Cambridge Core

Home > Journals > MRS Online Proceedings Library (OPL)
> Volume 26: symposium d – scientific basis for nuclear waste... > Thermodynamic Coupling of Heat ...

English | Français

(http://core-cms.prod.aop.cambridge.org/societies/materials-research-society)

Volume 26 (Symposium D – Scientific Basis for Nuclear Waste Management VII)
1983 , 1023

Thermodynamic Coupling of Heat and Matter Flows in Near-Field Regions of Nuclear Waste Repositories

C. L. Carnahan [a1]

DOI: https://doi.org/10.1557/PROC-26-1023
Published online by Cambridge University Press: 25 February 2011

Abstract

In near-field regions of nuclear waste repositories, thermodynamically coupled flows of heat and matter can occur in addition to the independent flows in the presence of gradients of temperature, hydraulic potential, and composition. The following coupled effects can occur: thermal osmosis, thermal diffusion, chemical osmosis, thermal filtration, diffusion thermal effect, ultrafiltration, and coupled diffusion. Flows of heat and matter associated with these effects can modify the flows predictable from the direct effects, which are expressed by Fourier's law, Darcy's law, and Fick's law. The coupled effects can be treated quantitatively together with the direct effects by the methods of the thermodynamics of irreversible processes. The extent of departure of fully coupled flows from predictions based only on consideration of direct effects depends on the strengths of the gradients driving flows, and may be significant at early times in backfills and in near-field geologic environments of repositories. Approximate calculations using data from the literature and reasonable assumptions of repository conditions indicate that thermal-osmotic and chemical-osmotic flows of water in semipermeable backfills may exceed Darcian flows by two to three orders of magnitude, while flows of solutes may be reduced greatly by ultrafiltration and chemical osmosis, relative to the flows predicted by advection and diffusion alone. In permeable materials, thermal diffusion may contribute to solute flows to a smaller, but still significant, extent.

Request permission (https://s100.copyright.com/AppDispatchServlet?publisherName=CUP&publication=OPL&title=Thermodynamic%20Coupling%20of%20Heat%20and%20Matter%2Field%20Regions%20of%20Nuclear%20Waste%20Repositories&publicationDate=2011-02-25&author=C.%20L.%20Carnahan&copyright=COPYRIGHT:%20%C2%A9%20Materials%20Research%20Society%26-1023&startPage=1023&endPage=undefined&orderBeanReset=True&volumeNum=26&issueNum=undefined)

Copyright

COPYRIGHT: © Materials Research Society 1984

References

Hide All

1. Tsang, C. F., Noorishad, J., and Wang, J. S. Y.. *Mat. Res. Soc. Symp. Proc.* 15, 515–522 (1983).10.1557/PROC-15-515 CrossRef (http://dx.doi.org/10.1557/PROC-15-515) | Google Scholar (https://scholar.google.com/scholar?q=1.+Tsang+C.+F.+Noorishad+J.+and+Wang+J.+S.+Y.+.+Mat.+Res.+Soc.+Symp.+Proc.+15+515%E2%80%93522+(1983).)

2. Cary, J. W. and Taylor, S. A., *Soil Sci. Soc. Amer. Proc.* 26, 413–416 (1962).10.2136/sssaj1962.03615995002600050004x CrossRef (http://dx.doi.org/10.2136/sssaj1962.03615995002600050004x) | Google Scholar (https://scholar.google.com/scholar?q=2.+Cary+J.+W.+and+Taylor+S.+A.+Soil+Sci.+Soc.+Amer.+Proc.+26+413%E2%80%93416+(1962).)

3. Cary, J.W. and Taylor, S. A., *Soil Sci. Soc. Amer. Proc.* 26, 417–420 (1962).10.2136/sssaj1962.03615995002600050005x CrossRef (http://dx.doi.org/10.2136/sssaj1962.03615995002600050005x) | Google Scholar (https://scholar.google.com/scholar?q=3.+Cary+J.W.+and+Taylor+S.+A.+Soil+Sci.+Soc.+Amer.+Proc.+26+417%E2%80%93420+(1962).)

4. Taylor, S. A. and Cary, J. W., *Soil Sci. Soc. Amer. Proc.* 2 167–171 (1964).10.2136/sssaj1964.03615995002800020013x CrossRef (http://dx.doi.org/10.2136/sssaj1964.03615995002800020013x) | Google Scholar (https://scholar.google.com/scholar?q=4.+Taylor+S.+A.+and+Cary+J.+W.+Soil+Sci.+Soc.+Amer.+Proc.+2+167%E2%80%93171+(1964).)

5. Groenevelt, P. H. and Bolt, G. H., Hydrology, J. 7, 358–388 (1969). Google Scholar (https://scholar.google.com/scholar?q=5.+Groenevelt+P.+H.+and+Bolt+G.+H.+Hydrology+J.+7+358%E2%80%93388+(1969).)

6. Pal, R. and Gupta, M. P., Hydrology, J. 13 278–280 (1971).10.1016/0022-1694(71)90229-0
CrossRef (http://dx.doi.org/10.1016/0022-1694(71)90229-0) |
Google Scholar (https://scholar.google.com/scholar?q=6.+Pal+R.+and+Gupta+M.+P.+Hydrology+J.+13+278%E2%80%93280+(1971).)

7. Raats, P. A. C., *Water Resour. Res.* 11, 938–942 (1975).10.1029/WR011i006p00938
CrossRef (http://dx.doi.org/10.1029/WR011i006p00938) |
Google Scholar (https://scholar.google.com/scholar?q=7.+Raats+P.+A.+C.+Water+Resour.+Res.+11+938%E2%80%93942+(1975).)

