

Economics of Water Pollution



A Brief Bibliographical Survey

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Economics of Water Pollution

1. Ahmad, J., B. N. Golder, S. Misra, M. Jakariya et al. (2002), 'Willingness to pay for arsenic free 'safe' drinking water in Bangladesh', (Field note / Water and Sanitation Program), New Delhi, India : Water and Sanitation Program - South Asia 16 p.

Content: Brief description of a study on willingness to pay for arsenic-free, safe drinking water in rural Bangladesh which investigated the factors that influence demand for arsenic-free, safe drinking water and examined preferences regarding household/community-based arsenic mitigation technologies. The focus of this report is on the design, particularly the methodology used for estimating willingness to pay (WTP). The estimates of WTP obtained are presented. Some key results of the field survey, together with the main findings and policy recommendations, have been published in a separate note entitled, 'Fighting arsenic, listening to rural communities : findings from a study on willingness to pay for arsenic-free, safe drinking water in rural Bangladesh'.

Full text available online at: http://www.wsp.org/pdfs/sa_arsenic_method.pdf
http://www.wsp.org/pdfs/sa_arsenic_learning.pdf

2. Cao, H. and S. Ikeda (2005), 'Inter-zonal tradable discharge permit system to control water pollution in Tianjin, China', *Environmental Science and Technology* 39(13): 4692-4699.

Abstract: In recent years, Chinese environmental authorities have expressed interest in the use of Tradable Discharge Permits (TDP) as a regulatory instrument to control pollutant emissions. Environmental professionals still have not had enough experience however, in designing and managing TDP systems, especially for non-uniformly dispersed pollutants. As an empirical study, this paper proposes an inter-zonal TDP system and analyzes its effectiveness in cost saving and environmental protection for reducing water pollutant COD (Chemical oxygen demand) in Tianjin, China. Zonal permit system (ZPS) and emission permit system (EPS) are discussed for comparison. The inter-zonal TDP System is demonstrated to improve cost efficiency by allowing permit trades between zones, as long as water quality constraints are satisfied. The transactions are assumed to proceed in a multilateral sequential way and are simulated with a circularly running linear programming (LP) model. The simulation of permit transactions among 20 firms shows that to reach the same COD removal target, ZPS, inter-zonal TDP system, and EPS lowered the total reduction cost by 12.8%, 14.6%, and 15.8%, respectively. EPS, however, brought about "hot spots" problem. Finally, the transaction costs and sensitivity of the three TDP systems to changes in both COD reduction rate and the initial permit allocation are discussed, and policy implications are addressed.

3. Chowdhury, N. T. (1999), 'Willingness to pay for water in Dhaka slums: A contingent valuation study', in Ahmad et al ed., *Environmental Economics in Bangladesh*, IUCN-The World Conservation Union, Association of Green Accounting, 105-116.
4. Dasgupta, P. (2004), 'Valuing health damages from water pollution in urban Delhi, India: A health production function approach', *Environment and Development Economics* 9 (1): 83-106.
5. Dwight, R. H, L. M. Fernandez, D. B. Baker, J. C. Semenza and B. H. Olson (2005), 'Estimating the economic burden from illnesses associated with recreational coastal water pollution – a case study in Orange County, California', *Journal of Environmental Management* 76 (2): 95-103.

Abstract: A cost-of-illness framework was applied to health and income data to quantify the health burden from illnesses associated with exposure to polluted recreational marine waters. Using data on illness severity due to exposure to polluted coastal water and estimates of mean annual salaries and medical costs (adjusted to 2001 values) for residents of Orange County, California, we estimated that the economic burden per gastrointestinal illness (GI) amounts to \$36.58, the burden per acute respiratory disease is \$76.76, the burden per ear ailment is \$37.86, and the burden per eye ailment is \$27.31. These costs can become a substantial public health burden when millions of exposures per year to polluted coastal waters result in hundreds of thousands of illnesses. For example, exposures to polluted waters at Orange County's Newport and Huntington Beaches were estimated to generate an average of 36,778 GI episodes per year. At this GI illness rate, one can also expect that approximately 38,000 more illness episodes occurred per year of other types, including respiratory, eye, and ear

infections. The combination of excess illnesses associated with coastal water pollution resulted in a cumulative public health burden of \$3.3 million per year for these two beaches. This paper introduces a public health cost variable that can be applied in cost-benefit analyses when evaluating pollution abatement strategies.

