Twenty Years after Chernobyl: Debates and Lessons
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Twenty Years after Chernobyl

Debates and Lessons

A vast amount of literature has been generated on the Chernobyl accident in April 1986. What lessons can we draw from the causes and sequences of the accident, the health and environmental consequences and what implications does the accident have for nuclear reactor safety and the future of atomic energy?

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Alina, aged fifteen, had been diagnosed with thyroid cancer in 1992, and her thyroid gland had been completely removed. She had just undergone a second surgery to remove knots that had spread to her trachea. Alina wobbled her head, straining to find ways of resisting the surgical pain... "I have to live...I was afraid of this second operation. The nodules can still spread into the lungs and to the brains. If they go into the brains it will be too late; it will be almost impossible to save me. But if the nodules spread into the lungs, they can still save me." She wanted to be saved. "But everything is normal right now", she reassures herself. "I have to drink iodine and take daily doses of thyroxine. If I don't have that hormone I'll be faint, and I won't be as lucky."
– Chernobyl 'Survivor' [Petryna 2002:80]

The accident at the Chernobyl nuclear reactor on April 26, 1986 remains the most destructive industrial accident to date. An enormous amount of literature has emerged analysing the causes of the accident, the sequence of events on that fateful night, the amount of radioactive material released into the environment, the health and environmental consequences of the accident, and the implications of the accident for nuclear reactor safety and the future of atomic energy. We outline the debates on some of these areas and explore in brief the underlying political and organisational dimensions of these debates as well as some of their implications.

April 26 and Immediate Aftermath

The Chernobyl power complex is 130 kms north of Kiev, Ukraine, and about 20 kms south of the border with Belarus. The unit 4 reactor at the complex was to be shutdown for routine maintenance on April 25, 1986. Reactor operators decided to take advantage of this shutdown to run a test to determine whether, in the event of a loss of station power, the emergency equipment could be operated until the diesel emergency power supply became operative [NEA 2002]. As part of the experiment, a number of safety features were disabled.

The Chernobyl reactor was of the so-called RBMK design, which has some undesirable characteristics with negative implications for safety.[1] Important among these is the positive void coefficient.[2] This means that if there is increased steam production in the fuel channels, either because of a power increase or a decrease in the flow of water used to transport the heat generated, there would be an increased rate of nuclear fission reactions. Under some conditions, particularly at low power levels, this would produce a positive feedback loop that makes the reactor prone to abrupt power surges. Early on April 26, during the experiment conducted by the operators, the reactor was operating in this domain and produced an overwhelming power surge.

The exact physical sequence of events remains a matter of debate. But it is fairly certain that the sudden increase in heat production ruptured part of the fuel, which reacted with water and caused a steam explosion. A few seconds later there was another explosion. The nature of the second explosion is unresolved; different people have argued that it was a steam explosion, a hydrogen explosion, and a nuclear explosion, respectively. But clearly an immense amount of energy was released; estimates are in the range of 100-250 tonnes of TNT [Kiselev and Checherov 2001; Martinez-Val et al 1990].[3] Though the RBMK design is often faulted for not having a structure to contain radioactive releases in the event of an accident, these calculated energy releases are so high that it is quite unlikely that any containment structure would have withstood such an explosion.[4]

The debate about the actual sequence of events results from two factors. First, there is incomplete information about the accident during the initial period, both because of the secrecy imposed by authorities, and because the data relevant for a detailed analysis could not be recorded. The second factor is the sheer complexity of the various processes underway during the course of the accident. Nuclear reactors are complex entities and their behaviour, even under slightly abnormal conditions, can defy precise understanding.[5] Understanding the course of a major accident like Chernobyl involves very detailed modelling of nuclear reactions, thermodynamic and hydraulic changes, the fragmentation of fuel, and complicated interactions between these different processes under inhomogeneous and rapidly evolving conditions. Thus, it is not surprising that different studies come to very different conclusions.

Whatever their nature, the two explosions sent radioactive fuel, reactor core components, and structural items into the air, producing a shower of hot and highly radioactive debris and exposing the damaged core to the atmosphere. The plume rose about one kilometre up in the air. Fires started in what remained of the unit 4 building and in adjacent buildings. Finally, the graphite that is used to slow down (moderate) neutrons in the reactor also caught fire. Efforts to put out the last fire proved ineffective and it burned for 10 days. The long duration had important health consequences. For example, only 40 per cent of the total release of iodine-131, a radioactive isotope of iodine that accumulates in the thyroid gland and can be responsible for thyroid tumours and cancers, occurred on the first day [UNSCEAR 2000:520].

The cloud from the burning reactor spread numerous types of radioactive materials, especially iodine and caesium radionuclides, over much of Europe. Iodine-131 has a short half-life (eight days) and largely disintegrated within the first few weeks of the accident. However, radioactive caesium-137, which contributes to both external and internal radiation doses, has a half-life of 30 years and has contaminated more than 2,00,000 square kilometres of Europe.[6] Over 70 per cent of this area was in the three most affected countries, Belarus, Russia and Ukraine, home to about five million people. But even people in regions further away were affected, some considerably so.

Multiple Repercussions

Though clearly having immense consequences, it is difficult to quantify the impacts of the accident, either in terms of public health or in terms of economic and social costs. There have also been other, less direct, consequences ranging from the widespread loss of faith in the safety of nuclear reactors and the honesty of officials in charge of nuclear installations, to the formation of political parties like the Green Party in Ukraine and the Popular Front party in Belarus.

