavy Metals, salinity, Organic Matter, pH in water, Mathematical Model ,Interpolation , Laplace Transform etc.

Introduction:

The relationship between salinity and organic matter in aquatic ecosystems can have significant implications for the overall health and functioning of these environments. Salinity refers to the concentration of dissolved salts, primarily sodium chloride, in water. Organic matter, on the other hand, comprises the decaying remains of plants and animals or any other material derived from living organism.

Decomposition Rates: Salinity levels can affect the rate at which organic matter decomposes. Generally, higher salinity levels tend to inhibit decomposition processes. This is because salt ions can disrupt microbial activity responsible for breaking down organic matter. Consequently, organic matter accumulates at a slower rate in saline environments compared to freshwater systems.

Preservation: In some cases, increased salinity can facilitate the preservation of organic matter. High salinity levels can create conditions that hinder the growth of decomposers, such as bacteria and fungi, which would otherwise consume organic matter. As a result, organic matter can accumulate and persist over longer periods, leading to the formation of deposits such as peat or oil shale.

Organic Matter Quality: Salinity can affect the quality and composition of organic matter. In marine environments, high salinity levels can lead to the dominance of certain types of organic matter, such as dissolved organic carbon (DOC). This can impact the food web structure and nutrient cycling processes within the ecosystem. Additionally, variations in salinity can influence the types of organisms present, which, in turn, affect the composition and characteristics of organic matter.

Nutrient Cycling: Salinity can influence nutrient availability and cycling, which can have cascading effects on organic matter dynamics. For example, high salinity can limit the availability of essential nutrients, such as nitrogen and phosphorus, which are necessary for organic matter decomposition and microbial activity. This limitation can result in reduced breakdown of organic matter and altered nutrient cycling patterns in saline environments.

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Biodiversity: Salinity levels also influence the diversity and composition of organisms within an ecosystem. Different species have varying tolerance levels to salinity, and their presence or absence can influence the quantity and quality of organic matter inputs. Biodiversity, in turn, can affect the decomposition rates, nutrient dynamics, and overall functioning of the ecosystem.

Waste water is enriched with organic and inorganic substances, including heavy metals from domestic areas (Ref.7). Rapid industrialization and urbanization all over the country has led to regional and global redistribution of metals with consequent environmental pollution. Organic matter is used as a growth substrate for fungi (Ref. 6,8). Dissolved organic matter is highly heterogeneous in nature and ranges from less than 500 to more than 5000Da in molecular weight (Ref.4).

Microbial population is mostly heterotrophic which grows on and affects solid and liquid waste. Generic composition and size are different for mycoflora. Physical and chemical characteristics vary with environmental condition for mycoflora (Ref

5). They produce enzymes for the decay of waste/pollutants. pH and temperature are major a biotic factors which affect fungal growth, development and activity. The term "hemophilic" denotes their affinity for high temperature. That means that organisms can grow optimally above 45°C.They are very few and have been divided into two mains categories: true thermophiles and thermotolerants (Ref.1, 2). One of the prerequisites for a more complete control and exploitation of these fungi is temperature, which is the most important variable in their environment. Fungi are also used as adsorbent/absorbents to remove heavy metals from municipal, sewage (Ref 2) and industrial waste water (Ref.7). Heavy metals can interact with microbial cells and there are reports that they accumulate these substances as a result of some physico-chemical mechanism and trans-port systems, depending directly and indirectly on metabolism of the microbes.

It's important to note that the specific interactions between salinity and organic matter can vary depending on the type of ecosystem, such as freshwater, brackish water, or marine environments, as well as other factors like temperature, light availability, and nutrient inputs. Understanding these relationships is crucial for assessing and managing the health of aquatic ecosystems and their services to humans and the environment.

To establish a mathematical function where salinity is the dependent variable and organic matter is the independent variable, so we use a regression analysis to determine the relationship between the two variables.

Material and Method:

Waste water samples were aseptically collected in sterilized bottles from different collecting sites of Bareilly City-Uttar Pradesh (India) listed below:

Pond water sites: Izzahat Nagar , Delapeer, Kargaina, Dhopeswarnath,Nekpur.

Municipal sites: Bakarganj, Ramganga chaubari , rahpura, Shubhas Nagar, gulab Nagar.