6. Diwakar, H. and N. Nagaraj (2002), 'Impact of water pollution on food security and environment: Bbearing the brunt', *Wasteland News*, August –October 2002.
7. Gunatilake, H. M., C. Gopalakrishnan and I. Chandrasena (2001), 'The economics of household demand for water: the case of Kandy Municipality, Sri Lanka', *Water Resources Development* 17(3): 277-288.
8. Harrington, W., A. Krupnick and W. Spofford (1989), 'The economic losses of a waterborne disease outbreak', *Journal of Urban Economics* 25: 116 - 137.
9. Hung, Ming-Feng and D. Shaw (2004), 'A trading-ration system for trading water pollution discharge permits', *Journal of Environmental Economics and Management* 49(1): 83-102.

Abstract: The fact that water flows to the lowest level uni-directionally is a very specific and useful property of water. By utilizing this property, we design a trading-ratio system (TRS) of tradable discharge permits for water pollution control. Such a trading-ratio system has three main characteristics: (1) the zonal effluent cap is set by taking into account the water pollutant loads transferred from the upstream zones; (2) the trading ratios are set equal to the exogenous transfer coefficients among zones; and (3) permits are freely tradable among dischargers according to the trading ratios. This paper shows that the TRS can take care of the location effect of a discharge and can achieve the predetermined standards of environmental quality at minimum aggregate abatement costs. Problems with hot spots and free riding can be avoided, and the burdens on both dischargers and the environmental authority should be relatively light.

10. Murty, M. N., A. J. James and S. Mishra (1999), 'Economics of water pollution: the Indian experience, xiii, 295 p, 0-19-564395-X, Oxford University Press, Delhi.
11. O'Shea, L. (2002), 'An economic approach to reducing water pollution: point and diffuse sources', *Science of Total Environment* 282-283: 49-64.

Abstract: A review of economic policy towards pollution control is presented which shows that appropriate measures will depend on whether the pollution is of a point or a diffuse nature. Regulation of the former is comparatively straightforward, with command and control and market instruments the tools of pollution control. The advantages and disadvantages of each measure are outlined. However, the inability to monitor emissions at source precludes the application of point source measures in the case of diffuse source pollution. Instead, methods are required which overcome the need for direct monitoring. Several suggestions that propose ways of achieving this have been put forward and these are described. It is concluded that appropriate measures depend on the particular features of the problem and it is not possible to offer a blanket solution to either point sources or diffuse pollution.

12. Paudel, K. P, H. Zapata and D. Susano (2005), 'An empirical test of environmental kuznets curve for water pollution', *Environmental and Resource Economics* 31(3): 325-348.

Abstract: The Environmental Kuznets Curve (EKC) on water pollution was investigated with both semi parametric and parametric models using watershed level data for the state of Louisiana, USA. The parametric model indicated the turning points within the range \$10241-\$12993, \$6636-\$13877, and \$6467-\$12758 for nitrogen (N), phosphorus (P), and dissolved oxygen (DO), respectively. However, only the parameters associated with N EKC were found to be significant. Model specification tests rejected parametric models in favor of semi parametric specification for P but not for N and DO.

13. Roy, J., S. Chattopadhyay, S. Mukherjee, M. Kanjilala, S. Samajpati and S. Roy (2003), 'An economic analysis of demand for water quality: A case from Kolkatta city', *Economic and Political Weekly* XXXIX (2): 186-192, January 10-16, 2004.

14. Sanchez-Choliz, J. and R. Duarte (2005), 'Water pollution in the Spanish economy: analysis of sensitivity to production and environmental constraints', *Ecological Economics* 53(3): 325-338.

Abstract: In this paper, we discuss the relationships between production processes and water pollution based on the recent Satellite Water Accounts (SWA) (INE (Spanish National Statistics Institute), 2002) and the 1997 input-output tables for the Spanish economy. The study focuses on four pollutants [biological oxygen demand (BOD), metals, nitrogen and phosphorus) and seven sector blocks. Firstly, we identify the roles of the various sector blocks as generators and consumers of each type of pollution. Secondly, we examine how pollution responds to changes in unit coefficients of pollution and final demand patterns to obtain the shadow prices for the different pollutants. The results obtained provide a sound basis for the design of improvements in environmental policy.
15. Yang, G., C. Gangcai and C. Yongguan (2004), 'The econometric assessment of losses by water pollution in Chongqing, Southwest China', *Chinese Journal of Geochemistry* 23(1): 94-100.

