HARVARD MEDICAL SCHOOL
BRIGHAM AND WOMEN'S HOSPITAL

CASES IN GLOBAL HEALTH DELIVERY

GHD-005
APRIL 2011

Polio Elimination in Uttar Pradesh

By the end of the twentieth century, polio had been eliminated from the Americas and Europe and had been confined to a few outposts in Africa and Southeast Asia. In its most devastating form, polio virus causes paralysis and death. Since 1955, an effective and inexpensive polio vaccine has been available. Large-scale vaccination programs, implemented through the coordinated action of international and local organizations, governments, and individuals, offered the promise of completely eradicating polio from the globe.

In 2002 there was a polio outbreak in India – where there had been just 265 cases in 2000 – accompanied by a six-fold increase in paralytic disease. The outbreak localized to the economically disadvantaged northern state of Uttar Pradesh, disproportionately affecting the minority Muslim population there. Following the outbreak, Dr. Jon Andrus, a veteran of a decade-long struggle in India to eliminate poliovirus, returned to Uttar Pradesh to observe a statewide polio immunization campaign. He reminisced about the battles he and his colleague, Dr. Kaushik Banerjee, had fought through the 1990s to eliminate polio in India and considered the challenges involved in eradicating the disease. He wondered why polio—which had been successfully eliminated from the Americas and Europe—persisted in Uttar Pradesh.

Could he and his colleagues learn from the successes and failures of the past to develop a strategy to finally eliminate polio from Uttar Pradesh?

Overview of India

India, the world's seventh largest country, was bordered by Pakistan to the west, Bhutan, China, and Nepal to the northeast, and Bangladesh and Burma to the east (see **Exhibit 1** for map). With a total area of 3.29 million square kilometers, it was one third the size of the United States.[1] India's northern states, which included large sections of the Himalayan and Karakoram mountain ranges, were difficult to traverse during the winter months. Parts of north-central, central, and south-central India were prone to floods during the rainy season, which began in midsummer and lasted through October.[1]

Daniel Blumenthal, Andrew Ellner, Sachin Jain, and Joseph Rhatigan prepared this case with assistance from Julie Rosenberg for the purposes of classroom discussion rather than to illustrate either effective or ineffective health care delivery practice.

In 2001 India's population was 15% of the world's population (see **Exhibit 2** for literacy rates and other statistical data in India, Uttar Pradesh, and Bihar). Although India had 27 cities with more than one million people, 72.2% of the population lived in rural villages (see **Exhibit 3** for more on urbanization, GSDP, life expectancy, and infant mortality in Indian states). In 2001 the Indian government officially recognized 16 different languages, but more than 50 different languages were spoken throughout the country. For many hundreds of years, the caste system had divided Hindu society into four distinct castes: (1) Brahmins, (2) Kshatriyas, (3) Vaishyas, and (4) Sudras, or untouchables.[2] The caste system was officially eliminated with India's independence in 1947, but in 2002 caste affiliations remained important for many Indians.[1]

Indians practiced a number of different religions, including Hinduism (80.5% of population), Islam (13.4%), Christianity (2.3%), Sikhism (1.9%), Buddhism (0.8%), and Jainism (0.4%).[1] In 2001 approximately 138 million Indian citizens practiced Islam. Muslim communities existed as a minority group in most of India's 35 states and provinces. Most Muslims who lived in north and central India had yearly incomes that placed them in the bottom 50% of the income bracket.[1]

History

India gained its independence from England in 1947 and passed a constitution instituting a parliamentary democracy in 1950. The States Reorganization Act of 1956 re-drew the map originally drawn by the British so that it would better align with ethnic and linguistic subgroups. New states were added over time, and there were ultimately 28 states and seven territories.[1] In the late 1980s, after years of Congress Party dominance, India entered an era of coalition government. Many different parties were represented in Lok Sabha, the National House of Representatives with no party controlling a majority of seats.[3]

From independence to the early 1990s, India pursued a strategy of centralized economic planning. In 1991 India liberalized economic policy, lessening government involvement in the Indian marketplace and seeking to attract private domestic and foreign investment capital.[4] From 1991 to 1996, India's economy grew as much as it had in the previous 40 years.[1] Rural states whose governments were slow to endorse market reforms – Bihar, Madhya Pradesh, Orissa, Rajasthan, and Uttar Pradesh – attracted significantly less investment than other states (see **Exhibit 4** for ranking of Indian states according to gross state domestic product (GSDP) per capita).[4]

Despite the national economic surge, much of India's population remained impoverished at the turn of the twenty-first century. Poverty rates in urban and rural India were very similar in 1990. Urban poverty rates had fallen by 1997, but rural poverty rates remained virtually unchanged.[5] In 1999 the unemployment rate for all of India was 4.4%, increasing to 9.1% by 2003.[6, 7] In 2001, 58.2% of the population worked in cultivation or agriculture (see **Exhibit 5** for distribution of workers in India, Uttar Pradesh, and Bihar).

Basic Socioeconomic and Demographic Indicators [1]

INDICATOR		YEAR
UN Human Development Index ranking	124 out of 173	2000
Population (thousands)	1,042,590	2000
Urban population (%)	27.7	2000
Drinking water coverage (%)	81	2000

[1] This data was comprised from the following sources: United Nations (UN), UNICEF, World Bank, United Nations Educations, Scientific, and Cultural Organization (UNESCO).

INDICATOR		YEAR
Poverty rate (% living under USD 1.25 per day)	42	2005
Gini index	37	2005
GDP per capita in PPP (constant 2005 international dollar)	1,718	2000
GDP per capita in constant 2000 USD	453	2000
Literacy (total, female, male)	61, 47.8, 73.4	2001

Health in India

In 2001 the top causes of death in India were ischemic heart disease (15%); lower respiratory infections (11%); cerebrovascular disease (7%); perinatal conditions (7%); and chronic obstructive pulmonary disease (5%). The top causes of under-five mortality included neonatal causes (infections, birth asphyxia, preterm birth, and congenital anomalies), diarrheal diseases, pneumonia, "other" and measles. Fifty percent of children were malnourished.[8]

In 2001, 65% of pregnant Indian women received some antenatal care, and 30% underwent all four recommended antenatal visits. More than half of all births took place at home.[9] Seventy percent of children born to families in the top 20% of India's income bracket were delivered in health care facilities (43% in public facilities and 57% in private facilities); 9% of infants born into families in the lowest 20% of the income bracket were delivered in health care facilities (83.3% in public facilities and 16.7% in private facilities).[9]

Prior to 1985 less than 50% of India's children received the three recommended doses of polio vaccine. By 1993 rates indicated that 94% of children under one year of age were immunized for polio, 89% for measles, 93% for diptheria-pertussis-tetanus (DPT), and 97% received the bacille Calmette-Guérin (BCG) vaccination for tuberculosis (TB). In 2002 India had 1,600 reported cases of polio and 38,835 cases of measles.

Health System and Epidemiologic Indicators [2]

INDICATOR		YEAR
Average life expectancy at birth (total, female, male)	61, 62, 60	2000
Maternal mortality ratio (per 100,000 live births)	450	2005
Under five mortality rate (per 1,000 live births)	94	2000
Infant mortality rate (per 1,000 live births)	68	2000
Vaccination rates (% of DTP3 coverage)	84	2001
Undernourished (%)	21	2001
Adult (15-49 years) HIV prevalence (per 100,000)	747	2005
HIV antiretroviral therapy coverage (%)	10	2006
Tuberculosis prevalence (per 100,000)	190	2000
DOTS coverage (%)	30	2000

[2] This data was comprised from the following sources: WHO, UNICEF, UN.

INDICATOR		YEAR
Malaria cases (per 1,000)	9	2006
Government expenditure on health as a % of total government expenditure	3.3	2000
Government expenditure on health per capita (international dollar, USD)	16, 5	2000
Total health expenditure per capita (international dollar, USD)	66, 20	2000
Physician density (per 10,000)	6	2004
Nursing and midwifery density (per 10,000)	13	2004
Number of hospital beds (per 10,000)	N/A	N/A

Health System

Indian citizens had three options for health care services: (1) the public health care system, (2) the private health care system, and (3) homeopathic or traditional healers. Public health care services were free of charge but varied widely in terms of quality. The percentage of total health care services provided by the public sector peaked in the late 1970s, at which time they covered the majority of the population. Private health care services were typically perceived to be of higher quality, but also were more expensive. There was dramatic growth in the private sector throughout the 1970s and 1980s in response to limited access to care in the public sector and feelings of skepticism and misgiving among the public.[10] There was also a trend toward greater state (as opposed to national) responsibility for the provision of publicly financed health care services, particularly of curative services. By 2001, 80% of all health spending was in the private sector.[10]

Trained homeopathic and traditional healers were an important source of care. Thirty-three percent of people preferred using homeopathic healers for common ailments, and 18% preferred them for more serious ailments. Only about 14% of people actually utilized homeopathic services. The reasons for preferring homeopathic cures were "no side effects" (31%), "cheap" (30%), "effective" (25%) and "doctor easily available" (11%). Utilization rates were only slightly higher in rural areas than urban.[11]

Systems for holding state governments and health care providers accountable for health care spending and service delivery records were either minimal or nonexistent. Most physicians developed practices in, or close to, urban areas. Many physicians were working in both the public and private health care systems, or had left the public system entirely to work in the private sector.

Uttar Pradesh

Uttar Pradesh, with a population of 166 million people, was the most populous state in India (see **Exhibits 2** and **6** for more on Uttar Pradesh, including a map); 500,000 to 750,000 new births occurred in Uttar Pradesh each month in 2000. Seventy nine percent of Uttar Pradesh's population lived in rural areas,[12] and 65% of residents were employed in cultivation or agriculture in 2001 (see **Exhibit 5** for distribution of workers in India, Uttar Pradesh, and Bihar).[6] A study of India's 14 most populous states indicated that Uttar Pradesh ranked twelfth in terms of urbanization and thirteenth in terms of per capita foreign direct investment secured from 1991 to 2001.[13] Uttar Pradesh had large populations of migrant workers who moved frequently between different parts of North India, following the demand for seasonal labor.

