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Comparative Studies on Physical Properties of Urine and Urine-Oxalic Acid Mixture of Healthy Individual and Patients Suffering from Urinary Calculi

P.C. SHUKLA* and D.K. CHAUBE
Biophysical Laboratory, Department of Chemistry
St. Andrews Post Graduate College, Gorakhpur, 273 001, India

Physical properties such as density, viscosity, surface tension, pH, and specific electrical conductivity of urine of healthy individual and urine of patients suffering from gall bladder stones and kidney stones have been measured. It has been found that basic physical properties differ significantly in the case of healthy individual and those of people suffering from urinary calculi. Urines were incubated with goat bladder membranes to measure physical properties. It has been found that while density and specific electrical conductivity decrease continuously with increase in oxalic acid concentration in urine, other properties show oscillatory behaviour at certain concentrations of oxalic acid in urine.

INTRODUCTION

Urine is a multi-component system[1–3]. Urinary bladder acts as a reservoir for urine and its primery function is passive collection and active expulsion of urine. The constituents of urine decide the frequency of urination in infection and also decide the functions of the body in both normal and pathological states. Physical properties of solutions are a fair measure of structural behaviour and their probable interactions with interface of various kinds[4–6]. The interphase region[7] has new properties and new structures as compared to bulk properties of solutions. Thus it becomes possible to predict interaction of the permeant with bladder interface. Since urinary process may be explained in terms of pressure[8] and electrical potentials, chances of adsorption of some constituents with urinary bladder interface cannot be ruled out.[9–12] During the adsorption process, capillaries may be filled which are not completely emptied at the same pressure on desorption[13]. Physical properties such as specific electrical conditivity and dielectric constant measurements have been used to predict calculi formation.[14, 15] The present attempt is to include a number of other physical properties in predicting stone forming tendencies in various individuals. As pH appears to be a controlling factor with respect to composition of calculi, physical properties of urine-oxalic acid mixture have been measured. Since cause of calculus formation is not known and it has been suggested that renal calculi develop when lymphatic drainage mechanism is overloaded or inefficient[16], attempts have been made to examine the role of physical properties for such situations. As generation of micturition wave leads to excretion of urine and stasis or sluggish flow of urine may be a factor for stone formation, emphasis has been made on inefficient functioning of the bladder due to changes in compositions of urine.[17]

Except gall bladder stones calculi occur in the renal pelvis or ureter or in the bladder, attempts have been made to explain probable causes of loose interactions of the permeant with interfaces which ultimately leads to nucleation and crystal growth. Since structural similarity of the bladder with renal pelvis, urethra and ureter exists and a large number of experimental studies have been made by us regarding interfacial behaviour of urinary bladder membranes, attempts have been made to study the behaviour of such systems taking urinary bladder as a model.

EXPERIMENTAL

Urine of three sets of individuals has been chosen. 12 h (night to morning) samples have been collected and preserved with formaldehyde solution.[2] The first set consists of urine of healthy individual aged 25 years. The second set consists of urine of a female aged around 35 years, suffering from gall bladder stones and the third set consists a boy of 15 years suffering from kidney stones. The experiment has been repeated thrice *i.e.*, three sets of urine of each at different days have been collected, preserved and experiments carried out. Every care has been taken to see that food habits practically remain the same.

Physical properties measured are density, viscosity, surface tension, pH and specific electrical conductivity, respectively.

The three sets of density measurement have been carried out with the help of pyknometer maintained at 30°C with the help of thermostat. Surface tension has been measured with the help of *Stalagmometer* and viscosity by viscometer. pH has been measured with the help of digital pH meter while conductance has been measured with the help of digital conductometer. For calibrating pH meter and conductometer use of buffer solutions and aqueous KCl solutions has been made.

In the case of urine-oxalic acid mixture, urine of healthy individuals have been taken and different volumes of 0.01 N oxalic acid have been mixed.

Membrane chosen is of urinary bladder of goat. Its characteristics have been preserved using formaline-alcohol system as described earlier[18]. In the highly organized animals (both invertebrates and vertebrates), three basic processes concerned with urine formation (filtration, reabsorption and secretion) are not unique to vertebrates; they also occur in many invertebrates. Kidneys even-though structures concerned are different. In view of this goat bladder membrane may give useful information. Presence of gall bladder and kidney stones have been verified by X-ray photographs.