Abstract: As an important industrial city, Chongqing has experienced rapid economic growth in recent years, but at the same time the growth has been accompanied by serious pollution problems. Water quality monitoring shows that the waters of Chongqing are widely polluted. In this paper, the human capital approach is applied to assessing the economic losses and damages caused by water pollution in Chongqing. Based on previous studies and empirical investigations, water pollution-induced damage can be categorized into two general types; damage to ecosystems, including agriculture; and damage to non-ecosystems, including industry. The economic loss estimation of each type of the damage is conducted by taking into account a group of relevant parameters and methods.
16. Young, A. R. and R. H. Haveman (1985), 'Economics of water resources: a survey', *Handbook of Natural Resource and Energy Economics*, Vol. II, A. V. Kneese and J. L. Sweeney ed., Elsevier Science Publishers.
17. Zabadal, J. R. S., M. T. M. B. Vilhena, S. Q. Bogado and C. A. Poffal (2005), 'Solving unsteady problems in water pollution using Lie symmetries', *Ecological Modelling* 186(3): 271-279.

Abstract: This work proposes an analytic method to simulate the environmental damage caused by accidents with chemical substances in rivers and lakes. The two-dimensional transport equation is solved by rules based on the Lie algebra in situations in which the velocity field is considered locally constant. The exponential of the differential operator, which arises in the formal solution, is locally approximated by the Taylor series. The initial condition is obtained by Lie symmetries. This method was by tested simulating scenarios that describe the blob's behavior through time and the results are compared with available data. Numerical results are shown.

Water Pollution and Health

18. Ahmad, S. A, M. H. Sayed, S. Barua, M. H. Khan, M. H. Faruquee, A. Jalil et al (2001), 'Arsenic in drinking water and pregnancy outcomes', *Environmental Health Perspective* 109(6):29-31.

Abstract: We studied a group of women of reproductive age (15-49 years) who were chronically exposed to arsenic through drinking water to identify the pregnancy outcomes in terms of live birth, stillbirth, spontaneous abortion, and preterm birth. We compared pregnancy outcomes of exposed respondents with pregnancy outcomes of women of reproductive age (15-49 years) who were not exposed to arsenic-contaminated water. In a cross-sectional study, we matched the women in both exposed and nonexposed groups for age, socioeconomic status, education, and age at marriage. The total sample size was 192, with 96 women in each group (i.e., exposed and nonexposed). Of the respondents in the exposed group, 98% had been drinking water containing ≥ 0.10 mg/L arsenic and 43.8% had been drinking arsenic-contaminated water for 5-10 years. Skin manifestation due to chronic arsenic exposure was present in 22.9% of the respondents. Adverse pregnancy outcomes in terms of spontaneous abortion, stillbirth, and preterm birth rates were significantly higher in the exposed group than those in the nonexposed group ($p = 0.008$, $p = 0.046$, and $p = 0.018$, respectively).

19. Ahmad. S. K., D. Bandaranayake et al (1997), 'Arsenic contamination in ground water and arsenicosis in Bangladesh', *International Journal of Environmental Health Research* 7: 271-276.
20. Alberini, A., G. S. Eskeland, A. Krupnick and G. McGranahan (1996), 'Determinants of diarrhoeal disease in Jakarta', *Water Resources Research* 32(7): 2259 - 2269.
21. Armstrong, C. W., R. B. Stroube, R. Rubio, E. A. Siudyla and G. B. Miller Jr. (1984), 'Outbreak of fatal arsenic poisoning caused by contaminated drinking water', *Archives of Environmental Health* 39(4): 276-279.

Abstract: An outbreak of subacute poisoning occurred among nine members of a family; eight were ill with gastrointestinal symptoms, four developed encephalopathy, and two died. Abnormal liver function tests and leukopenia were common laboratory findings. Epidemiologic and environmental investigations traced the source of arsenic exposure to a farm well with water containing 108 ppm arsenic. The soil adjacent to the well was also contaminated with arsenic, possibly from waste pesticide. Presumably, arsenic gained access to the well through obvious leaks in the well's casing. To our knowledge, this is only the second reported outbreak of fatal arsenic poisoning from contaminated drinking water and one of few instances where illness followed exposure to a toxic substance which was disposed of, or possibly disposed of, in an indiscriminate manner.