In Uttar Pradesh people from different backgrounds, castes, and religions often lived in separate communities.[14] A significant percentage of the population descended from lower-caste Hindus. Northern

India also had the second-largest Muslim population in the world, behind Indonesia. Uttar Pradesh was the predominant source of Muslim religious discourse in India. In 2001, 22.2% of Uttar Pradesh's residents practiced Islam.[13]

Several violent events exacerbated tensions between the Hindu and Muslim populations in Uttar Pradesh. During the 1970s, one UNICEF official explained, "the only service ever to go door to door [in Muslim Uttar Pradesh communities] was [a] family planning program." The family planning program's employees were compensated according to how many women they could convince to undergo tubal ligation. Later, in the 1980s, when India's door–to-door immunization program began, rumors spread that the vaccine program was a Hindu conspiracy to sterilize Muslim men.

In 1993 a major political rally occurred at Ayodhya, one of the most important Muslim religious sites in Uttar Pradesh. During the rally, Hindu extremists began shouting that the mosque had been built on an ancient Hindu temple. They initiated a successful campaign to remove the mosque. More than a decade later the destruction of the mosque in Ayodhya was "still one of the most sensitive [historic occurrences in Uttar Pradesh] to date," as one official noted.

Because the supply of electricity in Uttar Pradesh was erratic, the majority of businesses ran on generator power.[15] In 2003, three quarters of Uttar Pradesh's residents used a hand pump to collect their drinking water; 80% of rural families and 42,000 (30%) of the state's 138,600 schools lacked toilets.[14] As of 2006, 54.4% of Uttar Pradesh's villages were connected by all-weather roads.[14] Moradabad district, which had the largest Muslim population, had an overall and female literacy rate of 44.75% and 33%, respectively. In Moradabad 32% of the 1,559 villages contained a medical facility, and 5.6% of these villages contained a primary health center or sub-center. More than 97% of all villages had a source for safe drinking water, and 70% of these villages could be accessed via paved roads.[13]

In 2001, 35% of pregnant women in Uttar Pradesh received any antenatal care, and 7% underwent the recommended four antenatal visits.[9] Eighty-five percent of births in Uttar Pradesh occurred at home in 2001.[9] The state had the second-highest prevalence of malnutrition in children less than three years of age of any Indian state or territory. There were three hospitals and 34 beds per 100,000 population.[14]

Uttar Pradesh Health Indicators[3]

INDICATOR		YEAR
Literacy Rate (total, female)	56, 42	2001
Average Life Expectancy	58.4	2003
Maternal Mortality Ratio (per 1,000 live births)	517	2003
Infant Mortality Rate (per 1,000 live births)	76	2003
Percent of Children Immunized – Rural (fully immunized, partially immunized)[4]	19, 69.1	1999
Percent of Children Immunized – Urban (fully immunized, partially immunized)[5]	32.5, 85.8	1999

[3] This data was comprised from the following sources: Census of India, Registrar General of India, Government of Uttar Pradesh, Government of India Ministry of Health and Family Welfare, World Bank.

[4] A child was considered fully immunized if he or she had received one dose of BCG, three doses each of DPT and OPV, and one dose of measles vaccine.

[5] See **Exhibit 7** for graph of children without immunizations

Polio

Poliovirus is an enterovirus with three different serotypes – I, II, and III. The virus is transmitted from person to person via the fecal-oral route. While people of all ages can contract polio, the majority of cases occur in children and adolescents. Humans are the only known reservoir; the virus does not naturally infect any other living organism. People infected with polio, whether or not they have symptoms, excrete, or "shed," the virus in their stool for four to six weeks after contracting the virus. Once a person contracts polio, she develops lifelong immunity to the serotype of the virus that infected her but is still susceptible to the other serotypes.

More than 90% of polio infections are asymptomatic; 4% to 8% of polio infections lead to flu-like symptoms lasting two to ten days; and 1% to 2% of cases lead to a non-lethal aseptic meningitis (inflammation of the tissue lining the brain and spinal cord).[16] Less than 1% of all polio cases result in paralytic polio, or acute flaccid paralysis (AFP). AFP occurs when poliovirus destroys neurons in the anterior horn of the spinal cord that control muscle movements, resulting in a range of paralytic syndromes, including paralysis of one or two limbs, quadriplegia, and respiratory muscle paralysis. Two to five percent of paralytic polio cases in children and 15% to 30% of adult cases result in death.[17] Polio may be suspected based on a constellation of symptoms, but diagnosis is confirmed by identifying poliovirus in a stool sample or throat culture or by detecting antibody levels in the blood.[18]

Two different vaccines are used to immunize people against polio: an inactivated polio vaccine (IPV) and an orally administered polio vaccine (OPV). IPV – a vaccine developed by Jonas Salk in 1952– is a chemical mixture of killed virus. IPV induces an antibody-mediated immune response that prevents the virus from spreading to the nervous system. It induces little gut immunity, however, and therefore does not prevent immunized persons from carrying and spreading poliovirus to others. The vaccine is injected at 2 months, 4 months, 6 to 18 months, and 4 to 6 years of life. IPV costs more than five times as much as OPV and must be administered as an injection.[19]

OPV–Albert Sabin's vaccine approved for use in 1960–contains live virus that has been attenuated or weakened. OPV induces a more robust immune response than IPV, one that involves both cell- and antibody-mediated immunity. OPV confers life-long immunity to all serotypes and prevents immunized individuals from becoming carriers of the virus. It is shed in stool, and by fecal-oral spread it can confer some immunity on close contacts of immunized individuals. There is a slight risk that the attenuated virus will revert to its more virulent wild-type strain and, in rare cases, cause vaccine-associated paralysis, either in the vaccinated individual or a close contact.[20] The risk of vaccine-induced paralysis is estimated at one in every 2.5 million doses of vaccine.[21] Like normal poliovirus, vaccine-derived polio (VDP) is more likely to spread in areas where vaccine coverage is low, as OPV is protective against VDP.[22]

The price of OPV, when purchased for public health programs in developing countries, is USD 0.08 per dose (see **Exhibit 8** for vaccine production, introduction, and pricing in India).[21] OPV, which is administered in liquid form, can be delivered by untrained volunteers. It is very sensitive to heat exposure and loses potency after 24 to 48 hours of exposure to 90- to 100-degree heat. A study on risk factors for polio infection showed that OPV was often "less efficacious in developing countries… because of host and environmental problems, particularly interference with sero-conversion by other enteroviruses and the failure of the vaccine to establish infection in children with diarrhea."[23]

A person is considered fully immunized to polio if he or she has received at least three doses of either IPV or OPV or four doses of some combination of the two.[24] In the United States, where polio is no longer endemic, the US Centers for Disease Control (CDC) stopped recommending OPV in 2000.

During the smallpox eradication campaign, the concept of "herd immunity" was developed. Herd immunity implies that if a sufficient percentage of the population is immune to a particular pathogen, the ability of the pathogen to spread is limited, and the cycle of transmission is interrupted. Outbreaks become rare once a certain immunization threshold is reached. For polio, the CDC determined the herd immunity threshold to be 80% to 86% of a population, though some studies have found the threshold to be as high as 96%.[25, 26]

The Global Polio Eradication Initiative

In 1985 Rotary International ("Rotary"), a non-profit, non-governmental organization whose mission was to "advance world understanding, goodwill, and peace through the improvement of health, the support of education, and the alleviation of poverty," embarked on a fundraising campaign aimed at eradicating poliovirus from the world.[27] Through members the group raised USD 240 million in three years.

In 1988 the World Health Assembly passed a resolution that committed the World Health Organization (WHO) to eradicating polio by the year 2000. Rotary, WHO, The United States Centers for Disease Control (CDC), and the United Nations Children's Fund (UNICEF) formed a partnership called the Global Polio Eradication Initiative (GPEI) to meet the World Health Assembly's commitment to polio eradication. GPEI would be the single largest, internationally-coordinated public health project in the world.[28]

Rotary, which had 1.2 million members in more than 160 countries, funded polio eradication efforts by giving money directly to governments' ministries of health and finance. Rotarians (mostly professionals from middle- and upper-middle-class backgrounds) participated directly in polio elimination activities in many different countries by volunteering for immunization activities and helping with community advocacy and social mobilization programs. The Global Polio Eradication Initiative used OPV almost exclusively.