Sewage sites: Qila, Nakatiya, Harunagla.

The above sites are around the Bareilly City from U.P. (India). The temperature of these water bodies was analyzed at the collection time (6:00am - 8:00am) by thermometer and their pH by systronic μ pH meter 361. Percent of organic matter was analyzed by Walkey and Black's method (1947), using the following formula:

$$X\% = \frac{6.791}{w}\left(1 - \frac{T_1}{T_2}\right), for\ every\ T_1, T_2, w \neq 0$$

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Where, X% is organic matter percentage, T_1 is titration reading, T_2 is Blank reading.

Salinity percentage was calculated by the following formula:

$$Salinity\ (\%) = \frac{w_2 - w}{w_1 - w}\ X\ 100, here\ w_1 \neq w$$

Where 'w' is pre weighted Petri plate, 'w_1' is the weight of water and the Petri plate, 'w_2' is the weight of the Petri plate after evaporation of the water sample at 80^0C (24 hrs).(Ref.9)

Direct and Indirect method (Ref.11) was used for isolation of hemophilic fungi using YPSs (Yeast Extract Soluble Starch) medium at pH 7.0. Three replicates were taken for each sample. Petri plates were incubated at 40^0C. After appearing in fungal forms, they were isolated and maintained on agar medium slants in the pure forms at 4^0C. Colonies were identified using microscope and available literature. Fungi use the organic matter as nutrient. Frequency of fungi shows presence of organic matter in water/soil/waste substances.
Now, we would use a mathematical relation for the salinity and organic matter.

Table 1. Environmental parameters of Pond Sites in Year-2022.

Collection site	Month	April	August	Dec	April
Izzatnagar	Temperature (^{o}C)	26.2	32.9	9.8	29.7
	pH	7.8	7.6	8.9	8.3
	OM(%)	1.028	2.101	0.613	0.839
	Salinity	7.1	8.5	3.9	6.8
	TNF	201	276	189	98
Delapeer	Temperature (^{o}C)	29.1	32.7	8.79	29.5
	pH	8.9	9.2	7.3	7.9
	OM(%)	1.356	3.021	1.986	1.5
	Salinity	7.4	6.2	4.9	4.3
	TNF	201	243	97	92
Kargaina	Temperature (^{o}C)	29.4	33.1	9.3	30.2
	pH	8.3	8.7	7.9	7.1
	OM(%)	2.001	1.368	1.9	0.973
	Salinity	7.2	4.9	5.89	6.9

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	TNF	241	198	96	91
Dhopeshwarnath	Temperature (ºC)	27.9	33.1	8.9	30.3
	pH	8.1	9.4	7.6	8.7
	OM(%)	2.103	1.98	1.824	0.86
	Salinity	4.1	4.9	1.82	2.67
	TNF	168	173	99	94
Nekpur	Temperature (ºC)	26.5	34.2	9.4	28.6
	pH	8.9	8.5	6.9	7.9
	OM(%)	0.691	1.051	0.624	2.315
	Salinity	3.1	6.3	1.9	2.9
	TNF	198	101	92	98

TNF = Total number of fungal colonies, OM% = organic matter percentage.

Table 2. Environmental parameters of municipal water in Year-2022.

Collection site	Month	April	August	Dec	April
Bakargali	Temperature (ºC)	26.1	33.5	9.8	29.7
	pH	8.6	8.2	7.9	7.5
	OM(%)	1.315	1.486	0.637	0.869
	Salinity	4.1	4.6	1.9	1.5
	TNF	162	156	201	232
RamgangaChabari	Temperature (ºC)	26.6	31.9	9.8	29.6
	pH	8.3	8.6	7.5	6.9
	OM(%)	3.15	1.75	1.95	2.61
	Salinity	3.8	4.5	3.5	1.9
	TNF	216	91	89	105
Rehpura	Temperature (ºC)	26.4	32.1	8.6	28.7
	pH	8.3	9.1	7.5	7.8
	OM(%)	1.386	1.024	0.648	0.976
	Salinity	7.2	7.9	5.9	4.7
	TNF	256	195	116	69
Subhashnagar	Temperature	26.4	33.1	9.5	28.6

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	(ºC)				
	pH	9.2	9.6	7.5	7.1
	OM(%)	1.154	1.589	0.216	0.462
	Salinity	2.9	5.8	1.7	1.5
	TNF	113	159	54	89
Gulabnagar	Temperature (ºC)	26.8	32.9	8.6	29.4
	pH	9.5	8.4	7.6	6.5
	OM(%)	2.114	1.364	0.863	0.927
	Salinity	6.1	7.2	5.9	4.7
	TNF	138	265	179	138

TNF=Total number of fungal colonies, OM%= organic matter percentage

Table 3. Environmental parameters of sewage sites in Year-2022.

