Diffusion Mechanism and Quantitative Measurement of Moisture Transport in Porous Silica Gel Filter Using Dynamic Neutron Radiography Technique

Amr Abdelhady, Waleed I Abd El Bar and Mongy T*

Egyptian Atomic Energy Authority (EAEA), Egypt

***Corresponding author:**

packed bed of desiccant particles [10]. T. Patsahan and M. Holovko proposed a computer simulation model to study water molecules confined in silica gel particles [11]. A spherical gel (Si O_2) composite was designed as a porous medium of silica gel. The diffusion coefficients of water molecules were calculated at different temperatures and water densities. I. Mamaliga et al., characterized water vapour diffusion into spherical silica gel particles of diameter 3.57 mm [12]. The effective diffusion coefficient was experimentally calculated by knowing particle's porosity and the slope of the adsorbed molecules on the pore surface [10]. T e determination of di f usion coe f cients was based on the di f usion equation in cylinder coordinate (1).

$$\frac{\partial}{\partial} = \frac{1}{}\frac{\partial}{\partial}\left(\frac{\partial}{\partial} \right) \qquad (1)$$

where:

m_r is the water content in the radial direction (r),

D_c is the di f usion coe f cient,

t is the time in seconds.

T e initial condition for the water contents is 0 at time 0. T e gel fl ter was instantaneously exposed to the water vapour f ow with time.

Figure 2 represents a schematic diagram of the moisture di f usion inside the silica gel fl ter. T e fl ter has 20 cm length, 15 cm diameter and 2.5 cm wall thickness. T e moisture di f usion mechanism is surface di f usion toward the wall thickness (radial direction). T e fl ter was placed inside a stainless steel containment can with 10 cm inlet aperture and 5 cm outlet aperture. T e fl ter inner wall surface was exposed to a stationary water vapour f ow for 25 min. T e moisture generation was performed by increasing the water temperature at a constant increment from 25°C to 100°C for 10 min in addition to 15 min. a f er reaching vaporization. Figure 3 shows the fl ter arrangement layout inside the can.

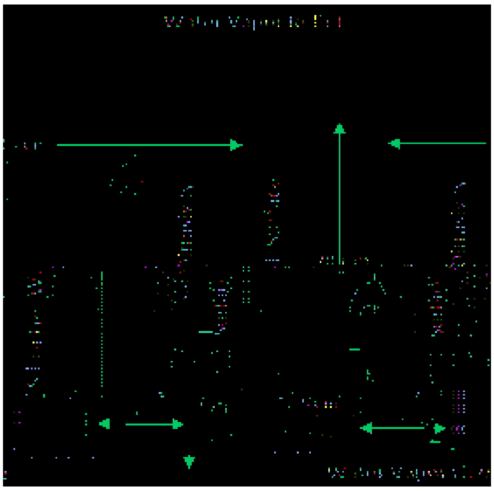

Figure 2: Schematic drawing of moisture di f usion mechanism inside cross section view of the silica gel fl ter.

T e function of the stainless steel can was to save water vapour, and allow the inner surface to expose to the moisture at a constant increment in relative humidity (RH).

Citation: Abdelhady A, Abd El Bar WI, Mongy T (2015) Diffusion Mechanism and Quantitative Measurement of Moisture Transport in Porous Silica Gel Filter Using Dynamic Neutron Radiography Technique. OMICS J Radiol 4: 205. doi:10.4172/2167-7964.1000205

T e initial radiographed images were represented by close contrast values. T e EH tool was adjusted to increases the global contrast of the images and modify the dynamic range [19]. By EH, the minimum detectable intensities were better distributed and visualized. T e sensitivity was enhanced and ranged from 0 to 1 normalized to the moisture absorbent mass at the end of the experiment.

T is EH technique possessed a method for efective and ef cient mean brightness preservation and contrast enhancement. T e method prevented intensity saturation and has the ability to preserve image fne details.

Profle

T e surface plot tool was used to monitor 3D infltration pattern inside the inner wall surface of the silica gel flter afer 5 min. and at 60°C. T e EH technique was applied before the surface plot.

Figure 5 shows the moisture infltration profle inside the wall of the silica gel flter. T e selective scanned lines AA, BB, CC, DD and EE are shown in Figure 6. T e moisture profles for the positioned scanned lines are plotted and are shown in Figure 7.

Figure 5: Surface plot showing moisture infltration profle inside the wall of the silica gel flter afer 5 min. T e EH provided a sophisticated method for modifying the dynamic range and contrast of the image.

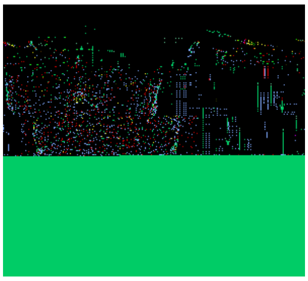

Figure 6: T e positioned scanned lines AA, BB, CC, DD and EE.