22. Astolfi, E., A. Maccagno, J. C. G. Fernandez, R. Vaccara and R. Stimola (1981), 'Relation between arsenic in drinking water and skin cancer', *Biological Trace Element Research* 3:133-143.
23. Barton, D. N. (2003), 'Transferring the benefits of avoided health effects from water pollution between Portugal and Costa Rica', *Environmental and Development Economics* 8: 351-371.
24. Beach, M. (2001), 'Water, pollution and public health in China', *Lancet* 358(9283): 735.

Summary: Discusses the issues of water, pollution and public health in China. Concern that the population is exposed to unsafe drinking water; Topic of urban sewage discharged into rivers; Contamination of groundwater with nitrite and ammonia; Outlook for government spending on the environment.

25. Borgono, J. M. and R. Greiber (1971), 'Epidemiological study of arsenicism in the city of Antofagasta', *Trace Substances in Environmental Health* 5:13-24.
26. Buchet, J. P., A. Geubel, S. Pauwels, P. Mahieu and R. Lauwerys (1984), 'The influence of liver disease on the methylation of arsenite in humans', *Archives of Toxicology* 55:151-154.

Abstract: The capacity for inorganic arsenic (As₃) methylation in 13 healthy volunteers and in 30 patients with different types of liver disease has been assessed by measuring the amount of

unmetabolized As_i, monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) excreted in urine within 24 h after the IV injection of 7.14 ^μg/kg AS_i. Liver disease does not affect the percent of the injected dose excreted within 24 h but has striking and opposite effects on the proportions of MMA and DMA. MMA excretion is highly correlated with the ¹⁴C-aminopyrine breath test ($r=0.73$; $P<0.05$). The reduction in the proportion of MMA excreted in urine and the increase in that of DMA are similar with regard to sensitivity and specificity for detecting liver impairment. Unlike the ¹⁴C-aminopyrine breath test, the inorganic arsenic methylation test offers the advantage of being unaffected by treatment with microsomal enzyme inducers.

27. Cebrian M. E., A. Albores, M. Aguilar and E. Blakely (1983), 'Chronic arsenic poisoning in the north of Mexico', *Human Toxicology* 2(1):121-133.

Summary: We compared the prevalence of signs and symptoms of chronic arsenic poisoning in two rural populations. The arsenic concentration in the drinking water of the exposed population was 0.41 mg/l, and 0.007 mg/l in the control population. The arsenic was present mainly (70%) in its pentavalent form. The objective was to quantitate health effects and risks derived from chronic ingestion of arsenic in contaminated water. In the exposed population, 21.6% of the sample, showed at least one of the cutaneous signs of chronic arsenic poisoning against 2.2% in the control town. Non-specific symptoms were more prevalent in the exposed population and they occurred more frequently in those individuals with skin signs. The relative risk of suffering a particular manifestation of poisoning, ranged from 1.9 to 36 times higher in the exposed population. We estimated the risks above mentioned, which were derived from exposure to minute quantities of arsenic in a known proportion of its oxidation states during a life time period.
28. Chakraborty, A. K. and K. C. Saha (1987), 'Arsenical dermatoses from tube-well water in West Bengal', *Indian Journal of Medicinal Research* 85:326-334.
29. Chakraborty, D., M. K. Sengupta, M. M. Rahman, S. Ahmad, U. K. Chowdhury, S. C. Mukherjee et al. (2004), 'Groundwater arsenic contamination and its health effects in Ganga-Meghna-Brahmaputra plain', *Journal of Environmental Monitoring* 6:74-83.
30. Chen, C. J., Y. M. Hsueh, M. S. Lai, M. P. Shyu, S. Y. Chen, M. M Wu *et al* (1995), 'Increased prevalence of hypertension and long-term arsenic exposure', *Hypertension* 25:53-60.
31. Chiou, H. Y., W. I. Huang, C. L. Su, S. F. Chang, Y. H. Hsu and C. J. Chen (1997), 'Dose-response relationship between prevalence of cardiovascular disease and ingested inorganic arsenic', *Stroke* 28(9):1717-1723. <http://stroke.ahajournals.org/cgi/content/full/28/9/1717>
32. Esrey, S.A., J. B. Potash, L. Roberts and C. Shiff (1991), 'Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, scchistosomiasis and trachoma', *Bulletin of the WHO* 69(5): 609-621.
33. Esrey, S., R.G. Feecham and J.M. Hughes (1985), 'Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities', *World Health Organization Bulletin* No. 63(4): 757-772.
34. Farid, S. (2002), 'Water pollution and its effects on human health in rural areas of Faisalabad', *Pakistan Journal of Applied Sciences* 2(8): 822-825.
35. Fewtrell, L. and J. M. Colford Jr. (2004), 'Water, sanitation and hygiene: interventions and diarrhoea – A systematic review and meta-analysis', *Water supply and sanitation board, The World Bank*. http://www1.worldbank.org/hmp/Pubs_Discussion/Fewtrell&ColfordJuly2004.pdf
36. Gleick, P. H. (1998), 'Water and human health', in R. Maria Seleth, ed., *Water Resources and Economic Development*, Edward Elgar Pvt. Ltd. United Kingdom.
37. Guha, Mazumdar D. N, J. Das Gupta, A. Santra, A. Pal, A. Ghose, S. Sarkar *et al* (1997), 'Non-cancer effects of chronic arsenicosis with special reference to liver damage', in C.O. Abernathy, R. L.

