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# Road Vehicular Traffic (RVT) Model Analogy with Diffusion through Porous Skin/Hide/Leather Media: Possible Solutions

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***Abstract*** **- There is a growing demand for finding solutions for transport processes. Skin/hide/leather (S/H/L) is a unique porous material arranged in a three dimensional weave pattern. Leather processing involves diffusion of various chemicals through the pores of the hide/skin/leather matrix. Since most of the unit operations in leather processing are diffusion controlled, diffusion plays a vital role in leather making. It is very important to have insight into diffusion in porous materials like S/H/L which is a micro level phenomenon. Hence comparison of diffusion through skin or leather with macro level transport processes such as road vehicular movement can be made as an analogy for better understanding and also attempt to find solution for both the processes. In the present paper diffusion pattern of molecules/substances through the S/H/L matrix has been compared as 'Road Vehicular Traffic (RVT) Model'. The parameters such as speed, pattern and path of a vehicle has been considered when it travels in a traffic packed road. Analogy between traffic movements and diffusion through S/H/L matrix has been proposed.**

## I.INTRODUCTION

Science is the driving force for scientific research which in-turn develops into suitable technology in some cases and expected to provide solution to some of the problems in common life. In leather science and technology, since skin/hide after its removal from the animal being bio-degradable is converted into biologically resistant useful material called 'leather' with improved functional properties by the process called 'tanning'. In the present paper comparison of diffusion through skin or leather has been made with macro level transport processes such as road vehicular movement as analogy for better understanding.

## II.LEATHER SCIENCE: TRANSPORT PROCESSES

Collagen is a fibrous protein involved in leather making. Leather processing can be broadly classified as pre-tanning for the removal of non-collagenous materials as a cleaning up process and preparation of the skin/hide for the subsequent tanning, tanning for the stabilization of the collagen from biological action and to impart hydrothermal resistance and post-tanning to impart required functional properties to the final leather. The processing involves diffusion of various chemicals through the pores of the hide/skin/leather matrix of pore size ranging from $3 \times 10^{-10}$ m to $15 \times 10^{-5}$ m. Diffusion plays a vital role in most of the unit operations in leather making. Extensive research work is being pursued in our laboratory for improving the diffusion rate of chemicals through micro porous skin/leather matrix using techniques such as ultrasound[1-5]. Our recent publication studies diffusion phenomena in leather processing and influence of ultrasound on enhancing the diffusion rate[6]. There are variations in compaction of weave, angle of weave; pore properties with respect to area of S/H/L. In addition to this, there are variations across the cross-section for a given area. Therefore, S/H/L is generally 'anisotropic' in nature. Due to the different levels of organization of collagen in skin different pore dimensions exist as reported[6]. Hence, S/H/L can be considered as a porous material capable of physical as well as chemical adsorption having non-uniform macro, micro and meso sized pores. Therefore, diffusing substances have to pass through different channels available in S/H/L matrix starting from the S/H/L surface to collagen fibre bundle, fibre, fibril, pentafibrillar arrangement and to collagen molecular level (relevant for tanning reactions). The sequence of transport and various factors affecting diffusion in leather processing has been explained earlier[7]. Diffusion in conventional leather processing is achieved by drumming /paddle action. Rate of diffusion of any chemical through the S/H/L matrix depends on various factors and is given.

$$R_D = f\,(C_{cb}, pH, B_f, T, S, M) \qquad (1)$$

Where,
$C_{cb}$ - concentration of chemical in the bulk solution bath, $pH$ - pH of S/H/L, $B_f$ – Degree of binding and/or adsorption of chemical in S/H/L fibre, $T$ - temperature of the bath, $S$ – Molecular / aggregate size of the chemical, $M$ - mechanical agitation.

General dimensions of different diffusing substances in various unit operations in leather processing have also been reported[6]. There is a need for finding solution for both diffusion through skin as well as vehicular traffic congestion in city roads. In the present paper, analogy between traffic movements and diffusion through S/H/L matrix has been proposed and solutions have been provided.

## III.ROAD VEHICULAR TRAFFIC (RVT) MODEL

Every day, we observe the vehicular traffic movement in the roads while traveling from Guindy (Chennai) railway station to CLRI, Adyar, Chennai; very often state of traffic congestion. Since I am engaged in research on diffusion through S/H/L matrix, the idea of making analogy between this and RVT has emerged. Let us consider the example of vehicular traffic in a busy road. We all in some point time held up in a heavy traffic or frequently experiencing it. There are various types of vehicles ranging from smaller (e.g. Bicycle) to larger (e.g. Container Truck) are plying as shown in Figure 2. There is a place of origin of journey and destination. There may be different turnings in roads during the journey. During the time of peak hours or in a situation of traffic jam (e.g. due to breakdown of larger vehicle on the road), the movement may become stagnant or slower. During this period, bigger vehicles may have only little scope for advancement. However, smaller ones like bicycle or bikes may have better scope for moving forward at a lower speed, but not through a straight path but in a tortuous path. In order to reach the destination and avoid delay in the stagnant/jammed situation, some of the smaller vehicles take tortuous path. This may take place due to vehicles not following lane discipline tend to find space through the gaps between bigger vehicles for forward movement.