Figure 7 showed that the scanned lines profle had diferent behaviors [20]. T e optical density axis (I/I0) represents dimensionless mass fraction water content [20,21], the axis presented moisture mass absorption at time t (5 min.) normalized to the moisture absorbent mass at the end of the experiment. T e other axis represents the wall thickness of the flter.

T e moisture profle took a smooth decay with the flter thickness at the upper part of the flter, as shown in the line AA. In contrast to the line AA, the profle EE was sharply decreased with the flter wall thickness at the inferior part. At the intermediate lower region (scanned line DD), the profle took a constant behaviour through 2 cm flter thickness, and decreased dramatically in the region from 1.5-2.5 cm. T e other lines BB and CC had almost the same behavior.

Figure 7: T e moisture profles for the scanned lines afer 5 min.

profle

T e difusivity can be intuitively described as the ease of the spread of water particles [21]. T e results of Figure 7 were consistent with the literature [21]. T e study indicated that the difusion process is anomalous and there is no one master curve for the water profles. T e study showed that the water difusivities were increased as the water content increased, this is clear for the scanned line profle DD. From the scanned line EE, it is clear that the ef ciency of the lower part of the flter for water infltration was insuf cient for water mobility.

Difusion

T e moisture pattern images are shown in Figure 8. T e corresponding scanned lines were also presented in Figure 9.

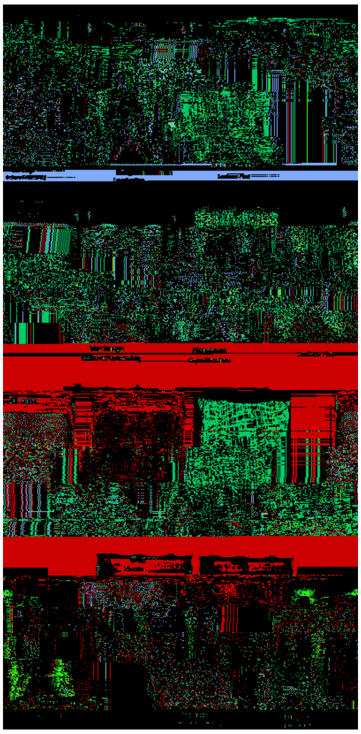

Figure 8: Surface plot for the moisture profle afer 10, 15, 20 and 25 min. at 100°C.

From Figure 8, t> 8,! s Ǽ l s p e 8,! sm ur

Reference [24] represented determination of moisture dif usivity in concrete by solving the dif usion equation. T e dif erential equation was solved by mathematical solutions under specifc temperature conditions and 50% RH. Moisture dif usivity calibration curves were obtained. T e distinction of this work was determination of moisture calibration curves by a trustable experimental technique. Equation (1) was the basis for determination the dif usion coe f cient of the scanned line AA, at dif erent moisture exposure time (t). T e governor equations that substituted into the dif usion equation were extracted from ftted trend curve profle from Figure 12. T e fgure presented the scanned line profle AA at dif erent temperature and time. Table 2 summarized the governing equations as a function of radial direction r, temperature (T), time interval (Δt) and the resultant dif usion coe f cients Dc for the scanned line AA at 1.5 cm flter wall thickness (r=0.015 m). From the obtained values, it is clear that increasing Dc with T and time.

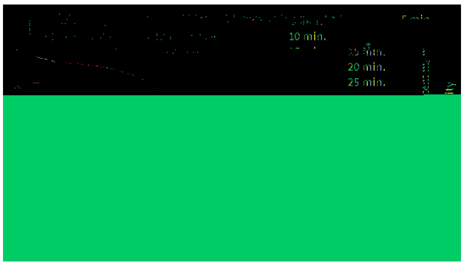

Figure 12: Scanned line profles AA at dif erent moisture exposure time.

t (min)	Δt (s)	T (°C)	Equation	Dc (m^2/s) × 10^{-5}
5	RV	25-60	m_r= -0.1148r^3+0.1956r^2-0.1629r-00.982	1.318
10	600	60-100	m_r= -0.1393r^4+0.4565r^3-0.4126r^2-0.0356r+0.9788	7.151
20	300	100	m_r= -0.081r^4+0.27r^3-0.32r^2-0.04r+0.82	6.337
15	600	100	m_r= -0.0967r^4+0.2663r^3-0.2419r^2-0.0555r-0.8892	33.71

12. Mamaliga I, Schabel W, Petrescu S (2010) Characterization of Water Vapour Difusion into Spherical Silica Gel Particles. REV CHIM 61: 1231-1234.
13. White J (2010) A CFD simulation on how the diferent sizes of silica gel will afect the adsorption performance of silica gel. Modelling and Simulation in Engineering.
14.