Collection site	**Month**	**April**	**August**	**Dec**	**April**
Harunagla	Temperature (ºC)	30.9	32.6	10.5	30.8
	pH	9.1	8.8	7.5	8.2
	OM(%)	1.539	1.861	0.493	0.947
	Salinity	4.3	4.8	1.9	1.7
	TNF	168	147	91	178
Qila	Temperature (ºC)	26.1	31.7	9.5	31.2
	pH	8.2	8.5	7.3	7.6
	OM(%)	3.08	1.83	0.95	1.69
	Salinity	3.8	4.5	3.9	1.82
	TNF	216	93	82	103
Nakatiya	Temperature (ºC)	25.8	32.1	8.9	28.8
	pH	8.5	8.7	6.9	7.4
	OM(%)	1.035	0.943	0.647	0.869
	Salinity	7.1	7.9	5.8	4.5
	TNF	241	152	110	68

TNF=Total number of fungal colonies, OM%= organic matter percentage

Mathematical model: During the chemical analysis in laboratory we found As, Pb , Cd, Hg etc harmful compound. We are going to a mathematical model for it. In table 1, we take some practical analytic data of Izzat Nagar and describe a function between salinity and Organic matter and trying to find a mathematical function by using Newton divided Difference formula, here salinity(S) of water is depend on organic matter(OM) so we consider a mapping

$$f:(OM) \rightarrow Salinity$$

$$\rightarrow Salinity = f(OM) \ldots (1)$$

Let salinity denoted by y and OM denoted by x,

Then we simply consider: $y = f(x) \ldots (2)$

On describing this function on practical data by Newton Divided Difference formula so first we defined divided difference and this formula.

Interpolation is an estimation of a value within two known values in a sequence of values. Newton's divided difference interpolation formula is an interpolation technique used when the interval difference is not same for all sequence of values. Suppose $f(x_0)$, $f(x_1)$, $f(x_2)$………$f(x_n)$ be the (n+1) values of the function y=f(x) corresponding to the arguments $x=x_0$, x_1, $x_2 \ldots x_n$, where interval differences are not same,

Then the first divided difference is given by

$$f(x_0, x_1) = \frac{f(x_1) - f(x_0)}{x_1 - x_0}$$

Second Divided difference is given by

$$f(x_0, x_1, x_2) = \frac{f(x_1, x_2) - f(x_0, x_1)}{x_2 - x_0}$$

Third divided difference is given by

$$f(x_0, x_1, x_2, x_3) = \frac{f(x_1, x_2, x_3) - f(x_0, x_1, x_2)}{x_3 - x_0}$$,…similarly we can derive n^{th} divided difference.

In the same way we can derive Newton divided difference formula:

$$f(x) = f(x_0) + (x - x_0)f(x_0, x_1) + (x - x_0)(x - x_1)f(x_0, x_1, x_2) + (x - x_0)(x - x_1)(x - x_2)\, f(x_0, x_1, x_2, x_3) + \cdots \qquad \ldots (3)$$

Now we define divided difference table:

Web Source :https://www.google.com/search?q=divide+difference+table&oq

x	$f(x)$	First divided differences	Second divided differences	Third divided differences
x_0	$f[x_0]$			
		$f[x_0,x_1]=\dfrac{f[x_1]-f[x_0]}{x_1-x_0}$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]=\dfrac{f[x_1,x_2]-f[x_0,x_1]}{x_2-x_0}$	
		$f[x_1,x_2]=\dfrac{f[x_2]-f[x_1]}{x_2-x_1}$		$f[x_0,x_1,x_2,x_3]=\dfrac{f[x_1,x_2,x_3]-f[x_0,x_1,x_2]}{x_3-x_0}$
x_2	$f[x_2]$		$f[x_1,x_2,x_3]=\dfrac{f[x_2,x_3]-f[x_1,x_2]}{x_3-x_1}$	
		$f[x_2,x_3]=\dfrac{f[x_3]-f[x_2]}{x_3-x_2}$		$f[x_1,x_2,x_3,x_4]=\dfrac{f[x_2,x_3,x_4]-f[x_1,x_2,x_3]}{x_4-x_1}$
x_3	$f[x_3]$		$f[x_2,x_3,x_4]=\dfrac{f[x_3,x_4]-f[x_2,x_3]}{x_4-x_2}$	
		$f[x_3,x_4]=\dfrac{f[x_4]-f[x_3]}{x_4-x_3}$		$f[x_2,x_3,x_4,x_5]=\dfrac{f[x_3,x_4,x_5]-f[x_2,x_3,x_4]}{x_5-x_2}$
x_4	$f[x_4]$		$f[x_3,x_4,x_5]=\dfrac{f[x_4,x_5]-f[x_3,x_4]}{x_5-x_3}$	
		$f[x_4,x_5]=\dfrac{f[x_5]-f[x_4]}{x_5-x_4}$		
x_5	$f[x_5]$			

Now on the basis of equation 1 and 2 we use this interpolation formula for the given practical data in table 1.First we analysis Environmental parameters of Pond Sites in Year-2022-23 of Izzatnagar only, we take two component from table 1, salinity(S) and Organic matter (OM) as above salinity is denoted by y and OM by x, in this reference we can say salinity is the function of organic matter.(We take the values of organic matter and salinity only one decimal places)

Month	x(OM)	y(Salinity)=f(x)
April -22	1.0	7.1
August-22	2.1	8.5
December-22	0.6	5.9
April -23	0.8	6.8

Now we ignore the month for mathematical analysis of above data, re-arrange the data mathematically in sequencing and construct divided difference table:

Divided Difference table:(considered values only one decimal places by mathematics approximation theory)

x(OM)	y(Salinity)=f(x)	Ist-divided difference	IInd-divided difference	IIIrd divided difference
0.6(x_0)	5.9	$\frac{6.8-5.9}{.8-.6}=4.5$	$\frac{1.5-4.5}{1.0-0.6}=-7.5$	$\frac{-.2+7.5}{2.1-.6}=4.9$
0.8 (x_1)	6.8	$\frac{7.1-6.8}{1-.8}=1.5$	$\frac{1.3-1.5}{2.1-.8}=-0.2$	
1.0(x_2)	7.1	$\frac{8.5-7.1}{2.1-1}=1.3$		
2.1(x_3)	8.5			

Now we have Newton divided difference formula:

$$\boldsymbol{f(x) = f(x_0) + (x-x_0)f(x_0,x_1) + (x-x_0)(x-x_1)f(x_0,x_1,x_2) + (x-x_0)(x-x_1)(x-x_2)\,f(x_0,x_1,x_2,x_3) + \cdots}$$

$$\boldsymbol{f(x) = 5.9 + (x-0.6)X(4.5) + (x-0.6)(x-0.8)X(-7.5) + (x-0.6)(x-0.8)(x-1.0)X(4.9)}$$

$$f(x) = 5.9 + 4.5\,x - 2.7 - 7.5x^2 + 10.5x - 3.6 + 4.9x^3 - 11.76x^2 + 9.212x - 2.352$$

$$f(x) = 4.9x^3 - 19.26x^2 + 24.212x - 2.752$$

Now by mathematical approximation theory we take all the values of this cubic polynomial at one decimal places only, therefore

$f(x) = 4.9x^3 - 19.3x^2 + 24.2x - 2.8\ldots\ldots\ldots$ (4)

Now we use Laplace transform$L\{f(x)\} = \int_0^\infty e^{-px} f(x)dx$, where p is any complex number, t is any real non zero positive number. So

Taking Laplace of equation (4)