WHO "provided the overall technical direction and strategic planning for the management and coordination of GPEI."[29] It played a major role in planning and implementing polio eradication activities, training new staff, and performing data collection and analysis. WHO was also responsible for implementing and monitoring surveillance networks for polio cases, overseeing a global network of laboratories, and creating resource mobilization networks.[29]

The CDC supplied GPEI with trained scientists to study polio. Epidemiologists, public health experts, and other scientists employed by CDC were loaned to WHO, UNICEF, and governments of foreign countries to work on disease surveillance, investigations of polio outbreaks, and developing and monitoring polio laboratories in roughly 145 countries that were part of the GPEI's "global polio laboratory network."[29] The CDC paid the salaries of the scientists whom it loaned to GPEI and paid for a significant percentage of polio vaccine used.[29]

UNICEF worked in 190 countries to advocate for the protection of children's rights, to help meet children's basic needs, and to expand children's opportunities to reach their full potential. UNICEF was in charge of polio vaccine procurement and allocation, organizing and paying for cold chains (networks of refrigerators for preserving heat-unstable medicines), and helping to deliver vaccine during immunization campaigns. UNICEF advised governments on how to improve routine immunization activities and counseled coordinators of national polio elimination programs on how to create "action plans" and secure logistics in hard-to-reach places. Logistics security was particularly relevant for countries in the midst of violent conflicts. UNICEF was also largely responsible for generating employee training materials, creating and implementing a marketing strategy to advertise polio campaigns, and organizing social mobilization and community advocacy programs.[29]

In 1988, the year the GPEI was launched, polio was endemic in more than 125 countries. The number of polio cases decreased from an estimated 350,000 cases in 1988 to 1,919 in 2002 - a more than 99% reduction. In 2002, seven countries were still polio-endemic: India, Nigeria, Pakistan, Egypt, Afghanistan, Niger, and Somalia.[28, 30]

Polio in India

Eradication Efforts Before 1993

The Indian Government was in charge of all polio elimination activities that occurred in India and had to approve GPEI activities. The smallpox immunization campaign had paved the way for a government program called the Universal Immunization Program (UIP). Beginning in 1985, UIP coordinated all surveillance and routine immunization programs in India for polio, measles, tetanus, diphtheria, whooping cough, and childhood TB. The UIP reached national coverage by 1990. Every district in India had at least one fixed immunization site, and OPV was also available in many health centers. By that time, there was a national cold chain, meaning all peripheral health centers had refrigeration equipment, and enhanced local vaccine production capacity.[29] The government surveillance system for polio cases relied on notification from health centers, which were supposed to report suspected polio cases to the UIP. Experts believed that the numbers collected through the passive reporting system represented, at most, 10% of the real disease burden. Despite that, the reported numbers had India accounting for at least half of the world's reported cases. The government paid the salaries of all non-GPEI employees (including UIP employees and staff at government-run immunization booths who delivered OPV), covered transportation costs, and purchased all vaccines made in India.

The Polio Immunization Campaign

In September 1993 Dr. Kaushik Banerjee, a former teacher at a medical college in India and an employee of Delhi's state immunization program, was asked to join the UIP. Banerjee believed that India still needed supplemental immunization strategies in addition to the routine vaccinations that occurred at health clinics to eliminate polio.[29]

Dr. Jon Andrus arrived at the WHO's Southeast Asian regional office in New Delhi in November 1993 to create new polio immunization programs for the WHO's 11 Southeast Asian countries, including India. Previously, Andrus had served as the lead immunization technical advisor for the Pan-American Health Organization. Andrus explained, "Part of [the] intent [of the new polio program] in Southeast Asia was … applying technical strategies that were tried and proven in the Americas. My goal was to take that model and get it established in Southeast Asia."

Starting Local

Both Andrus and Banerjee were new to New Delhi and to Indian national politics. They quickly became good friends. The Deputy Commissioner for Maternal and Child Health in the Ministry of Health and Family Welfare for the Indian National Government was Banerjee's supervisor. The Deputy Commissioner was one of the few influential central government members who opposed starting supplemental immunization activities (SIAs). She believed in improving surveillance before working on immunization activities and that starting SIAs would be expensive and a waste of resources. Banerjee saw

this as a "chicken and egg situation: Surveillance would not improve until the program secured more funding, but the best way to attract new funding was to initiate an immunization campaign."

New Delhi held local elections in 1994. Dr. Harsh Vardhan, a surgeon and Bharatiya Janata Party (BJP) member whom Banerjee knew well, became Minister of Health for the state of New Delhi. In 1993–1994, the BJP also took control of several other state governments in India. Soon after Vardhan's election, Banerjee and Andrus approached him about organizing SIAs in New Delhi. Harsh Vardhan agreed to hold two immunization rounds, spaced four to six weeks apart, in New Delhi in the winter of 1994–1995. More than 80% of New Delhi's children were immunized during these two rounds.

Banerjee and Andrus next set about implementing supplementary immunization programs throughout India. Vardhan wrote letters to his counterparts in other states, telling them how effective the campaign had been in Delhi and "what a benefit it would be if everybody were immunized and polio was finished," Banerjee recalled. Rotary, with 33,177 clubs in India, contacted many of India's state and national politicians to rally support for the national SIA campaign. In March 1995 Banerjee, Andrus, and representatives from Rotary held a meeting with the immunization program managers of India's southern states. At this meeting, Banerjee presented a plan to conduct state-level SIAs in each of the southern states if the National Government could not be persuaded to do so by the end of 1995. Rotary's members, who had personal relationships with the Ministers of Health of each southern state, contacted each Minister to promote the plan and alleviate concerns about the SIAs. Each Minister eventually backed the state-level SIAs, and the southern states' immunization managers unanimously agreed to hold state-level immunization days in the winter of 1995–1996 if nationwide immunization activities did not happen by that time.

Preparing for National Action

In April 1995 Banerjee scheduled a meeting with India's Minister of Health to discuss starting national SIAs. To secure this meeting, Banerjee had to go around his supervisor, the Deputy Commissioner. The Minister of Health and Prime Minister agreed to back Banerjee's proposal and gave him USD 15 million to fund supplementary SIAs against polio. Shortly thereafter, Banerjee's supervisor left the Ministry of Health. Banerjee remembered that "India [was] a funny place in the sense that … there [was] a lot of inertia, and no one [wanted] to change anything. Any change that [happened] in India, [occurred because] individuals … stuck their necks out in a way."

Banerjee and Andrus next tried to secure the support of various state and local government officials through letters about what the program was and how they could help. They traveled extensively throughout the country to mobilize support and educate key people on the polio eradication strategies. When Bangladesh was able to implement some of their strategies and hold the first National Immunization Day (NID), the Parliament of India took notice and mobilized support; it did not want to lag behind.

Banerjee and the GPEI decided that two critical activities needed to occur during the first round of national SIAs or NIDs, which was scheduled for December 1995: "One, we [needed to buy] the vaccine and we [needed] to get [it] down to the last level – to the outpost – and have a booth there with a guy to [man] it. The second thing was that we needed to get the message out so the children would come [to the immunization posts] to take it."

An estimated 300 million doses of OPV were needed to carry out the first two Supplemental NIDs for India's 125 million children under the age of five. "Nobody in the world had that [quantity] of vaccine at that time," Banerjee said. Vaccine manufacturers required a six-month lead time for vaccine orders. And, when Banerjee placed India's vaccine order in June 1995 for the December 1995–January 1996 NIDs, the order still exceeded the vaccine manufacturer's capacity. From their small amount of surveillance data, the

leaders of India's polio program determined that 84% of all polio cases occurred in children under three years of age and decided to use the first two NIDs to target this age group.

Making the Campaign Happen

To prepare for the campaign, from late spring to December 1995, state immunization managers traveled to the capital every three weeks to meet with Banerjee. Banerjee used the meetings to outline "what [needed] to be done now, [and] what [needed] to be achieved" in general, as he explained. Banerjee taught the immunization managers to make timelines that started six months before the first scheduled NID, and Banerjee and Andrus worked hard to prepare a national polio eradication field guide. The Deputy Commissioner for Maternal and Child Health approved the guide, and it was translated into dozens of languages in time to be circulated to volunteers and health workers before the first NID. Meanwhile, the GPEI partnered with India's school system, railroad companies, banks, and telephone companies to alert people about the upcoming NIDs. One telephone company played a reminder about the December 6 NID before the dial tone came on the phones of all of its customers.

One of the biggest challenges was ensuring that the vaccine reached the booths without being compromised by heat. Once made, vaccine was stored at the manufacturer and in government facilities in New Delhi and other large cities across India. In the weeks before a round began, vaccine was disseminated to different states via trains, trucks, and cars and stored temporarily in health centers, the homes of local community members, and wherever else the GPEI or the state could locate a refrigerator. Each booth was supposed to be supplied with a small portable vaccine carrier equipped with frozen ice packs to keep the vaccine cold throughout the immunization day. The GPEI relied on donations to pay for cold packs and vaccine carriers and on volunteers to deliver them to the immunization booths in each state. Many, though not all, of India's states succeeded in supplying all of their booths with vaccine carriers and ice packs. Andrus equated a working cold chain to a new car that had just been purchased: "You did well for a while, but eventually the cold chain needed to be repaired."

During the two 1995–1996 NIDs, which were held on Sundays, vaccine was administered at 650,000 fixed polio immunization "booths" across India. Each booth was manned by an average of four people. The Indian Government and the GPEI recruited health care workers, government employees, and volunteers to staff the booths; they were joined by Rotary volunteers and WHO and UNICEF employees. All government booth workers were paid the same per-diem wage. People who took time off from work to volunteer for the polio program were paid for the missed workdays. On the first NID alone, 87 million children received two drops of the oral vaccine.[31]

The estimated cost of India's first NIDs was USD 30.3 million and included contributions from India (USD 18.0 million), the British Overseas Development Agency[6] (USD 6.1 million), Rotary (USD 5.0 million), and the United States Agency for International Development (USAID) (USD 1.2 million).[32]

Increasing Coverage and Surveillance

The GPEI mobilized teams of outside experts to monitor and evaluate the campaign implementation. National data indicated that 90% of children were immunized during these rounds. After the NIDs in 1995–1996, many southern and small northeastern states interrupted transmission of endemic polio. Following these NIDs, polio cases and outbreaks across India also decreased in frequency and number and became more localized. Two more rounds of NIDs took place in the winter of 1996–1997 and targeted all children in

[6] The British Overseas Development Agency was replaced by the United Kingdom Department for International Development (DFID) in 1997.

India under five years old. The US CDC paid for the 130 million additional doses of OPV that were needed to immunize children between the ages of three and five. The GPEI placed its vaccine order one year in advance, and vaccine manufacturers filled it successfully. Banerjee was pleased with these early efforts, though a senior-level manager at GPEI headquarters in Geneva believed that surveillance and data reporting were not consistent enough to draw any conclusions about the quality of the NIDs. At the end of 1996, polio surveillance mainly consisted of reporting confirmed polio cases from hospitals or large health care clinics. Hospitals did not report cases of "non-polio AFP," cases of AFP that were thought to be caused by something other than poliovirus.