- Calderon and W. R Chappell, (eds.) Arsenic: exposure and health effects, London, Chapman and Hall, 112-123.
38. Guha, Mazumder D. N. , R. Haque, N. Ghosh et al (2000), 'Arsenic in drinking water and the prevalence of respiratory effects in West Bengal, India' , International Journal of Epidemiology 29:1047-1052.
 39. Hertz-Picciotto I., H. M. Arrighi and S. W. Hu (2000), 'Does arsenic exposure increase the risk of circulatory disease?', American Journal Epidemiology 151:174-181.
 40. Hsueh, Y. M., W. L. Wu, Y. L. Huang, H.Y. Chiou, C. H Tseng and C. J.Chen (1998), 'Low serum carotene level and increased risk of ischemic heart disease related to long-term arsenic exposure', Atherosclerosis 141:249-257. http://www.ec.gc.ca/water/en/manage/poll/e_poll.htm
 41. Huet, P. M., E. Guillaume, J. Cote, A. Legare, P. Lavoie and A. Viallet (1975), 'Noncirrhotic presinusoidal portal hypertension associated with chronic arsenical intoxication', Gastroenterology 68:1270-1277.
 42. Khan, A. W. et al (1997), 'Arsenic contamination in groundwater and its effect on human health with particular references to Bangladesh', Journal of Preventive and Social Medicine 16(1): 65-73.
 43. Kurokawa, M., K. Ogata, M. Idemori, S. Tsumori, H. Miyaguni, S. Inoue et al (2001), 'Investigation of skin manifestations of arsenicism due to intake of arsenic-contaminated groundwater in residents of Santa, Jessore, Bangladesh', Archives of Dermatology 137:102-103.
 44. Lai, M.S., Y. M. Hsueh, C.J. Chen, M.P. Shyu, S.Y. Chen, T. L .Kuo et al (1994), 'Ingested inorganic arsenic and prevalence of diabetes mellitus', American Journal of Epidemiology 139:484-492.
 45. Majumdar, D. and N. Guha (1996), 'Treatment of chronic arsenic toxicity as observed in West Bengal', JIMA 94, 41-42.
 46. Maduka, Hugh, C. C. (2006), 'Water pollution and man's health', Internet Journal of Gastroenterology 4(1): 1.
 47. Mitra, A. K., B. K. Bose, H. Kabir, B. K. Das and M. Hussain (2002), 'Arsenic-related health problems among hospital patients in Southern Bangladesh', Journal of Health, Population and Nutrition 20(3): 198-204.
 48. Rahman, M., M. Tondel, S. A. Ahmad and O. Axelson (1998), 'Diabetes mellitus associated with arsenic exposure in Bangladesh', American Journal of Epidemiology 148:198-203.
 49. Rahman, M., M. Tondel, S.A. Ahmad, I.A. Chowdhury, M.H. Faruquee and O. Axelson (1999), 'Hypertension and arsenic exposure in Bangladesh', Hypertension 33:74-8.
 50. Smith, A. et al (1992), 'Cancer risks from arsenic in drinking water', Environmental Health Perspectives 97: 259-267.
 51. Saha, K. C. (1995), 'Chronic arsenical dermatosis from tube well water in West Bengal during 1983-1987', Indian Journal of Dermatology 40:1-12.
 52. Tondel, M., M. Rahman, A. Magnuson, I. A. Chowdhury, M. H. Faruquee and S. A. Ahmad (1999), 'The relationship of arsenic levels in drinking water and the prevalence rate of skin lesions in Bangladesh', Environmental Health Perspective 107(9): 727-729.