RESULTS AND DISCUSSION

Gall bladder stones are formed from constituents of the bile-cholesterol, bile pigments and calcium salts in various proportions along with other organic material. Although exact mechanism of stone formation remains debatable and it seems likely that changes in the composition of bile, local factors in the gall bladder and biliary tract infection are predisposing causes.

Factors which favour the formation of renal stones are the following[16]:

(i) increased concentration in the urine of stone forming crystalloids,
(ii) abnormally low or high urine pH,
(iii) presence of protective substances in the urine,
(iv) urinary tract obstruction with stasis of urine.

Although a number of metabolic and nonmetabolic factors[19] are responsible for stone formation, the role of urinary bladder in stone formation need be studied in detail.

Calculi occur in the renal pelvis or ureter or in the bladder, although some of the latter originate in the kidneys and subsequently enlarge in the bladder. An analysis of observation reveals[14] that in the case of stone formers there is a fault in solute transformation system in the kidney at the membrane level. It has been suggested that renal calculi develop when lymphatic drainage mechanism is overloaded or ineffficient. The most common cause of urinary stones is chronic infection of the urinary tract with urea splitting organism. The process of stone formation may be explained in terms of chemical laws of nucleation, crystal growth and particle aggregation.[20]

The concentration of materials, or products or ions in a liquid system may be one of the three zones:

(i) below the solubility of liquid phase in which case the solution is undersaturated;
(ii) above the solubility level and below the level of spontaneous precipitation;
(iii) above the solubility level in which case solution is oversaturated and spontaneous precipitation must occur.

It is probably oversaturation that gives rise to crystals which may be observed in the urine. The simplest model of stone formation is based on solubility consideration processes that occur in four stages. First there is nucleation phase during which crystal embryos are formed by spontaneous precipitation from urine excessively saturated with one of the salts.

Secondly there is a period during which primary crystallites grow and aggregate rapidly to form larger secondary particles.

Thirdly, one of these particles must become sufficiently large within transit time of urine through the urinary tract to become trapped at some narrow section.

Finally, this trapped particle acts as a focus or growth point for formation of urine.

Urinary bladder is an example of transitional epithelial tissue which has elastic muscular walls, and membranous folds. Such epithelia are found in urethra, ureter and renal pelvis. Thus understanding of the bladder may be helpful for understanding other parts of the body as well.

Since the composition of urine is a decisive factor in urinary calculi formation, the role of interfaces acquires prime importance as far as interaction of permeants with surfaces is concerned.

Results of physical properties of three sets of individuals have been given in Table-1. It has been found that various properties differ in every case. This may be due to a number of reasons.

TABLE-1
PHYSICAL PROPERTIES OF URINE

S. No.	Properties	Human urine without calculi	Human urine with gall bladder stone	Human urine with kidney stone
1.	Density (g/cm^3)	1.0067	1.0049	0.9979
2.	Surface tension (dynes/cm)	69.24	67.33	71.51
3.	Viscosity (poise $\times 10^{-3}$)	8.16	8.54	8.43
4.	Specific conductance (1×10^{-5} ohm^{-1} cm^{-1})	2.40	1.80	1.40
5.	pH	5.81	6.22	6.42
6.	EMF (mV)	072	048	036

The change in surface tension is reflective of a change in surface free energy and consequently many other properties of surfaces are changed as well. If a substance decreases free energy of the surface, then the solute will concentrate on the surface and surface tension will decrease. On the other hand, if solutes were to raise the surface tension of the solution, it would be unfavourable for it to concentrate at the surface. Change of surface tension with increase in concentration of oxalic acid is shown in Fig. 2. It has been observed that the presence of bile salts in urine causes lowering of surface tension.