With the information that it had collected during the 1996–1997 NIDs, the GPEI concluded that India's NIDs were missing too many children. The next NIDs from December 1997 to January 1998 included one day of booth immunization activities followed by two to three days of "house-to-house" activities. For house-to-house activities, the four people staffing a booth site would split up into teams of two to walk through the surrounding communities and immunize unvaccinated children. House-to-house activities increased immunization coverage by 2–3%.

Banerjee left the Ministry of Health in 1997 to start the National Polio Surveillance Project (NPSP), a joint initiative between WHO and the Indian Government. Some government employees were released from government service for a five-year period to work for NPSP. WHO paid their wages, which were competitive with government salaries. The CDC also loaned employees to the NPSP and shared the costs associated with running the program. The Indian government gave the NPSP its own office in New Delhi.

GPEI began discussions with the Danish National Development Agency (DANIDA) about helping fund the polio eradication campaign. When DANIDA was not interested in polio eradication, Andrus convinced DANIDA that polio was an entry point to developing capacity for public health surveillance—its main interest. DANIDA soon approved USD 12.3 million for the development of active AFP surveillance in India.

Using part of the DANIDA grant, GPEI hired and trained 59 health care professionals to become the NPSP's surveillance medical officers (SMOs). Most of the trainees were physicians who worked full time in hospitals or health care clinics before agreeing to become SMOs. The training took place over two weeks and was full-time. The SMOs were told not only to look for polio cases, but for all cases of AFP and to investigate them so they could then classify them as polio or non-polio AFP. To do this, the SMO would need to ensure that a stool sample from the affected child was sent to a national lab to be tested for polio virus. After the two-week training session, each SMO was given a car, a laptop, and a mobile phone and was assigned to a particular region of India to conduct polio surveillance. Many states were too large to be covered by one SMO, so sub-regions within each state were created, and sub-regional surveillance officers (SSOs) were subsequently hired to oversee other newly hired employees, including district surveillance officers (DSOs) and small teams of field volunteers.

Once the SMOs began reporting to NPSP headquarters, Banerjee received continuous data via fax from 30 state field offices and eight national laboratories. He decided that each of these offices and laboratories would be allowed to send only one fax per week, on Wednesday, to NPSP headquarters. After instituting this system, on Fridays the NPSP would send a summary of the data back to the labs and offices.

In addition to better surveillance for polio cases, there was a push to improve children's immunization status monitoring (see **Exhibit 9** for reported national vaccine coverage by antigen). Ellyn Ogden, the director of USAID's Global Polio Program, Andrus, and Banerjee had been lobbying India's Ministry of Health to implement a program to monitor the immunization of infants. They had grown increasingly concerned that infants were not receiving the recommended number of OPV immunizations shortly after birth. In 2000 the Indian Government agreed to implement an initiative to monitor the immunization status

of all households with children under five years of age. Ogden thought that a "baby tracking system" – which would monitor the immunization status of every child less than one year of age – was the best method for increasing the number of infants who received the recommended doses of OPV and other vaccinations such as DPT, Measles, and BCG.

Concerns in Northern India

In 1999 the GPEI found that "a major [coverage] gap" still existed in parts of India, particularly in the north (see **Exhibit 10** for maps of polio distribution). Surveillance data showed that routine immunization coverage was less than 20% in many districts in Northern India, and very few people were being immunized at district and local hospitals and community health centers. After a sustained outbreak of Type III polio that started in late 1998 and continued through much of 1999, the GPEI learned that a portion of the vaccine administered during the 1998–1999 campaign had been sub-potent.

A large number of citizens in Northern India had concerns about the campaign and began to refuse to allow their children to be vaccinated. They asked the vaccination teams why they kept coming back and why they did not bring other medicines, nutritional supplements, and vaccines to prevent the diseases that were afflicting them far more commonly than polio. In 1999 Andrus conducted an informal study of the childhood case fatality rate (CFR) due to measles in Uttar Pradesh and found that the CFR was 38%. He concluded that malnutrition and vitamin deficiencies "left children particularly susceptible to [many diseases, including] measles."

Andrus knew that Pan-American Health Organization-led polio immunization campaigns in Central and South America had delivered vaccines against tetanus, measles, diphtheria, and pertussis, as well as vitamin supplements and oral rehydration packets, along with polio vaccine. The GPEI and the Indian Government discussed initiating a similar "multi-antigen" campaign in India but ultimately deemed it unfeasible.

The 4+2 Program

In late spring of 1999, WHO's global Technical Advisory Group (TAG) was invited to New Delhi to review India's progress toward polio elimination. This group included prominent scientists from around the world and gave scientific and technical advice to the GPEI. Most regions of the world, as well as some large or particularly challenging countries, also had region- or country-specific TAGs. This meeting was the first gathering of the India Expert Advisory Group, India's country-specific TAG. Andrus and Banerjee argued that India needed to increase the number of immunization rounds it performed each year to six in the North and four in the South and presented recent surveillance data to support their proposal.

The government agreed, and in 1999–2000 six separate rounds of immunization activities were carried out in Northern India (four NIDs and two sub-NIDs) and four rounds in Southern India (two NIDs and two sub-NIDs). This new immunization schedule was called the "4+2" program. Normally, the two winter NIDs "[knocked] out polio [for a few months], and then it [came] right back in the rainy season," Banerjee said. The six rounds in the North fulfilled "the absence of population immunity" for six months.

India's vaccine requirements increased significantly during the 4+2 program, from 400 million doses in 1998–1999 to about 1 billion doses in 1999–2000. Indian manufacturers had produced 30% of all OPV used in India in 1993, but since 1997–1998, they had been manufacturing the majority of OPV used in India.

Polio cases in India dropped from 1,126 in 1999 to 265 in 2000 and 268 in 2001 (see **Exhibit 11** for graph of Type I cases by year). Andrus believed that India "had the virus cornered in Western Uttar Pradesh" after

the 1999–2000 campaign. By the end of 2000, India was the only country in the WHO's Southeast Asian region that had not yet interrupted transmission of wild polio virus.[33]

Polio in Uttar Pradesh

Between 1993 and 2001, even during the 4+2 program, Uttar Pradesh consistently reported more cases of paralytic polio than any other state in India. In 2001, 216 of India's 268 polio cases occurred in Uttar Pradesh. The majority of polio cases in Uttar Pradesh habitually occurred in 13 districts in Western Uttar Pradesh, which had larger Muslim populations as a proportion of total population than most other districts.[13] The Moradabad district consistently suffered the largest number of cases of any district.

The NPSP had data showing that virtually all newborns in Uttar Pradesh were infected with non-polio enteroviruses by two weeks of age. WHO experts estimated this exposure, in addition to the area's population density, prevalence of diarrhea, and routine immunization coverage, cut the vaccine's efficacy in half.

Organizing the State Response

To help organize polio immunization and surveillance activities in Uttar Pradesh, the GPEI and the Government of India divided the state into three sub-regions: Western Uttar Pradesh, Central Uttar Pradesh, and Eastern Uttar Pradesh. Each sub-region was then divided into districts.

For example, Lucknow district, which had a population of 4,724,459, was comprised of Lucknow City, the capitol of Uttar Pradesh, and the surrounding region. Lucknow's polio program divided Lucknow district into 31 different planning units. Lucknow's district magistrate oversaw the district polio program on a day-to-day basis. Lucknow district's chief medical officer worked directly beneath the district magistrate. The chief medical officer oversaw both the district immunization officer and Lucknow's 31 divisional officers, who each managed a number of other physicians and health care workers.

Each district in Uttar Pradesh had a surveillance medical officer (SMO), the NPSP's most senior district-level employee, and a number of paid employees called field volunteers. The field volunteers almost always came from communities in the district where they worked, and with the SMO, they coordinated polio surveillance activities within their district.

As in the rest of the country, polio elimination activities in Uttar Pradesh were a joint project of the Indian National Government, the State Government of Uttar Pradesh, UNICEF, Rotary, and the NPSP, but Uttar Pradesh's Ministry of Health officially ran and oversaw all activities. By 2002 UNICEF's polio program in Uttar Pradesh was its largest state-level polio program in India. Rotary also had an extensive presence; the majority of Rotarians in Uttar Pradesh volunteered for polio immunization campaigns. These Rotarians staffed immunization booths to administer polio vaccine, handed out whistles and other toys during the immunization campaigns, and helped with social mobilization activities and community advocacy (see **Exhibit 12** for Campaign against Polio and other media materials). Each Rotary club had a polio program representative who worked with other Rotary club polio program representatives in his/her district and the District PolioPlus Coordinator to organize Rotary's volunteers and provide Rotary's booths with OPV and toys. Rotary handed out millions of toy whistles each year in India.

Despite all of this attention, Uttar Pradesh's polio program continued to struggle to recruit volunteers to disseminate coolers and ice packs to different regions of the state. The program also lacked the necessary funding to purchase adequate supplies of coolers and ice packs, and the procurement of refrigerators for vaccine storage – which would be needed for six immunization rounds and for vaccine storage between

rounds – remained a serious worry. The polio partners attempted to get the local milk producer or the local religious leader to endorse the immunization campaign and support efforts to create cold chain infrastructure.

A Typical Immunization Day

A typical immunization event in Uttar Pradesh included one day of fixed-site immunization activities followed by five or six days of house-to-house immunization activities. Immunization team supervisors, health officers, and district-level leaders of the program all had micro-plans for their district, which included the name of every high-risk area in each city, the numbers of houses in each district, the status of the houses, and the names of and contact information for the district's health officers.[34] The high-risk areas in each city were also ranked according to their relative levels of immunization coverage.