Abstract: To determine the relationship of arsenic-associated skin lesions and degree of arsenic exposure, a cross-sectional study was conducted in Bangladesh, where a large part of the population is exposed through drinking water. Four villages in Bangladesh were identified as mainly dependent on wells contaminated with arsenic. We interviewed and examined 1,481 subjects [Greater/equal to] 30 years of age in these villages. A total of 430 subjects had skin lesions (keratosis, hyperpigmentation, or

hypopigmentation). Individual exposure assessment could only be estimated by present levels and in terms of a dose index, i.e., arsenic levels divided by individual body weight. Arsenic water concentrations ranged from 10 to 2,040 microg/L, and the crude overall prevalence rate for skin lesions was 29/100. After age adjustment to the world population the prevalence rate was 30. 1/100 and 26.5/100 for males and females, respectively. There was a significant trend for the prevalence rate both in relation to exposure levels and to dose index ($p < 0.05$), regardless of sex. This study shows a higher prevalence rate of arsenic skin lesions in males than females, with clear dose-response relationship. The overall high prevalence rate in the studied villages is an alarming sign of arsenic exposure and requires an urgent remedy.

53. Tseng, W. P., (1977), 'Effects and dose-response relationships of skin cancer and blackfoot disease with arsenic', *Environment Health Perspective* 19:109-119.
54. Valentine, J. L., H. K. Kang and G. Spivey (1979), 'Arsenic levels in human blood, urine and hair in response to exposure via drinking water', *Environmental Science and Pollution Research* 1: 24-32.
55. Xia, Y. and J. Liu (2004), 'An overview of chronic arsenism via drinking water in PR China', *Toxicology* 198(1-3): 25-29.

Abstract: Chronic endemic arsenism via drinking water was first found in Taiwan in 1968, and reported in Xinjiang Province in mainland China in the 1980s. Arsenism has become one of the most serious endemic diseases in China in the last two decades. Up to now, the disease has been found in Inner Mongolia, Shanxi, Ningxia, Jilin and Qinghai provinces. According to the Chinese maximum limit standard of arsenic (As) in drinking water, over 2 millions people have been exposed to high arsenic and about 10,000 persons were diagnosed as arsenism patients. There are different As concentrations in the water of different sites, even in the same area. Most of the As concentrations range from 0.05 to 2.0mg/l. The incidence of arsenism increases as As concentrations in drinking water and the drinking time increase. The age distribution of patients with arsenism ranged from 3 to 80 years old with peak prevalence in adults. A dose-effect relationship between the status of arsenism and arsenic level and drinking time has been shown. New high-arsenic areas in China have been discovered during recent investigations. In order to reduce the adverse health effects of arsenism, the central and local governments of China have provided significant funds to change water levels of As and at the same time take general measures to "reduce arsenic intake, remove arsenic from the body and treat the patients". After the implementation of these control measures in certain regions, the clinical symptoms and signs of 30% of the patients were improved. There was no change in 52% of patients and only 18% of patients got worse. It is suggested that future work in the research and control of arsenism in China should include: (1) identify all the high arsenic areas in China, (2) study the association of arsenism with fluorosis, (3) determine individual susceptibility, (4) select biomarkers for diagnosis in the early stage of a arsenism, and (5) investigate the molecular mechanisms of carcinogenesis.

56. Wu, M. M., T. I. Kuo, Y. H. Hwang and C. J. Chen (1989), 'Dose response relation between arsenic concentration in well water and mortality from cancers and vascular diseases', *American Journal of Epidemiology* 66: 888-892.

Ground Water Pollution

57. Abdalla, C. W., B. A. Roach and D. J. Epp. (1992), 'Valuing environmental quality changes using averting expenditures: an application to groundwater contamination', *Land Economics* 68 (May):163-169.

Abstract: Water quality is a major environmental issue. Pollution from nonpoint sources is the single largest remaining source of water quality impairments in the United States. Agriculture is a major source of several nonpoint-source pollutants, including nutrients, sediment, pesticides, and salts. Agricultural nonpoint pollution reduction policies can be designed to induce producers to change their production practices in ways that improve the environmental and related economic consequences of production. The information necessary to design economically efficient pollution control policies is almost always lacking. Instead, policies can be designed to achieve specific environmental or other similarly related goals at least cost, given transaction costs and any other political, legal, or informational constraints that may exist. This report outlines the economic characteristics of five instruments that can be used to reduce agricultural nonpoint source pollution (economic incentives, standards, education, liability, and research) and discusses empirical research related to the use of these instruments.