Most of our people travelling in our city roads experience hectic traffic jams especially in peak hours. The traffic congestion or slow vehicular traffic movement create stress among drivers leading to mental as well as physical fatigue[8-9]. This fatigue could very well affect a person going to the office. In addition, traffic jam may lead to a situation where a scientist fail to catch a flight in his busy schedule or reach important meetings in his institute or elsewhere. Therefore, it is essential to find some solution to this vehicular traffic congestion, particularly in city roads also as we search for solution for the hindered diffusion in skin/leather matrix which is of great social concern.

## IV.BULK, PORE AND HINDERED DIFFUSION IN S/H/L MATRIX

Considering diffusion in leather dyeing process with leather immersed in a dye solution. Schematic representation of diffusion is shown in Figure.1. Initially bulk diffusion of chemical takes place from bulk solution to the S/H/L thin boundary layer, from thin boundary layer to S/H/L surface layer. Then diffusion has to take place through pores of S/H/L matrix. Conventional process vessels such as drum or paddles can only bring the chemicals from bulk solution to the S/H/L surface layer. Then further pore diffusion is dependent mainly on the concentration gradient across the layers and degree of binding on the fibre surface. In case of binding of substances on the fibre surface (Figure.1), may block the subsequently diffusing substances ending up in hindered diffusion in conventional leather processing. This may also lead to hindered or 'traffic jam situation' for substances diffusing through skin/leather matrix. Complete penetration throughout the cross section of S/H/L is essentially required for good quality of the final leather. Hence some techniques such as use of ultrasound for facilitating the pore diffusion process by providing additional driving force are being purs

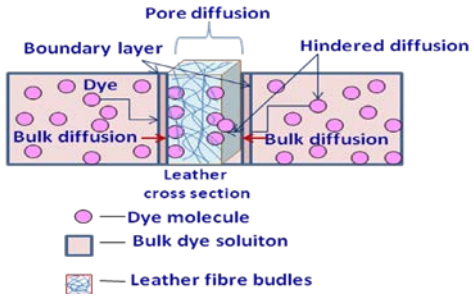


Fig.1 Diffusion phenomena in leather processing: Blocking of path leading to hindered diffusion through skin or leather matrix

**Analogy between RVT and diffusion in S/H/L matrix**

The analogy between RVT movement and diffusion in S/H/L matrix is shown in Table 1. Different factors such as size, direction, movement, flow pattern, forces acting etc. have been compared for analogy.

**Solutions to Hindrance: Analogy for traffic jam with diffusion in S/H/L matrix**

It is also important to find out solutions for the hindrance experiencing in both the cases and making analogy for the same (see Table 2). In case of diffusion through skin/leather matrix, hindrance may be taken care to the extent possible with the use of techniques such as ultrasound. In case of RVT, Some of the factors such as traffic discipline and road conditions highly influence the traffic movement as a whole. It is very essential that these factors are taken care. The policy makers and planning authorities may take the suggestions made for the improvement.