8. Carnahan, C. L., Hydrology, J. 31, 125–150 (1976).10.1016/0022-1694(76)90025-1
CrossRef (http://dx.doi.org/10.1016/0022-1694(76)90025-1) |
Google Scholar (https://scholar.google.com/scholar?q=8.+Carnahan+C.+L.+Hydrology+J.+31+125%E2%80%93150+(1976).)

9. Reed, W. E., Geophys., J. *Res.* 75, 415–430 (1970).
Google Scholar (https://scholar.google.com/scholar?q=9.+Reed+W.+E.+Geophys.+J.+Res.+75+415%E2%80%93430+(1970).)

10. Hanshaw, B. B. and E-An Zen, , *Geol. Soc. Amer. Bull.* 76, 1379–1386 (1965).10.1130/0016-7606(1965)76[1379:OEAOF]2.0.CO;2
CrossRef (http://dx.doi.org/10.1130/0016-7606(1965)76[1379:OEAOF]2.0.CO;2) |
Google Scholar (https://scholar.google.com/scholar?q=10.+Hanshaw+B.+B.+and+E-An+Zen+Geol.+Soc.+Amer.+Bull.+76+1379%E2%80%931386+(1965).)

11. Greenberg, J. A. and Mitchell, J. K. in: *Aquitards in the Coastal Ground Water Basin of Oxnard Plain*, Ventura County, Bulletin No. 63-4 (State of California, The Resources Agency, Department of Water Resources 1971) pp. 129–141.
Google Scholar (https://scholar.google.com/scholar_lookup?title=Aquitards+in+the+Coastal+Ground+Water+Basin+of+Oxnard+Plain&publication+year=1971&author=Gree 141)

12. Fitts, D. D., *Nonequilibrium Thermodynamics* (McGraw-Hill, New York 1962).
Google Scholar (https://scholar.google.com/scholar_lookup?title=Nonequilibrium+Thermodynamics&publication+year=1962&author=Fitts+D.+D.)

13. DeGroot, S. R. and Mazur, P., *Non-equilibrium Thermodynamics* (North- Holland, Amsterdam 1969).
Google Scholar (https://scholar.google.com/scholar_lookup?title=Non-equilibrium+Thermodynamics&publication+year=1969&author=DeGroot+S.+R.&author=Mazur+P.)

14. Katchalsky, A. and Curran, P. F., *Nonequilibrium Thermodynamics in Biophysics* (Harvard University Press, Cambridge 1967).
Google Scholar (https://scholar.google.com/scholar_lookup?title=Nonequilibrium+Thermodynamics+in+Biophysics&publication+year=1967&author=Katchalsky+A.&author

15. Onsager, L., *Phys. Rev.* 37, 405–426 (1931); 38, 2265–2279 (1931).10.1103/PhysRev.37.405
CrossRef (http://dx.doi.org/10.1103/PhysRev.37.405) |
Google Scholar (https://scholar.google.com/scholar?q=15.+Onsager+L.+Phys.+Rev.+37+405%E2%80%93426+(1931);+38+2265%E2%80%932279+(1931).)

16. Miller, D. G. in: *Foundations of Continuum Thermodynamics*, Delgado Domingos, J. J., Nina, M. N. R., and Whitelaw, J. H., eds. (MacMillan Press, London 1974) pp. 185–214.
Google Scholar (https://scholar.google.com/scholar_lookup?title=Foundations+of+Continuum+Thermodynamics&publication+year=1974&author=Miller+D.+G.&author=De214)

17. Wang, J. S. Y., Mangold, D. C., and Tsang, C. F., *Mat. Res. Soc. Symp. Proc.* 15, 531–538 (1983).10.1557/PROC-15-531 CrossRef (http://dx.doi.org/10.1557/PROC-15-531) |
Google Scholar (https://scholar.google.com/scholar?q=17.+Wang+J.+S.+Y.+Mangold+D.+C.+and+Tsang+C.+F.+Mat.+Res.+Soc.+Symp.+Proc.+15+531%E2%80%93538+(1983).)

18. Hodges, F. N. in: *Engineered Barrier Development for a Nuclear Waste Repository in Basalt*: An Integration of Current Knowledge, Report RHO-BWI-ST-7, Smith, M. J. et al. (Rockwell International 1980) pp. 2-105–-2-133.
Google Scholar (https://scholar.google.com/scholar_lookup?title=Engineered+Barrier+Development+for+a+Nuclear+Waste+Repository+in+Basalt&publication+year=1980&105-2-133)

19. Srivastava, R. C. and Avasthi, P. K., *J.Hydrology* 24, 111–120 (1975).10.1016/0022-1694(75)90145-6
CrossRef (http://dx.doi.org/10.1016/0022-1694(75)90145-6) |
Google Scholar (https://scholar.google.com/scholar?q=19.+Srivastava+R.+C.+and+Avasthi+P.+K.+J.Hydrology+24+111%E2%80%93120+(1975).)

20. Letey, J. and Kemper, W. D., *Soil Sci. Soc. Amer. Proc.* 33. 25–29 (1969).10.2136/sssaj1969.03615995003300010012x
CrossRef (http://dx.doi.org/10.2136/sssaj1969.03615995003300010012x) |
Google Scholar (https://scholar.google.com/scholar?q=20.+Letey+J.+and+Kemper+W.+D.+Soil+Sci.+Soc.+Amer.+Proc.+33.+25%E2%80%9329+(1969).)

21. Thornton, E. C. and Seyfried, W. E., *Science* 220, 1156–1158 (1983).10.1126/science.220.4602.1156
CrossRef (http://dx.doi.org/10.1126/science.220.4602.1156) |
Google Scholar (https://scholar.google.com/scholar?q=21.+Thornton+E.+C.+and+Seyfried+W.+E.+Science+220+1156%E2%80%931158+(1983).)