TABLE-2
PHYSICAL PROPERTIES OF URINE-OXALIC ACID MIXTURE SYSTEM

S. No.	System	Density g/cm^3	Surface tension dyne/cm	Viscosity (Poise $\times 10^{-3}$)	pH	EMF
1.	100 mL urine	1.0067	69.24	8.16	5.81	072
2.	95 mL uring + 5 mL oxalic acid	1.0062	70.15	8.21	6.20	044
3.	90 mL urine + 10 mL oxalic acid	1.0060	69.66	8.18	6.18	055
4.	85 mL urine + 15 mL oxalic acid	1.0054	70.09	8.10	6.02	045
5.	80 mL urine + 20 mL oxalic acid	1.0046	67.75	8.25	6.13	060
6.	75 mL urine + 25 mL oxalic acid	1.0043	69.54	7.99	5.94	061
7.	70 mL urine + 30 mL oxalic acid	0.9999	74.40	7.93	5.95	064
8.	65 mL urine + 35 mL oxalic acid	0.9995	73.14	7.87	5.89	067
9.	60 mL urine + 40 mL oxalic acid	0.9996	73.88	8.70	5.80	072
10.	55 mL urine + 45 mL oxalic acid	0.9984	75.74	8.57	5.64	082
11.	50 mL urine + 50 mL oxalic acid	0.9900	75.71	8.42	5.55	087

S. No.	System	Density g/cm^3	Surface tension dyne/cm	Viscosity (Poise × 10^{-3})	pH	EMF
12.	45 mL urine + 55 mL oxalic acid	0.9978	77.12	8..48	5.55	087
13.	40 mL urine + 60 mL oxalic acid	0.9974	76.80	8.51	5.28	103
14.	35 mL urine + 65 mL oxalic acid	0.9984	77.10	8.28	5.29	102
15.	30 mL urine + 70 mL oxalic acid	0.9983	77.44	8.02	5.15	111
16.	25 mL urine + 75 mL oxalic acid	0.9977	77.75	8.22	4.96	122
17.	20 mL urine + 80 mL oxalic acid	0.9971	76.49	8.48	4.89	126
18.	15 mL urine + 85 mL oxalic acid	0.9967	75.61	8.42	4.52	148
19.	10 mL urine + 90 mL oxalic acid	0.9964	79.08	8.45	4.28	162
20.	5 mL urine + 95 mL oxalic acid	0.9958	78.67	8.27	3.78	192
21	100 mL oxalic acid	0.9955	70.59	7.85	3.32	219

pH and specific electrical conductivity decrease with increase in concentration of oxalic acid in urine as shown in Fig. 3 and 4. It has been observed earlier[15] that specific electrical conductivity of urine in stone formers is low as compared to that of non-stone formers. Thus pH and specific electrical conductivity have been chosen as a measure of stone forming tendency in the system.

TABLE-3
SPECIFIC ELECTRICAL CONDUCTIVITY OF URINE-OXALIC ACID SYSTEM

S. No.	System	Specific conductance (1 × 10^{-5} ohm^{-1} cm^{-1})	
		Human urine without calculi	Human urine with kidney stone
1.	100 mL urine	2.40	1.40
2.	90 mL urine + 10 mL oxalic acid	2.20	1.20
3.	80 mL urine + 20 mL oxalic acid	2.00	1.00
4.	70 mL urine + 30 mL oxalic acid	1.80	1.00
5.	60 mL urine + 40 mL oxalic acid	1.60	0.80
6.	50 mL urine + 50 mL oxalic acid	1.60	0.60
7.	40 mL urine + 60 mL oxalic acid	1.20	0.60
8.	30 mL urine + 70 mL oxalic acid	1.00	0.40
9.	20 mL urine + 80 mL oxalic acid	0.60	0.40
10.	10 mL urine + 90 mL oxalic acid	0.40	0.20
11.	100 mL oxalic acid	0.00	0.00