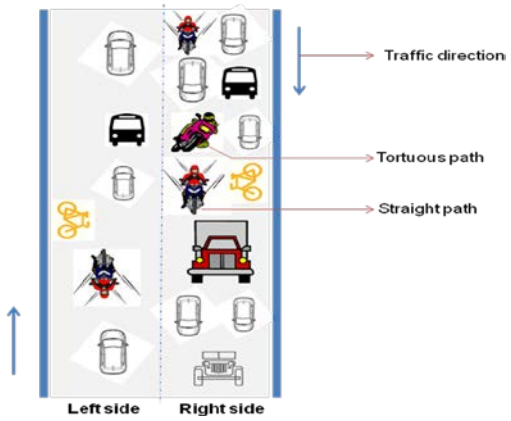


Fig. 2 Vehicular traffic movement in a busy road

TABLE I ANALOGY BETWEEN ROAD VEHICULAR TRAFFIC AND DIFFUSION THROUGH SKIN / LEATHER MATRIX

| S.No. | RVT movement | Diffusion in S/H/L matrix |
|---|---|---|
| 1 | Roads | Channels in S/H/L matrix |
| 2 | Vehicles | Chemicals / Molecules / substances diffusing through the matrix |
| 3 | Type of roads:<br>Wider Road (100-200 ft)<br>Medium size road (50- <100)<br>Smaller road (10 - <50) | Type of Pores in S/H/L matrix<br>Macro pores (>500 Å)<br>Meso pores (20 – 500 Å)<br>Micro pores (upto 20 Å) |
| 4a | Type of vehicles:<br>Larger size vehicles<br>e.g. Truck, Lorry, Bus etc. | Type of Diffusing substances:<br>Larger size substances/ molecules / aggregates<br>e.g. Vegetable tanning agents, Polyphenoloic syntans, Dyes etc. |
| 4b | Medium size vehicles<br>e.g. Car, Auto, Van etc. | Medium size substances/ molecules / aggregates<br>e.g. Chrome tanning agents, Fatliquor emulsions etc. |
| 4c | Smaller size vehicles<br>e.g. Bicycle, Motor cycle etc. | Smaller size substances/ molecules / aggregates e.g. Hydrogen / Hydroxyl ions, Lime, Ammonium salts etc. |
| 5 | Origin is starting point | Origin is bulk solution containing diffusing substances |
| 6 | Velocity: Measure of speed movement of a vehicle in a given direction; Case specific; ~10-20 m/s; | Diffusion coefficient (*D*): Measure of speed of diffusion of substance through the matrix: In the case of leather dyeing using Acid Red dye: $D = 3.8 \times 10^{-10}$ $m^2/s$; |
| 7 | Destination is place to reach | Middle layers of S/H/L matrix |
| 8 | Type movement:<br>Mainly on roads | Type of diffusion:<br>Bulk diffusion and Pore diffusion |
| 9 | Direction of traffic:One way to four way | Direction of diffusion:<br>Mostly one way in the direction of higher to lower concentration; Two-way due to equilibrium dynamics. |
| 10 | Traffic Path: Mostly straight; often tortuous due to stagnant traffic | Diffusion path:<br>Mostly tortuous path in S/H/L matrix |
| 11 | Narrow roads or lanes | Constrictions in S/H/L matrix |
| 12 | Halting on the path during the journey | Binding or adsorption on the S/H/L fibre |
| 13 | Free movement of vehicles | Free bulk diffusion or pore diffusion of smaller molecules through free channels |
| 14 | Slow movement or Traffic jam | Hindered diffusion |
| 15 | Driver is a human | Driver is self such as molecule, aggregate, substances |
| 16 | Driving energy is from fuel (Petrol/ Diesel) | Driving force is predominantly concentration gradient |
| 17 | Dimension: Macro 2 dimensional | Micro 3 dimensional |
| 18 | Forces acting: Physical | Physical, chemical as well as biological |
| 19 | Facilitating the traffic movement by better controls such as signal, lane discipline, good vehicles etc. | Facilitating diffusion through S/H/L matrix by providing additional driving force such as use of ultrasound; *D* value using ultrasound – $2.1 \times 10^{-9}$ $m^2/s$; |

TABLE II SOLUTIONS TO HINDRANCE EXPERIENCED AS ANALOGY BETWEEN RVT AND DIFFUSION THROUGH SKIN/LEATHER

| S.No. | Road vehicle traffic | Diffusion through skin/leather matrix |
|---|---|---|
| 1 | Wider roads may be useful depending on the volume of traffic | Wider pore sizes may be useful for diffusion. But since skin/leather is a natural material, it is not feasible to have a control over pore sizes. However we can provide reversible pore-size changes during diffusion, by some techniques such as ultrasound. |
| 2. | Strictly following the lane discipline may be useful. | Whether diffusing molecules or substances following the lane discipline has to be studied separately |
| 3 | Parking should strictly be avoided on the road way causing hindrance | Generally molecule may not stop, but they do get adsorbed on the fibres |
| 4 | Separate outlets may be provided for break down vehicles at suitable intervals of distance | There may not be any breakdown |
| 5 | Pedestrian crossings may be replaced by mini over bridges | There may be crossing of some other substances on the path of one diffusing substances in a 3D weave pattern of skin/leather, which may not be under control. |
| 6 | Use of larger vehicles for individual purposes such as bigger cars may be avoided | Larger size substances are ought to be used such as in case of vegetable tanning process. However, particle size of the aggregates may be reduced by use of techniques such as ultrasound. |
| 7 | Use of mobile phones while driving should be avoided | There is no communication between diffusing chemical substances; However may be feasible for biological substances such as enzymes. |
| 8 | Bright flash lights at night times should be avoided for visibility of vehicles coming in opposite direction | May be applicable photosensitive chemicals and biological substances. |
| 9 | Road conditions are to be improved. Pit holes in the road to be repaired immediately. | Here diffusing channel in skin/leather matrix is a natural one, hopefully with good condition! |
| 10 | Strategic one way at highly dense traffic places; partially for larger vehicles sparing two wheelers | Two way with equilibrium operative |

## V.CONCLUSION

In the present paper, diffusion through S/H/L matrix has been studied in analogy with RVT. In case of RVT driver is a human, who may feel stress when he/she experiences traffic congestion in a jam situation. While in case of diffusion through S/H/L matrix, it is molecule or aggregate or chemical substance which may also undergo molecular traffic jam condition during hindered diffusion situation. Hence, finding solutions to both these problems are essential. This has been studied as analogy between the two cases. Augmentation techniques such as use of ultrasound for diffusion rate enhancement in S/H/L matrix have been explored. Improving the RVT movement for reducing traffic jam has also discussed as suggestions in Table.2, which could be beneficial. The presented analogy aims at better understanding of the diffusion in skin or leather matrix with possible solutions for hindered diffusion in the matrix. Much more concepts can be unraveled in the diffusion through porous media by adopting the analogy techniques existing in nature or other forms of life.

### Abbreviations

S/H/L – Skin or Hide or Leather
RVT – Road Vehicular Traffic
$D$ – Diffusion coefficient ($m^2$/sec)

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