District polio programs organized immunization booths for the fixed-site immunization activity, and each booth was staffed by at least three people. Workers wore white lab coats and blue hats supplied by Rotary that read "Poliofree India." After administering the vaccine to a child, the workers would draw a black line on the child's fifth finger with a black marker.

Booth supervisors traveled from booth to booth throughout the day to oversee the activities. The supervisors distributed bags of whistles to each booth they visited; the whistles were used to alert the community of the immunization event. Supervisors spent up to 30 minutes visiting each booth. They inquired about how many children the booth had immunized that day; whether booth staff had encountered any resistance to vaccination; if they needed assistance from the administration; and, if there were any problems with the vaccine supply or cold chain. Booth workers relayed any observations and feedback to supervisors, and supervisors helped in the planning for the next NID. They offered suggestions such as shifting the booth to make it more accessible or more visible to residents. Supervisors checked the temperature of the cold chain and examined the vials of vaccine to make sure that the vaccine vial monitors (temperature-sensitive labels on the vials that would turn purple if the vial had not been properly refrigerated) had not expired. Supervisors' mobile phones contained the numbers of the district administration officer, the district magistrate, the chief medical officer, the state cold chain officer, and the local district immunization officer, who was responsible for providing medicines and vaccines to the district's hospitals and health care clinics. The booth workers often reported that they got "a morale boost" from the supervisor visits.

In the evening of the first day of an immunization event, a meeting was held for an hour to review the day's events. Both UNICEF's and Rotary International's district-level leaders attended the meeting, as did the supervisors of each of the district's planning units, most of whom were physicians. The group discussed any problems that arose during the day, any cases of vaccine refusal, and the data that had been collected by the vaccination teams.

House-to-house activities commenced on the second day. Teams visited 80 to 140 houses per day to check for children under five who had not yet been immunized during the August immunization round. Team supervisors were also in the field, visiting the various communities where their teams were working.

Beginning in 2002, house-to-house vaccination teams began using chalk to write two fractions on the door or wall of all houses that they visited. One fraction consisted of the house number in the numerator and the team number in the denominator. The second fraction had either a "P" or an "X" in the numerator and the date in the denominator; "P" meant that either all the children under five living in the house had been immunized or that no children under five lived in the house, and "X" signified that the team had missed a child under five who lived in the house. There were five different sub-categories of "X houses" that

the vaccine teams did not write on the house itself but recorded in their notes, indicating the cause for missing a child (see **Exhibit 13** for code descriptions).

At the end of the day, physicians knocked on the doors of a number of "P" houses, asking the person who greeted them if any children under five lived there. If the answer was yes, the two pediatricians asked that the children be brought to the door. The physicians then checked for a black ink mark on the children's finger nails to see if they had been vaccinated that day. If the answer was no or no one answered their knocks, the doctors recorded this information in their log books, which they carried with them at all times, and moved on to another house.

All the vaccination teams and physician monitors brought their tally sheets to a central supervisor who reviewed them, recorded data on the number of houses that each team visited that day and the numbers and types of X houses that each team encountered. If some teams did not come back to the community health center at the end of the day, the administrator contacted one of the team members to get information about their day's work. The administrator then began to synthesize the data into a format that would be faxed to an overseer later that evening.

Outbreak

In the summer of 2000, Andrus suffered a heart attack and returned to the United States, and Banerjee resigned from NPSP later that fall. Against Banerjee's and Andrus's advice, the Indian government decided to scale back the 4+2 immunization program to two NIDs and two sub-NIDs in Northern India. The new director of NPSP explained that the government thought that it could control polio outbreaks with "smaller [immunization] rounds" that could be quickly organized and carried out in response to local outbreaks, called "mopping-up" campaigns.

In 2002 India suffered a polio outbreak, and 1,600 children came down with paralytic polio (see **Exhibits 11, 14** and **15** for information on monthly cases in Uttar Pradesh and India). Of the 1,600 polio cases that were identified, 1,242 occurred in Uttar Pradesh. Fifty-six percent of these cases were from Muslim communities**.** Data collected by the NPSP demonstrated that a pool of unvaccinated children had accumulated prior to 2002 and highlighted the existence of polio-endemic regions "in Northern India where [polio] just never basically stopped," as WHO's Chris Maher said. Polio retreated to these areas in bad times and expanded into surrounding areas when conditions were more conducive for transmission.

When Andrus returned to Uttar Pradesh that year, he reminisced about the efforts to eliminate the disease and looked forward to observing the government's renewed campaign against the virus. He suspected that Uttar Pradesh would prove to be the most difficult place in the world from which to eliminate polio.

Exhibit 1 *Map of India and Southern Asia*

Source: www.lib.utexas.edu/maps/

Exhibit 2 *Literacy Rates and Other Statistical Data in India Uttar Pradesh and Bihar, 2001*

	India	Uttar Pradesh	Bihar
Population			
Persons	1,028,610,328	166,197,921	82,998,509
Males	532,156,772	87,565,369	43,243,795
Females	496,453,556	78,632,552	39,754,714
Literacy rate			
Persons	64.8%	56.3%	47.0%
Males	75.3%	68.8%	59.7%
Females	53.7%	42.2%	33.1%
Average HH income (rupees)	27,128	26,003	21,175
Land holding per HH (acres)	3.1	2.7	1.9
Income inequality measure	0.8	0.69	0.72
Villages with an NGO	10.6%	1.4%	2.6%
Percentage of villages electrified			
1985	64.02%	56.03%	49.63%
1998	86.67%	78.11%	70.82%
Change	22.65%	22.08%	21.19%

Source: Census of India. Available at: http://www.censusindia.gov.in.

Exhibit 3 *Urbanization, GSDP, Life Expectancy, and Infant Mortality in Indian States*

	Rates of Urbanization (%)		Rates of Growth of Per Capita GSDP	Life Expectancy at Birth (Years)	Infant Mortality Rate (per 1,000)
	1981	1991	1992–93 to 1998–99	1993	1998
Andhra Pradesh	23.32	26.84	3.7	62.8	66
Bihar	12.47	13.17	-0.2	58	67
Gujarat	31.1	34.4	7.8	62	64
Haryana	21.88	24.79	2.6	64	70
Karnataka	28.89	30.91	3.5	63.9	58
Kerala	18.74	26.44	4.6	75.6	16
Madhya Pradesh	20.29	23.21	3.9	54.6	98
Maharashtra	35.03	38.73	6.8	65.8	49
Orissa	11.79	13.43	1.6	56.2	98
Punjab	27.68	29.72	2.8	68.4	54
Rajasthan	21.05	22.88	4.4	59.4	83
Tamil Nadu	32.95	34.2	5.0	62.8	53
Uttar Pradesh	17.95	19.89	1.6	56	85
West Bengal	26.47	27.39	4.8	62.8	53

Source: Sachs JD, Bajpai N, Ramiah A. Understanding Regional Economic Growth in India. Asian Economic Papers. 2002;1(3):32-62; 43-44.

Exhibit 4 *Indian States Ranked According to Gross State Domestic Product (GSDP) per Capita*

	1980–1981	1998–1999
1	Punjab	Maharashtra
2	Maharashtra	Punjab
3	Haryana	Gujarat
4	Gujarat	Haryana
5	West Bengal	Tamil Nadu
6	Kerala	West Bengal
7	Karnataka	Karnataka
8	Tamil Nadu	Kerala
9	Andhra Pradesh	Rajasthan
10	Madhya Pradesh	Andhra Pradesh
11	Uttar Pradesh	Madhya Pradesh
12	Orissa	Uttar Pradesh
13	Rajasthan	Orissa
14	Bihar	Bihar

Highest income = 1; lowest income = 14

Source: Sachs JD, Bajpai N, Ramiah A. Understanding Regional Economic Growth in India. *Asian Economic Papers*. 2002;1(3):32-62; 43-44.