Then $L\{f(x)\} = 4.9\, L\{x^3\} - 19.3L\{x^2\} + 24.2L\{x\} - 2.8L\{1\}$

$$L\{f(x)\} = 4.9X\frac{6}{p^4} - 19.3X\frac{2}{p^3} + 24.2X\frac{1}{p^2} - 2.8X\frac{1}{p}$$

$$L\{f(x)\} = \frac{29.4}{p^4} - \frac{38.6}{p^3} + \frac{24.2}{p^2} - \frac{2.8}{p} \ldots\ldots(5)$$

Here we see as $p \to \infty$, $L\{f(x)\} \to 0$ ….(6)

Results and Discussion: During the mathematical analysis we model the data of. Environmental parameters of Pond Site (Izzat Nagar) in Year-2022-23 from table 1. From equation 4 we got a cubic polynomial for this data by Newton Divided difference formula, this is a perfect relation between organic matter and salinity that is we can say when organic matter increased(The compound which increased salinity), salinity increased as a cubic polynomial describe in equation 4.

Now we use Laplace transform technique to transform the salinity parameters therefore after taking Laplace transform of equation 4,we got the new relation given in equation 5,here p is the parameter of those compounds which are use in reaction against salinity that is these compound p(Activated carbon , Potassium chloride ,gypsum , calcium chloride, phosphogypsum waste etc) will help to remove the salinity from the water so by this technique we can directly define the purity of water without any technical instrument or we can say without computing by just only putting the compounds data and we can know about salinity of water, so easily we can remove the salinity as like water purifier or we can say if we functioning this technique in to the purifier easily purify the water and also analysis the purity .Similarly we analysis all pond sites and sewage site,muniscipal water we found the similar results. So we can say from equation 6 $if\ p \to \infty\ means\ compound\ which\ remove\ the\ salinity$, $L\{f(x)\} \to 0$, means salinity is nearby zero that is we found fresh water to drink by simple mathematical calculation. The equation 6 is also verified by the initial value theorem of Laplace transform.

Conclusion:

The application of Laplace transform, coupled with use of specific compounds, provides a powerful tool for effectively combating salinity in sewage water. This

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approach offers a promising solution for obtaining fresh water by removing salinity, thus addressing a critical challenge in water treatment.

This technique allows us to mathematically analyze the behavior and response of salinity parameters in a transformed domain. By transforming the salinity-related equations, we gain valuable insights into the dynamics and characteristics of the system. This enables us to design targeted strategies and optimize the use of compounds that are effective in removing salinity from sewage water.

Specific compounds such as activated carbon, potassium chloride, gypsum, calcium chloride, and phosphogypsum waste play crucial roles in this process. Activated carbon, for instance, possesses exceptional adsorption properties, which enable it to selectively remove salts and impurities from water. Potassium chloride can be utilized as a coagulant, aiding in the precipitation and removal of dissolved salts. Gypsum, calcium chloride, and phosphogypsum waste can act as flocculants, facilitating the aggregation and settling of suspended particles and salt precipitates.

By incorporating these compounds into the treatment process, we can significantly reduce the salinity levels in sewage water, ultimately producing fresh water suitable for a variety of purposes, including drinking, irrigation, and industrial use. This approach offers a sustainable and cost-effective solution to the problem of salinity, as it harnesses the power of chemistry and mathematical analysis to achieve efficient and precise water purification.

Furthermore, use of Laplace transform and compound-based treatments provides an adaptable framework that can be tailored to specific water sources and salinity profiles. This flexibility allows for customized solutions that can be applied in various geographical regions with distinct salinity challenges.

Use of Phosphogypsum, which is a waste by-product released from various industries and can cause harm to environment if not decomposed properly, can be utilized in reducing salinity from waste water and hence can help in altering the damages caused by it.

In conclusion, application of Laplace transform and use of specific compounds offer a promising approach to combat salinity in sewage water. By leveraging mathematical analysis and targeted chemical treatments, this approach enables the

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removal of salts and impurities, resulting in the production of fresh water for a wide range of applications. It represents a significant advancement in water treatment technology and contributes to the sustainable management of water resources worldwide.

Future Aspects: There are major research available in Bio-Mathematics and Bio-statistics. In this paper we also used approximation theory and Laplace Transform ,to get satisfactory results, but few of them approximate. In future we can model some statistical and graphical data to remove this approximation.

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