58. Ahmad, J., B. N. Goldar, S. Misra and M. Jakariya (2002), 'Fighting arsenic, listening to rural communities: willingness to pay for arsenic-free, safe drinking water in Bangladesh', www.wsp.org/publications/sa_arsenic_learning.pdf
59. Ahmad K. (2001), 'Wide spread arsenic contamination in Bangladesh', *Lancet* 358:133.
60. Ammann, A. A., E. Hoehn and S. Koch (2003), 'Ground water pollution by roof runoff infiltration evidenced with multi-tracer experiments', *Water Research* 37(5): 1143-1154.

Abstract: The infiltration of urban roof runoff into well permeable subsurface material may have adverse effects on the ground water quality and endanger drinking water resources. Precipitation water from three different roofs of an industrial complex was channelled to a pit and infiltrated into a perialpine glaciofluvial gravel-and-sand aquifer. A shaft was constructed at the bottom of the pit and equipped with an array of TDR probes, lysimeters and suction cups that allowed measuring and sampling soil water at different depths. A fast infiltration flow was observed during natural rainfall events and during artificial infiltration experiments. For a better understanding of the behaviour of contaminants, experiments were conducted with cocktails of compounds of different reactivity (ammonium, strontium, atratone) and of non-reactive tracers (uranine, bromide, naphthionate), which represent different classes of pollutants. The experiment identified cation exchange reactions influencing the composition of the infiltrating water. These processes occurred under preferential flow conditions in macropores of the material. Measuring concentration changes under the controlled inflow of tracer experiments, the pollution potential was found to be high. Non-reactive tracers exhibited fast breakthrough and little sorption.

61. Central Ground Water Board (July 1999), 'High incidence of arsenic in ground water in West Bengal', Ministry of Water Resources, Government of India.
62. Chakraborty, D., G. Samanta et al (1994), 'Arsenic in ground water in six districts of West Bengal, India: biggest arsenic calamity in the world', *Analyst* 119, 168-170.
63. Chakraborty, D., G. Samanta et al (1996), 'Arsenic in ground water in six districts of West Bengal, India: biggest arsenic calamity in the world', *Environmental Geochemistry and Health* 18, 5-15.
64. Chakraborty, D., S. C. Mukherjee, S. Pati, M. K. Sengupta, M. M. Rahman and U. K. Chowdhury (2003), 'Arsenic groundwater contamination in Middle Ganga Plain, Bihar, India: a future danger', *Environmental Health Perspectives* 111(9):1194-1201.

65. Chowdhury, U.K., B. K. Biswas, T. R. Chowdhury, G. Samanta, B. K. Mandal, C. Basu et al (2000), 'Groundwater arsenic contamination in Bangladesh and West Bengal, India', *Environmental Health Perspective* 108:393-97.

66. Chaudhury, S. (2004), 'Soil and ground water pollution in Faridabad', *Environment and Ecology* 22(3):636-641.

Abstract: To assess the quality of soil and groundwater in Faridabad (Haryana, India), 5 sampling stations were selected: Buria nala, Yamuna river, bus stand, railway station and village (residential area), and analysed during winter and monsoon seasons. The range of variation in different parameters was pH 7.2-9.04, DO 4.52-6.93 mg, EC 1.12-1.8 mmho, BOD 1.93-21.63 mg/litre, COD 13.77-56.11 mg/litre, alkalinity 208-366 mg/litre, hardness 308-544 mg/litre, sodium 0.05-674 mg/litre, potassium 0.04-1.40 mg/litre, magnesium 31.8-72.05 mg/litre, sulfate 0.03-40.23 mg/litre, phosphate 0.02-0.72 mg/litre and moisture content 8.69-18.69% during winter and monsoon seasons. The range of almost all the parameters was found to be highest in Buria nala except DO and moisture content. Groundwater in Faridabad was dark black in colour, alkaline and unpleasant in taste. All the heavy metals were within the prescribed range except iron which was between 0.15-18.59 mg/litre. Based on the concentration of different parameters studied, the selected site may be arranged in the order of Buria nala > Yamuna river > bus stand > railway station > residential colony. Results revealed that groundwater of Faridabad is highly polluted as the level of all the tested parameters was higher than the admissible limits and unfit for drinking.