Exhibit 5 *Distribution of Workers in India, Uttar Pradesh and Bihar, 2001*

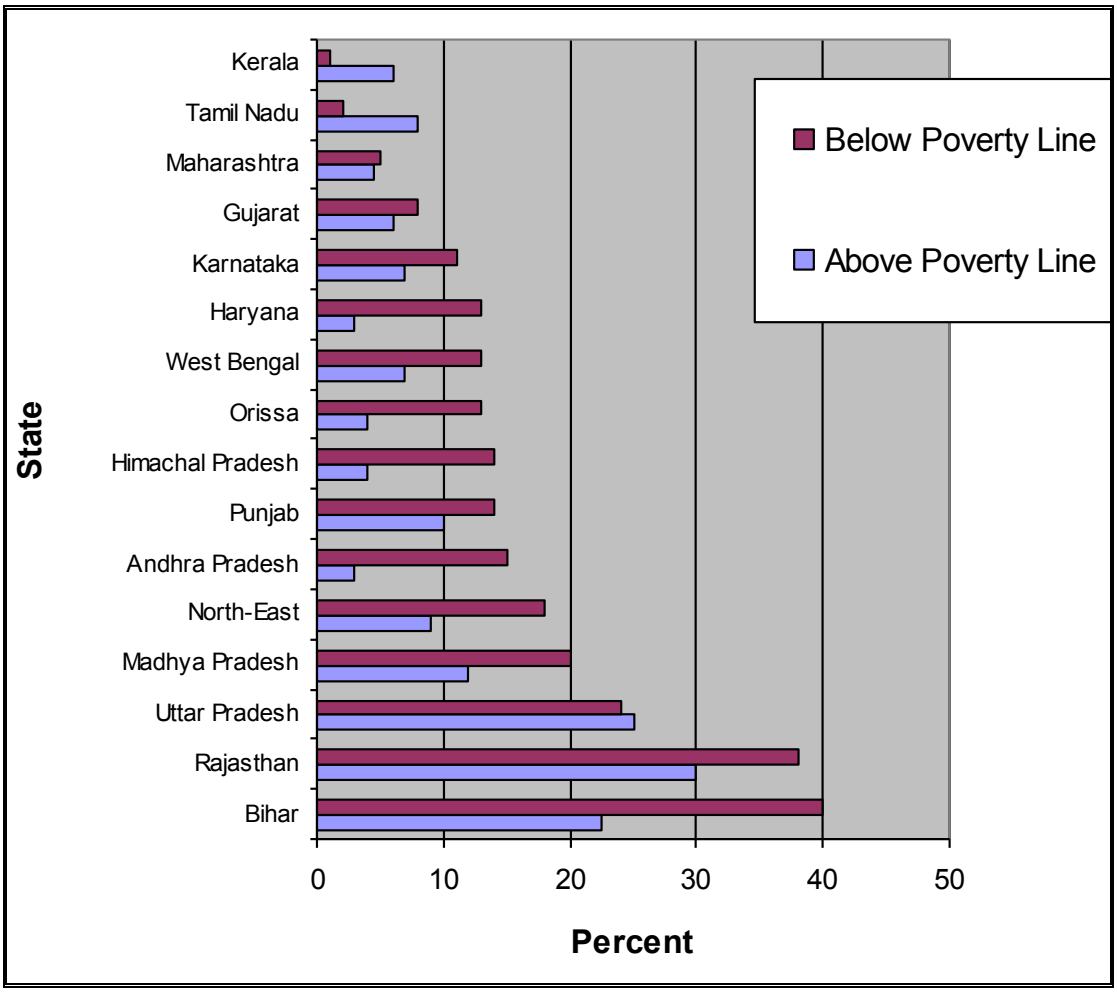
Distribution of Workers	India	Uttar Pradesh	Bihar
Total workers			
Persons	402,234,724	53,983,824	27,974,606
Males	275,014,476	40,981,558	20,483,003
Females	127,220,248	13,002,266	7,491,603
Cultivators			
Persons	127,312,581	22,167,562	8,193,621
%	31.7%	41.1%	29.3%
Males	85,416,498	17,479,887	6,457,265
%	31.0%	42.7%	31.5%
Females	41,896,353	4,687,675	1,736,356
%	32.9%	36.1%	23.2%
Agricultural laborers			
Persons	106,775,330	13,400,911	13,417,744
%	26.5%	24.8%	48.0%
Males	57,329,100	8,245,599	8,730,251
%	20.8%	20.1%	42.6%
Females	49,446,230	5,155,312	4,687,493
%	38.9%	39.6%	62.6%
Household industry workers			
Persons	16,956,942	3,031,134	1,100,424
%	4.2%	5.6%	3.9%
Males	8,744,183	1,946,545	656,662
%	3.2%	4.7%	3.2%
Females	8,212,759	1,084,619	443,762
%	6.5%	8.3%	5.9%
Other workers			
Persons	151,189,601	15,384,187	5,262,817
%	37.6%	28.5%	18.8%
Males	123,524,695	13,309,527	4,638,852
%	44.9%	32.5%	22.6%
Females	27,664,906	2,074,660	623,992
%	21.7%	16.0%	8.3%

Source: Census of India.

Exhibit 6 *Map of the Districts in the State of Uttar Pradesh, India*

Source: Adapted from public domain.

Exhibit 7 *Indian Children Aged 12–23 Months without Any Immunizations*



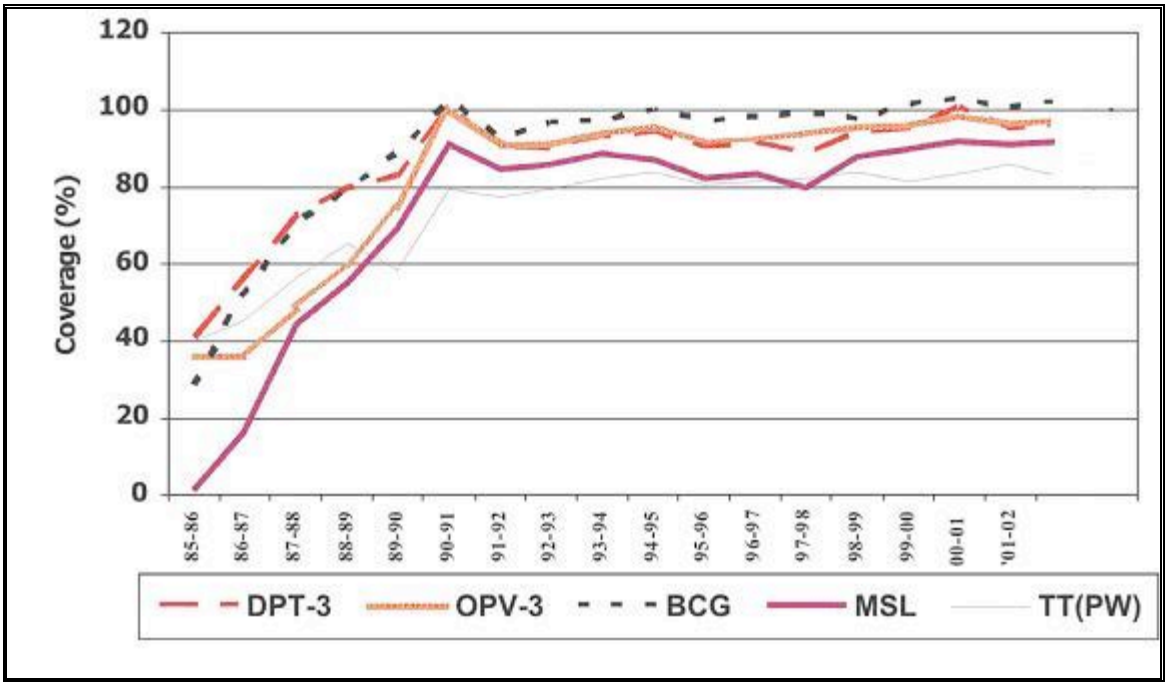
Source: Created by case writers using data from multiple sources.

Exhibit 8 *Vaccine Production, Introduction, and Pricing in India*

Category	Vaccine	Production Technique	Year of Introduction		Necessary Quantity	Price of Full Immunization From Indian Companies (USD)	
			World	India		Public Sector	Private Sector
Primary under UIP	OPV	Monkey kidney cell culture vaccine	1962	1967	Three doses	0.03	0.16
	DPT	Purified toxoids inactivated with formaldehyde	1920s	1920s			
		Purified toxoids adsorbed to aluminum hydroxide	1963	1978	Three doses	0.08	~0.09 to 1.34
	TT	Purified toxoids inactivated with formaldehyde	1920s	1920s	Two doses	0.01	0.02
		Purified toxoids adsorbed to aluminum phosphate	1963	1972	Two doses	~0.01 to 0.02	0.15
	DT	Purified toxoids inactivated with formaldehyde	1920s	1920s			
		Purified toxoids adsorbed to aluminum hydroxide	1963	1978	Two doses	0.02	---
	Measles	Tissue-culture-based vaccine	Late 1980s	1989	One dose	None	~0.59 to 11.69
New / Improved Vaccines	Hepatitis B	Recombinant DNA technology	1980s	1997	Pediatric	None	~2.80 to 11.30
					Adult	None	~6.05 to 9.35
	R-Vac (rubella)				One dose	None	0.76
	Measles-Mumps-Rubella				One dose	None	1.01
	Meningococcal A & C				One dose	None	1.01
	Influenza B				Three doses	None	~23.07 to 24.94
	Typhoid	Heat-phenolized whole-cell vaccine	1915	1920	Three doses	None	5.71
	Oral typhoid		1984	1994 (marketed by private sector)	One dose	None	27.96
	Chickenpox				One dose	None	27.96
Other Vaccines	Smallpox	Glycerinated lymph	1890s	1898			
		Live attenuated freeze-dried	1941	1965			
	Plague	Whole-cell killed bacteria	1897	1897			
	Cholera	Attenuated whole-cell preparation	1892	1892			
		Agar-grown heat inactivated Vibro cholerae whole-cell vaccine	1902	1911			
		Cholera vaccine prepared using modern techniques	1986	Not yet			
	Yellow fever	Live attenuated (passing through cell lines) virus vaccine	1941	1965			
	IPV	Inactivated polio vaccine	1955	1984			
	Improved IPV, OPV	Vero cell cultures	1988-1989	Marketed by private sector			

Source: Madhavi Y, Vaccine Policy in India, PLoS Medicine Vol. 2, No. 5, e127 http://medicine.plosjournals.org/perlserv/?request=getdocument&doi=10.1371/journal.pmed.0020127&ct=1.