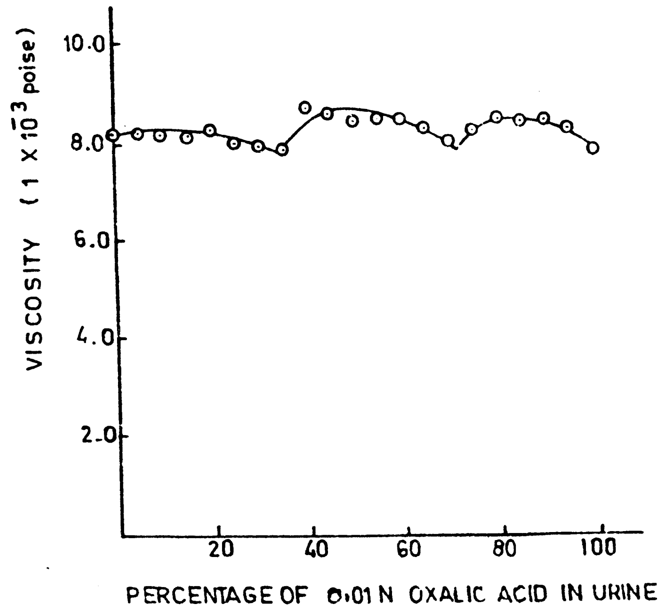

Fig. 1. Viscosity vs. composition of oxalic acid in urine

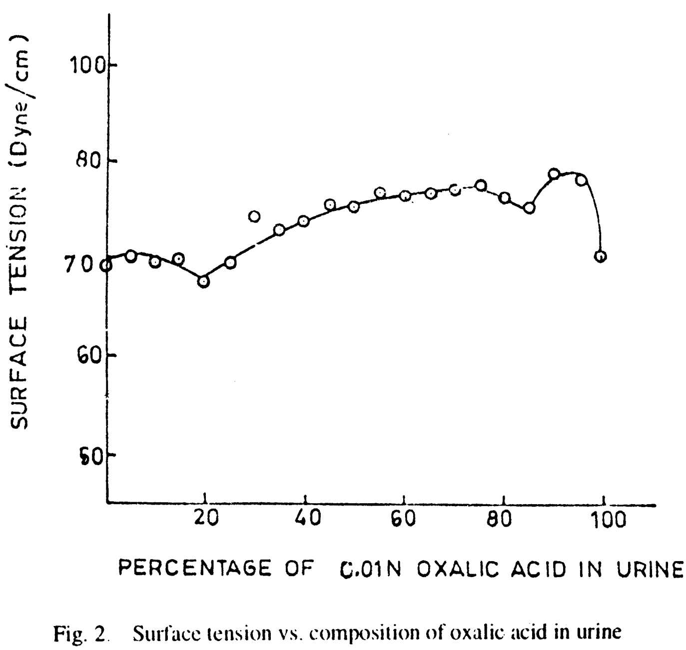

Fig. 2. Surface tension vs. composition of oxalic acid in urine

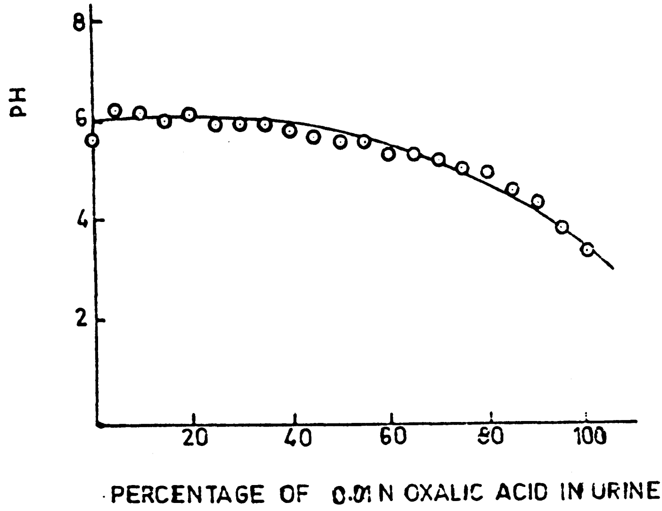

Fig. 3. pH vs. concentration of oxalic acid in urine

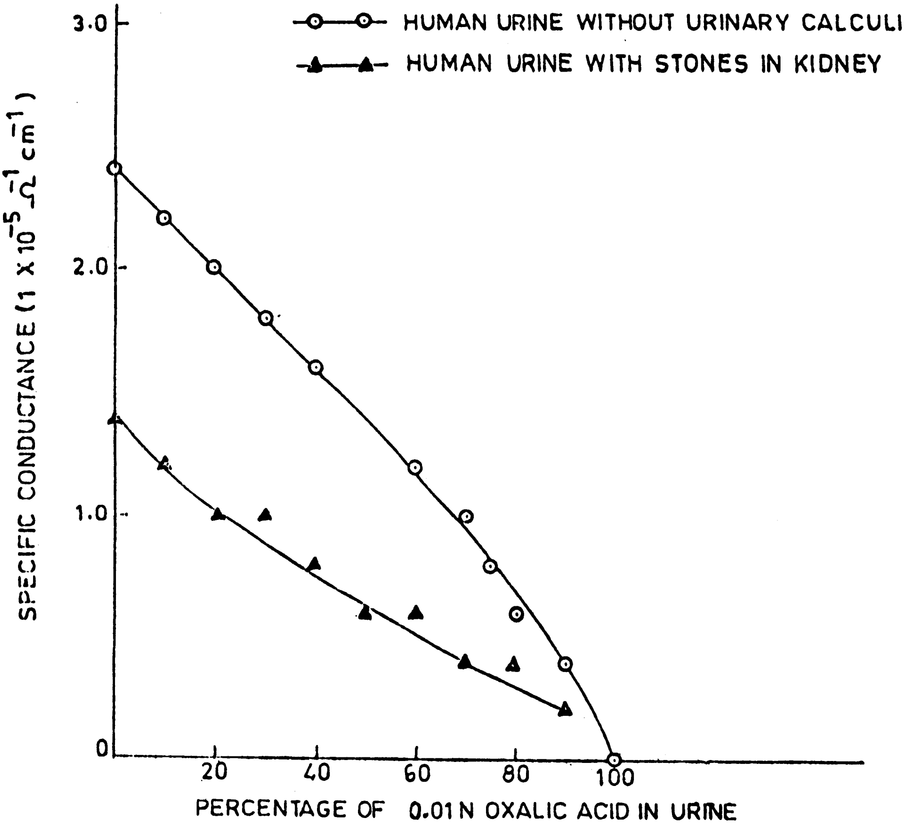

Fig. 4. Dependence of specific electrical conductivity against concentration of oxalic acid in urine

Since composition of stone varies markedly at different stages of development[21] and dietary patterns[22] have been implicated as a major contributor of the high prevalence of upper urinary tract stones, only mechanism of interaction of permeant with interface may be of some help.

Groups or sites on the membrane[23] surface in general are of weak acid type and so their ionization will depend on the pH of the medium in which they exist. The surface potential will alter the pH value at the surface. When surface potential is zero, membrane surface pH will be equal to the pH of the medium. If it is negative $pH_m < pH_b$ where 'm' represents membrane and 'b' bulk of solution.

Since urinary process is explained in terms of pressure and electrical potentials and these forces may act simultaneously in one or opposite directions, the bladder membrane experiences effects of these forces differently. The polarizability first increases with increase of pressure, reaches to certain maximum value and then starts decreasing as the bladder contracts.[24]

Thus resultant of surface potential and streaming potential decide the frequency of urination. Oscillatory behaviour of surface potential with certain concentrations shows loose interactions of the permeant with bladder interface, as a result of which force responsible for micturition becomes quite weak and ultimately leads to sluggish flow of urine from the bladder. Passive collection and active expulsion of urine from the bladder is restricted up to certain concentration of constituents of urine.[25-27] The moment concentration changes abruptly, the behaviour of bladder undergoes drastic changes.

The results of the measurements may be summarized as follows:

Renal calculi develop when lymphatic drainage mechanism is overloaded or insufficient as a result of which some disorder in the solute transfonnation system in the kidney takes place at the membrane level. Since the structural behaviour of renal pelvis, ureter, urethra and urinary bladder is quite similar, studies of interfacial potential and other physical properties are of great relevance. The very fact that the oscillatory behaviour of oxalic acid-urine mixture is limited to certain composition only shows that it develops interactions with bladder/ureter/reneal pelvis interface. It is probably this region in which the particle gets trapped and acts as a growth point. The sticky behaviour of urine-oxalic acid mixture is further confirmed from the electrokinetic measurements[28] in which it has been observed that oxalic acide has a tendency to move inwards whereas other permeants such as urea, glucose etc. have reverse trend.

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