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Abstract: To better understand the magnitude of arsenic contamination in groundwater and its effects on human beings, a detailed study was carried out in Jalangi, one of the 85 arsenic affected blocks in West Bengal, India. Jalangi block is approximately 122 km² in size and has a population of 215538. Of the 1916 water samples analyzed (about 31% of the total hand tubewells) from the Jalangi block, 77.8% were found to have arsenic above 10 microg l(-1) [the World Health Organization (WHO)-recommended level of arsenic in drinking water], 51% had arsenic above 50 microg l(-1) (the Indian

standard of permissible limit of arsenic in drinking water) and 17% had arsenic at above 300 microg l(-1) (the concentration predicting overt arsenical skin lesions). From our preliminary medical screening, 1488 of the 7221 people examined in the 44 villages of Jalangi block exhibit definite arsenical skin lesions. An estimation of probable population that may suffer from arsenical skin lesions and cancer in the Jalangi block has been evaluated comparing along with international data. A total of 1600 biologic samples including hair, nail and urine have been analyzed from the affected villages of Jalangi block and on an average 88% of the biologic samples contain arsenic above the normal level. Thus, a vast population of the block may have arsenic body burden. Cases of Bowen's disease and cancer have been identified among adults who also show arsenical skin lesions and children in this block are also seriously affected. Obstetric examinations were also carried out in this block.

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Policy and Management Issues

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- Abstract: Severe environmental degradation appears to be threatening the long-term development prospects of countries all over the world, particularly the developing ones such as Nigeria. The paper reviews relevant literature and examines the process of environmental degradation via water pollution in Nigeria. While it notes that a careful management of water as a resource is essential for meeting a major demand created by accelerated urbanization, industrialization and agricultural development, it highlights loss of revenue and declining health-care as some of the economic implications. The paper explores the possibility of applying economic instruments to mitigate environmental degradation, with particular reference to water pollution in Nigeria with a view to incorporating environmental costs in the decision-making process of producers and consumers. The paper posits that water pollution control need to be supported by coordinated policy, adequate legal and institutional framework which are essential tools for sustainable development.
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- Summary: This paper presents the analysis and results of three simulation studies on economic growth and pollution, undertaken for the 1992 World Development Report (WDR) on Development and the Environment. Because of anticipated large increases in economic and human activity, the paper tries to determine whether and to what extent pollution could be reduced in the course of the next four decades, once environmental policies were in place, and what the effects on economic growth might be. These questions were addressed by undertaking studies in particular sectors - electric power generation, the use of gasoline and diesel fuels in urban transport, and water and sanitation - and then by gathering some information to see how far similar results might apply in other areas such as soil erosion, indoor and outdoor air pollution, emissions and effluents from various industrial activities, and the long-term reduction of CO₂ emissions from fossil fuels. The paper presents the huge scale of the prospective economic benefits from reforming prices and institutional arrangements in the sectors studied, and the scope for pollution abatement through the adoption of low-polluting technologies and practices. Although the costs of the latter are sometimes significant, they are generally small when compared with the benefits of improving economic efficiency.
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- Abstract: The Mersey Basin has been significantly polluted for over 200 years. However, there is a lack of quantitative historical water quality data as effective water quality monitoring and data recording only began 30–40 years ago. This paper assesses water pollution in the Mersey Basin using a Water Pollution Index constructed from social and economic data. Methodology, output and the difficulties involved with validation are discussed. With the limited data input available the index approximately reproduces historical water quality. The paper illustrates how historical studies of environmental water quality may provide valuable identification of factors responsible for pollution and a marker set for contemporary and future water quality issues in the context of the past. This is an issue of growing research interest.

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permit requirement, and, more recently, to enforcement of a mandate to achieve water quality standards. This Article describes the evolution of federal water pollution control legislation in the United States. It focuses particularly on the 1972 statute prescribing feasibility-based controls for point sources and its 1977 modification, the increasing concern with toxic pollution in the 1980s, and recent litigation requiring total maximum daily loads for waters that fail to meet *water* quality standards. The Article then examines this description to evaluate the accomplishments and failures of each step in the legislative evolution, and to extract practical lessons so that future water pollution control legislation may be successful.

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Summary: This paper analyzed the state of water pollution in China, and several control measures are promoted. The importance of waste water recycling as the effective way to resolve the contradiction of limited water resource and growing demand is emphasized.

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