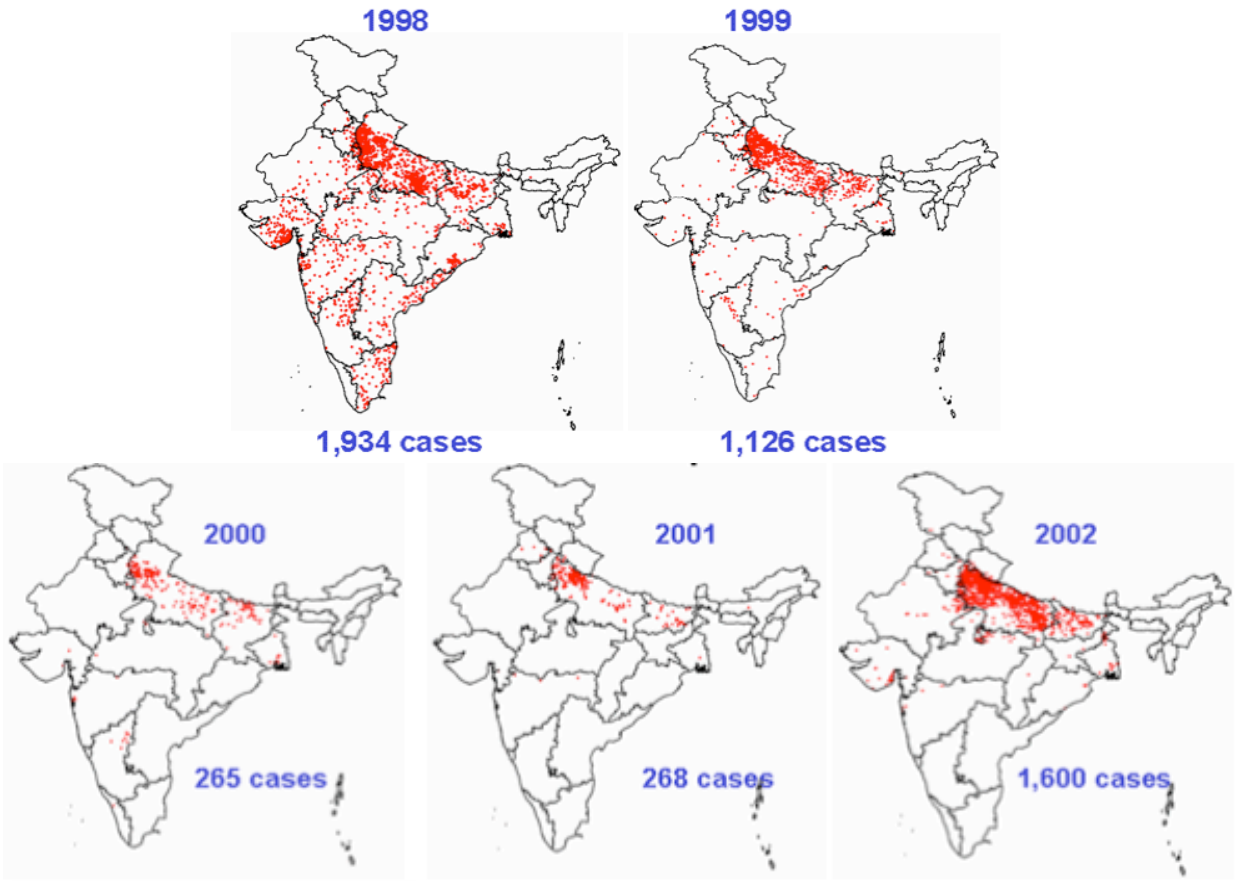
Exhibit 9 *Reported National Vaccine Coverage by Antigen, 1985-2002*



Note: TT(PW) indicates tetanus toxoid (TT) immunization of pregnant mothers.

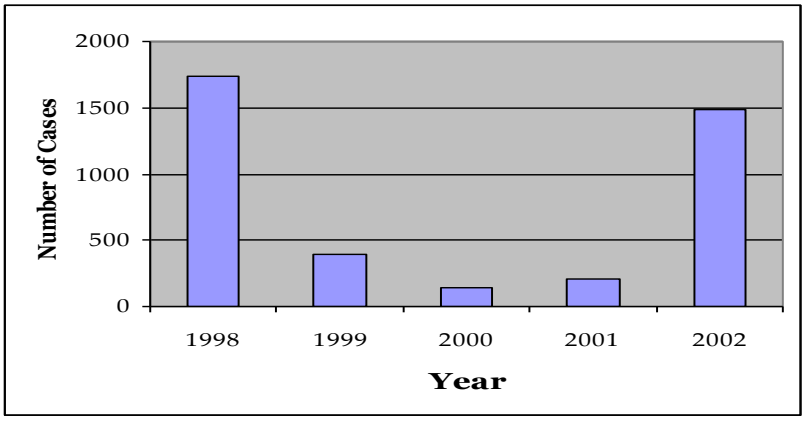
Source: www.whoindia.org/LinkFiles/Routine_Immunization_Acknowledgements_contents.pdf.

Exhibit 10 *Maps of Polio Case Distribution in India, 1998-2002*



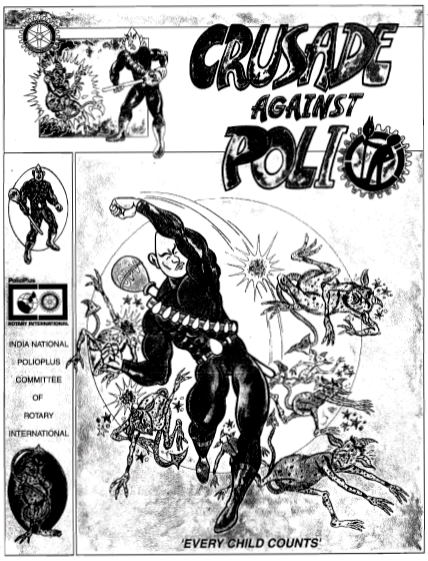
Source: The National Polio Surveillance Project, http://www.npspindia.org/.

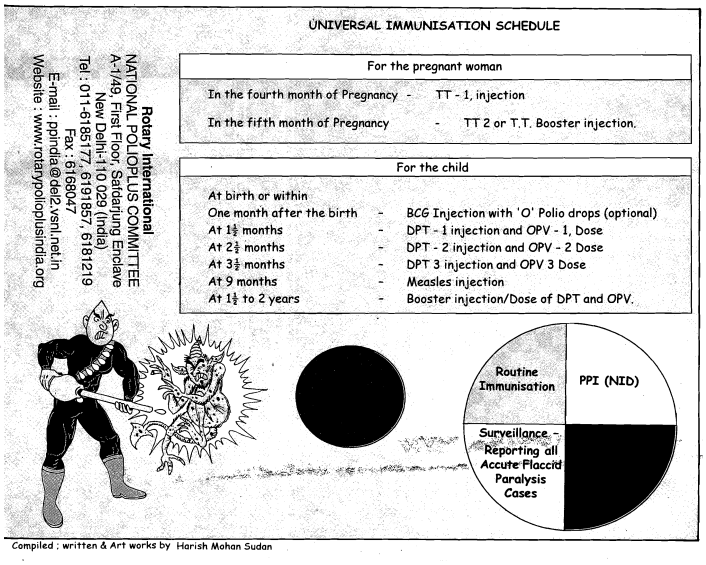
Exhibit 11 *Type 1 Polio Cases in India, 1998-2002*



Source: Created by case writers using data from the National Polio Surveillance Project, http://www.npspindia.org/.

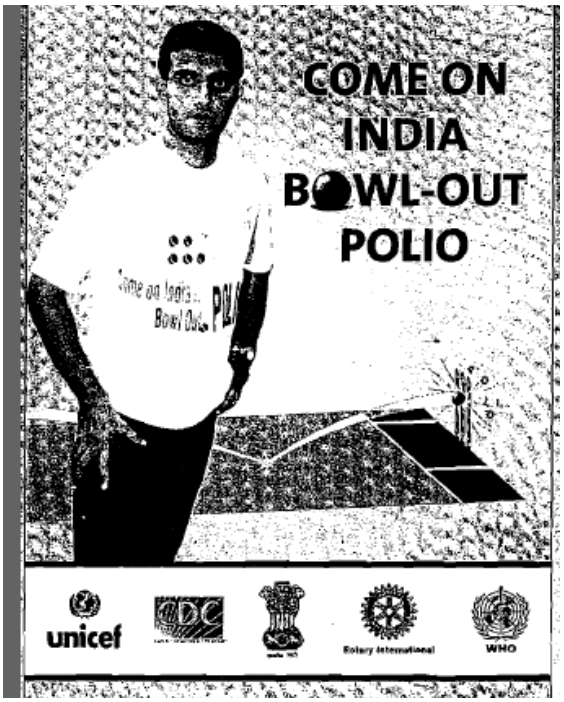
Exhibit 12a *Comic Book,* Crusade Against Polio, *Front and Back Cover*

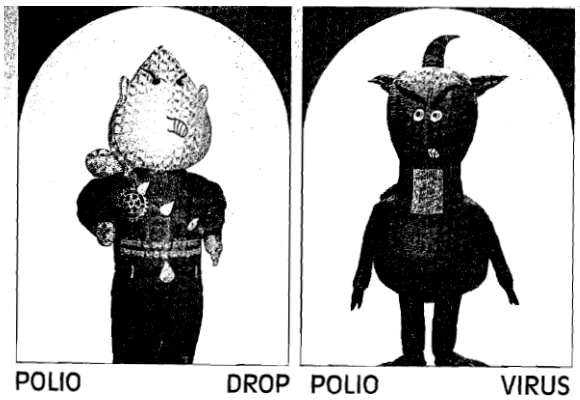




Source: Rotary International.

Exhibit 12b *Awareness Campaign Materials, Poster and Inflatable Toys*





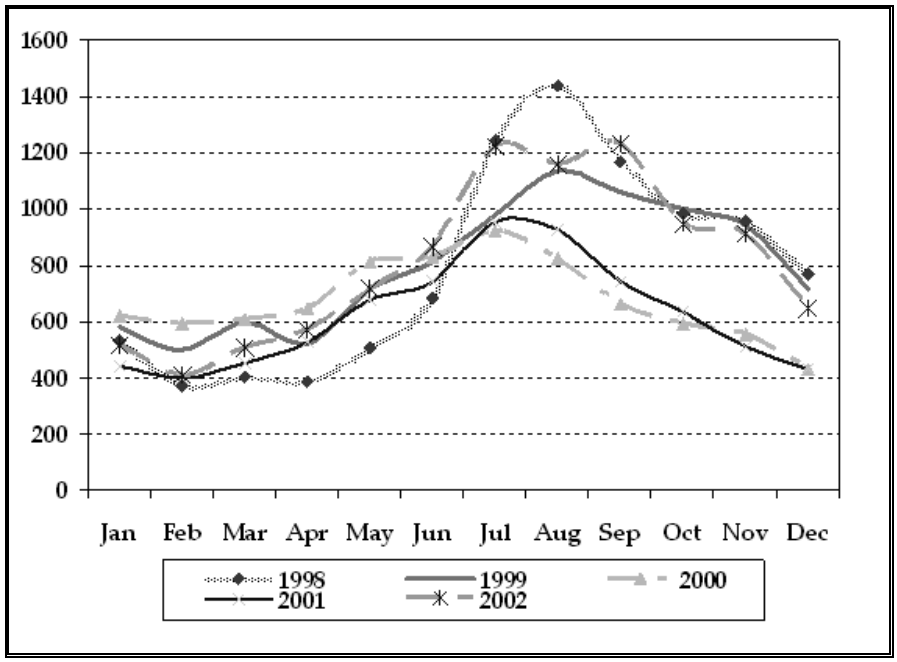
Source: Global Polio Eradication Initiative.

