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Research Paper

Experimental Study and Statistical Analysis of Parameters Influencing Dissolution Kinetics of Naturally Grown and Surgically Removed Kidney Stone

Physics

KEYWORDS :

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ABSTRACT

Kidney stone formation is a biological process that involves complex crystallization phenomena. Various factors contribute to the formation of kidney stone in human body. For better understanding of mechanism of crystal growth formation, dissolution kinetics study were carried out using morphological investigation technique on naturally grown and surgically removed kidney stones.

Experimentation on these kidney stones was conducted at different temperature with various solutions and dissolution kinetics were monitored by measuring etch pit density. Based on Regression analysis, etch pit density as a dependent variable of independent variables stone type, solution and location was established.

Introduction

Urinary stones have afflicted mankind since ancient times. It is estimated that in India nearly 2 million people are affected with kidney stone. Also, there is a 20% probability of re-occurrence of kidney stone in such patients. There have been remarkable technological advances in the field of medical science for treatment of kidney stones. Few such examples are Lithotripsy and Endourology. However, curative techniques are frequently employed, advances in prevention or pre-mature dissolution of kidneys stones has not gain pace due to our lack of understanding of the causes of stone formation.

Jungers et.al. [1] in their work suggested that in human urine, occurrence of Calcium Oxalate Monohydrate (COM) and Calcium Oxalate Dihydrate (COD) depends also on the molar ratio of calcium and oxalate. Dorian et. al. [2] observed evidence of aggregation in Oxalate stone formation using SEM. Recent work in this field involves studies of kidney stone dissolution using different chemicals. Dalia et. al. [3] in their work investigated ability of Hibiscus sabdariffa flower extracts to inhibit crystallization of COM crystals. Iswar Das et. al.[4] used bio-functional plant extracts in study of dissolution of tri-calcium phosphate (TCP).

Researchers all across the globe have tried various combinations of solutions and studied dissolution kinetics of kidney stones. Until the kidney stone is not surgically removed from the body and tested, exact chemical composition cannot be ascertained. There are about seven types of kidney stone identified based on the chemical composition. It is imperative for the medical practitioner to have a good judgment of the type of stone carried by the patient before administering the appropriate drug. This also makes it crucial to have a drug with universal effect and can cater to all or at least most of the type of kidney stone materials. Such a drug would remove the element of uncertainty pertaining to the type of stone material and will benefit the patient by avoiding the otherwise time lost in trial and error of combination of drugs. Also, proactive measures can then be taken easily to avoid re-occurrence of the kidney stone in future which poses a far more serious threat to the patient.

In the present work efforts to establish statistical dependence of etch pit density as a dependent variable over independent variables type of stone, location and solution is undertaken.

Experimentation Study

Experimental Setup

A glass beaker cleaned with dil. HCl solution and rinsed with distilled water was de-moisturized with the help of a hair dryer. Slices of various kidney stones were derived using a diamond based rotating round blade which runs at a uniform speed under the continuous flow of water to avoid overheating of the surface. These thick wafers were polished with fine emery paper to derive an optically reflected surface suitable for experiment and viewing under a microscope. Metallurgical research microscope with high resolution camera and labovision software tool was used to study the specimen. The software commands the camera to take a snapshot of the etched specimen and measures size and number of etch pits at the site under observation. This data is transferred on an Excel Utility. Using statistical tool SPSS, regression analysis was performed on the experimental data.

Methodology

Table 1 shows the parameters showing the scope of present work. Three types of kidney stone were studied with five types of solutions at different temperature ranges.

Experiments were first conducted on all the three type of stones using these etchants at room temperature under different etching time of specimen. Specimen was held up in solution from 5 sec. to 35 sec. in steps of 5 sec. It was observed that maximum number of etch pits were observed at 15 sec. etching time. Accordingly, etching parameter was held constant at 15 sec. for rest of experiments.

Table 1 - Parameters of Experimental study

Kidney stone type	1) Calcium Oxalate Monophosphate COM 2) Calcium Oxalate Diphosphate COD 3) Struvite ST
Solution	1) Orthophophoric acid (OPA) 2) Tri-potassium phosphate (TPP) 3) Sodium Benzoate (SBZ) 4) Sodium Methyl Paraben (SMP) 5) Sodium Propyl paraben (SPP)
Location	SG region Saurashtra region

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Observations & Discussion

Data analysis

Data obtained from the Labovision utility was tabulated at various temperature values. This data represents the widths of etch pits. On an average, etch pits were found in the range of 250 to 1000 nos. Of these, etch pits which were square in nature were considered for further analysis.

Data thus obtained was appropriately filtered and the average of these was taken as the reference width to plot the graph of natural logarithm of width (in microns) on y-axis and inverse of temperature (in Kelvin) on x-axis. Data was used to perform regression analysis as under:

Dependent variable: Etch pit density

Independent variables: Location, stone type, solution

Statistical analysis

Linear regression was performed on the data set. Table 2 shows the list of variables entered as independent variables. Table 3 shows the model summary. R square observed for the model is 0.125. Table 4 shows the ANOVA results of regression. Significance is less than 0.001. Table 5 shows the coefficient table for the regression results.

Density = 324.204 + 17.145 * Solution + 18.692 * Location + (-9.855) * Type

Above equation shows the regression model of etch pit density as a dependent variable.

Based on R square value, the model explains 12.5% of dependence of etch pit density over variables solution, location and type of stone.

Table 2: Variables Entered / Removed

Model		Variables Entered	Variables Removed	Method
dimension0	1	TYPE, SOLUTION, LOCATION[a]	.	Enter
a. All requested variables entered.				
b. Dependent Variable: DENSITY				

Table 3: Model Summary

Model		R	R Square	Adjusted R Square	Std. Error of the Estimate
dimension0	1	.354[a]	0.125	0.115	61.407
a. Predictors: (Constant), TYPE, SOLUTION, LOCATION					

Table 4: ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	143613.342	3	47871.114	12.695	.000
	Residual	1003024.765	266	3770.770		
	Total	1146638.107	269			

Table 5: Coefficients[a]

Model B		Unstandardized Coefficients		Standardized Coefficients		Sig. Tolerance	Collinearity Statistics	
		Std. Error	Beta		t		VIF	
	(Constant)	324.204	17.514		18.511	.000		
	SOLUTION	17.145	3.222	.306	5.321	.000	.993	1.007
	LOCATION	18.692	7.901	.143	2.366	.019	.897	1.115
	TYPE	-9.855	4.736	-.126	-2.081	.038	.902	1.108

Conclusions & Future work

It can thus be concluded that etch pit density is dependent on location of stone, solution used and type of kidney stone. While this explains 12.5% of kidney stone weathering in solution there is still a significant part of variability which needs to be discovered.

Future work should be directed towards identifying further parameters that explains the weathering of kidney stone. Other solutions should also be tried for performance. Statistical analysis should be performed with another set of data on similar experiments to establish robustness of the existing data set.

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