Exhibit 13 *Codes Used by Vaccine Teams to Indicate Cause for Missed Child*

Code	Reason for Missing Child
XR	resistance to vaccination
XS	sick children
XL	locked houses
XH	children were not home, but were expected to return later in the day
XV	child had traveled out of the village or city, often because the mother had taken her child or children with her to visit her parents or other relatives

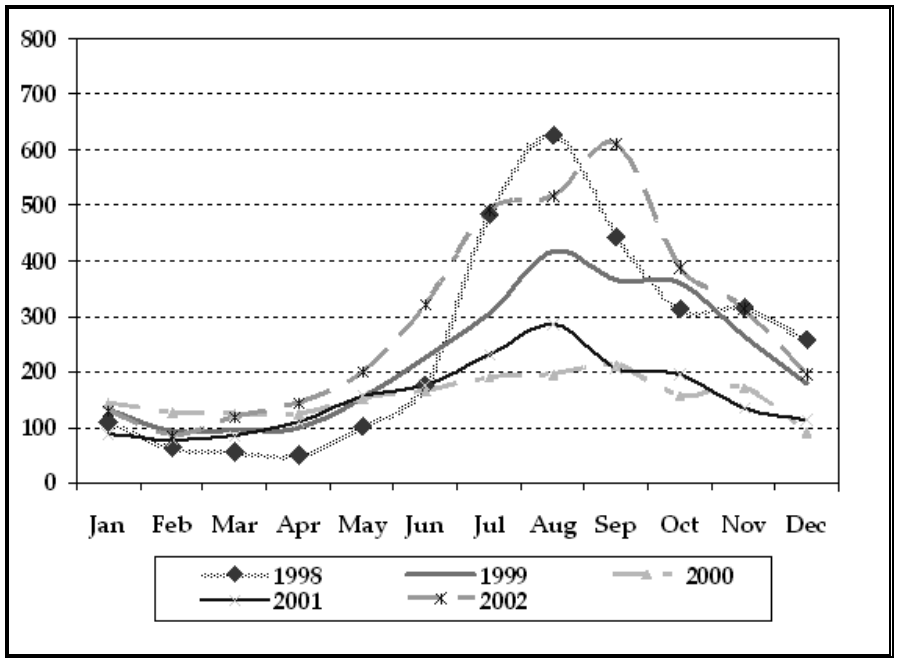
Source: Created by case writers.

Exhibit 14 *Monthly incidence of AFP cases, India 1998-2002*



Source: National Polio Surveillance Project.

Exhibit 15 *Monthly incidence of AFP cases, Uttar Pradesh, 1998-2002*



Source: National Polio Surveillance Project.

Appendix *Useful Abbreviations*

AFP	Acute flaccid paralysis
BCG	Bacille Calmette-Guérin
CDC	Centers for Disease Control
CFR	case fatality rate
DANIDA	Danish International Development Agency
DOTS	directly observed treatment short course
DPT	diptheria-pertussis-tetanus
DTP3	Third dose of diphtheria toxoid, tetanus toxoid, and pertussis vaccine
DSO	District Surveillance Officer
GDP	gross domestic product
GPEI	Global Polio Eradication Initiative
GSDP	gross state domestic product
IEAG	India Expert Advisory Group
IPV	inactivated polio vaccine
NID	National Immunization Day
NPSP	National Polio Surveillance Project
OPV	orally administered polio vaccine
PPP	purchasing power parity
SIA	supplemental immunization activity
SMO	Surveillance Medical Officer
SSO	Sub-regional Surveillance Officer
TAG	Technical Advisory Group
TB	tuberculosis
UIP	Universal Immunization Program
UN	United Nations
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USD	United States dollar
VDP	vaccine-derived polio
VVM	vaccine vial monitor
WHO	World Health Organization

References

1. Walsh J. *A Brief History of India*. New York: Facts on File; 2006.
2. Suchak N, Narasimhachary M. The Caste System: an Overview: "So, You Want to Marry My Daughter?" *Indian Culture in the Modern World*. London, UK: Oxford Centre for Hindu Studies.
3. Lal V. Indian History and Politics. http://www.sscnet.ucla.edu/southasia/History/mainhist.html. Accessed July 15, 2007.
4. Sachs JD, Bajpai N, Ramiah A. Understanding Regional Economic Growth in India. *Asian Economic Papers.* 2002;1(3):32-62; 43-44.
5. Eastwood R, Lipton M. Rural-Urban Dimensions of Inequality Change. *Working papers, 0782-8233*. Helsinki, Finland: UNU/WIDER 2000.
6. CIA. World Factbook. 2002.
7. CIA. World Factbook. 2004.
8. USAID. Congressional Presentation: India. http://www.usaid.gov/pubs/cp2000/ane/india.html). Accessed July 16, 2008.
9. Stephenson R, Tsui A. Community influences on reproductive health service utilisation in Uttar Pradesh, India. *Studies in Family Planning.* 2002;33(4):312.
10. Samandar R, Kleefield S, Hammel J, Mehta M, Crone R. Privately funded quality health care in India: a sustainable and equitable model. *International Journal of Quality in Health Care.* Aug 2001;13(4):283-288.
11. Singh P, Yadav RJ, Pandey A. Utilization of indigenous systems of medicine and homoeopathy in India. *Indian Journal of Medical Research.* Aug 2005;122(2):137-142.
12. Health Education to Villages. Rural-Urban Distribution of Population - India and States/Union Territories. http://hetv.org/india/population-2001.htm. Accessed July 15, 2007.
13. Census of India. http://www.censusindia.gov.in. Accessed July 15, 2007.
14. Government of Uttar Pradesh. Chapter 5: Human Development. In: Planning Department, ed. *Annual Plan for 2006-2007 for the State of Uttar Pradesh*; 2005.
15. Sachs J. Chapter 2: Improving the Climate for Investment and Growth. *Bihar: Towards a Development Strategy*: World Bank; 2002.
16. Gladwin M, Trattler B. *Clinical Microbiology Made Ridiculously Simple*. Miami: MedMaster; 2007.
17. Centers for Disease Control and Prevention. Poliomyelitis. In: Public Health Foundation, ed. *Epidemiology and Prevention of Vaccine-Preventable Diseases, 10th edition*; 2007.
18. Merck. The Merck Manuals Online Medical Library: Polio. http://www.merck.com/mmhe/sec23/ch273/ch273h.html. Accessed July 3, 2008.
19. Sabine Vaccine Institute. Polio Vaccines. http://sabin.org/vaccine_science/polio.html. Accessed June 29, 2008
20. Andrus J, Strebel P, de Quadros C, Olive J. Estimated risk of vaccine-associated paralytic poliomyelitis in Latin America, 1989-1991. *Bulletin of WHO.* 1995;73(1):33-40.
21. Global Polio Eradication Initiative. Polio Vaccines. http://www.polioeradication.org/vaccines.asp. Accessed June 29, 2008
22. World Health Organization. What is Vaccine-Derived Polio? http://www.who.int/features/qa/64/en/index.html. Accessed June 29, 2008
23. Grassly NC, Fraser C, Wenger J, et al. New strategies for the elimination of polio from India. *Science.* Nov 17 2006;314(5802):1150-1153.
24. Centers for Disease Control and Prevention. Polio Disease: Questions and Answers. http://www.cdc.gov/vaccines/vpd-vac/polio/dis-faqs.htm. Accessed July 15, 2007.

25. Centers for Disease Control. Smallpox: Disease, Prevention, and Intervention. www.bt.cdc.gov/agent/smallpox/training/overview. Accessed July 14, 2008.
26. VN . El-Sayed SA-J, K . Hennessey , M . Salama , M . Watkins , J . Abdelwahab , M . Pallansch , H . Gary , M . Wahdan , R . Sutter Survey of poliovirus antibodies during the final stage of polio eradication in Egypt. *Vaccine.* April 2007;25(27):5062 - 5070.
27. Rotary International. http://www.rotary.org/EN/ABOUTUS/Pages/ridefault.aspx. Accessed August 24, 2007
28. Global Polio Eradication Initiative. Global Polio Eradication Initiative: History. http://www.polioeradication.org/history.asp. Accessed July 17, 2008.
29. Global Polio Eradication Initiative. *Global Polio Eradication Initiative Strategic Plan 2004-2008.* Switzerland: WHO; 2003.
30. World Health Organization. Changing epidemiology of Polio prompts tactical shift in world's largest public health initiative: Supplementary Polio immunization to be narrowed to key countries. Press Release. BRUSSELS/GENEVA/TOKYO/WASHINGTON DC: WHO; 2002.
31. WHO. *India's Effort for Polio Eradication*: WHO Southeast Asia Regional Office; 1998.
32. Centers for Disease Control. Progress Toward Poliomyelitis Eradication -- India, December 1995 and January 1996. *Morbidity and Mortality Weekly Review.* 1996;45(18):370-373.
33. Aylward B, Heymann D. Polio Eradication: Ongoing Innovation to end an Acient Scourge. 2006:1-36.
34. Lucknow District Polio Program. Overview of August 2007 Sub-NID in Lucknow District. 2007:34.