Among the worst affected by the accident were the "liquidators" – those involved in emergency actions on the site during the accident and the subsequent clean up operations, and who were exposed to high radiation doses. It is estimated that up to about 6,00,000 people were involved in such activities [NEA 2002:13]. Also subjected to significant radiation doses were the over 1,00,000 people, mostly from within a radius of 30 kms around Chernobyl, who were evacuated during the first few weeks following the accident. Finally, about 2,70,000 people continued to live in contaminated areas of the former Soviet Union, with high levels of caesium and requiring protection measures. All three population groups have undergone great suffering in terms of health, social conditions, and economic opportunity.

The extent of health consequences, usually measured in numbers of deaths, resulting from the accident and consequent radiation exposure, has been subject to wide debate.[7] Such estimates range from a few tens (31 was the official Soviet figure for some years after the accident) to hundreds of thousands [Vidal 2006]. "Reality", to use a cliché, is likely to be somewhere in between. The use of the quote marks around the term reality is because much depends on what criteria are used to attribute deaths to radiation. This is for at least two important reasons.

First, it is intrinsically difficult to unambiguously calculate the number of cancers and other health effects induced by radiation exposure. There are two kinds of effects due to radiation exposure: deterministic and stochastic. Deterministic effects occur only at high radiation doses. Only the firemen and the personnel of the power station on the night of the accident were exposed to such high radiation doses. Of these, at least 134 were clinically diagnosed with "acute radiation sickness".

At lower radiation doses, the health impacts take time to develop and are not uniform; in other words, not all people exposed to the same level of radiation will exhibit the same effects. However, exposure to radiation does result in a statistically increased number of health effects of various kinds, particularly cancers [UNSCEAR 2000; National Research Council 2006]. But the increase would be against a much larger number of cancers induced by both natural and anthropogenic (other than radiation from Chernobyl) causes. It is often difficult to determine if the excess of cancers is merely a statistical fluctuation of the background or if it is caused by radiation exposure due to the accident.

The second reason is that the figures for casualties are the site of intense political battles. On the one hand, there has been a sustained effort, mostly by or at the instigation of institutions and people connected to the nuclear industry, to diminish the magnitude of the numbers of deaths attributed to the accident. This is understandable – they can then argue that if even the worst nuclear disaster has resulted in only a relatively small number of deaths, then nuclear power is safe. On the other hand, there are vested interests on the side of institutions and individuals, especially in the affected areas, that drive them to exaggerate the extent of deaths and other health consequences.

Estimates of the number of thyroid cancers resulting from the accident offer a good example of this political contest. Thyroid cancer was one of the health impacts expected to manifest itself quickly; early estimates suggested that there would be "thousands to tens of thousands of... thyroid tumours over the next few decades" [Von Hippel and Cochran 1986]. In 1991, the International Atomic Energy Agency (IAEA), whose primary mandate is to promote the use of nuclear energy, concluded that "there is no clear pathologically documented evidence of an increase in thyroid cancer of the types known to be radiation related" [International Chernobyl Project and International Atomic Energy Agency 1991]. This was despite the reports that had been submitted to the IAEA by 1990 that "unusually numbers of thyroid cancer cases in children" had been noted in Belarus and Ukraine [Williams 2002]. But the IAEA underplayed them.

As time proceeded, the increase in thyroid cancers could scarcely be denied. In 2000, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), recorded that there were an "unusually high numbers of thyroid cancers observed in the contaminated areas during the past 14 years" and went on to observe that "the number of thyroid cancers (about 1,800) in individuals exposed in childhood, in particular in the severely contaminated areas of the three affected countries, is considerably greater than expected based on previous knowledge. The high incidence and the short induction period are unusual... If the current trend continues, additional thyroid cancers can be expected to occur, especially in those who were exposed at young ages" [UNSCEAR 2000]. These "form the largest number of cancers of one type, caused by a single event on one date, ever recorded" [Williams 2002].

More recently, the IAEA has convened the Chernobyl Forum in 2003 to "generate 'authoritative consensual statements' on the environmental consequences and health effects attributable to radiation exposure arising from the accident as well as to provide advice on environmental remediation and special healthcare programmes, and to suggest areas where further research is required" [Forum 2005]. In September 2005, the IAEA put out a press release announcing that the Forum had determined that only up to 4,000 people could eventually die as a result of radiation exposure from the accident. This was hailed by officials from the nuclear establishment as having settled the debate on "how many deaths and how much disease really resulted from the accident" [Parthasarathy 2005]. But this was widely criticised by civil society groups, especially those in the affected countries. Many have produced counter-reports suggesting that the number of deaths would be in the range of 30,000-60,000 [Fairlie and Sumner 2006], to about 93,000 [Greenpeace 2006].

There are several problems with the Forum's report. One is their focus on just the most heavily exposed areas, and ignoring the much larger populations in the affected countries themselves and the rest of the world, who have been exposed to lower levels of radiation from Chernobyl. There is general scientific consensus that no matter how small, radiation exposure always increases the risk of cancer [National Research Council 2006]. Further, there is also considerable theoretical and empirical support for the assumption that the biological risk is a linear function of radiation dose at low doses. Then, if a given dose is shared among N people, the risk of cancer death per person is reduced to 1/N, but since each of N people now suffers this risk, the total probable number of cancer deaths remains the same. Thus, the combined effect of a low level of radiation exposure to large populations could be sizeable.

The estimated collective radiation dose to the entire world from Chernobyl is 6,00,000 person-Sv [UNSCEAR 1993:23].[8] The most recent estimate of risk from radiation exposure is 0.057 cancer deaths per Sv [National Research Council 2006]. Therefore, the collective radiation dose mentioned above would result in roughly 34,000 deaths over a long period of time, much higher than the misleading figure of 4,000 from the IAEA.[9]

The Chernobyl Forum's estimates also suggest a systematic pattern of avoiding attribution of various other health impacts by arguing that increases in these do not correlate adequately with estimated radiation doses. As a leading expert on thyroid cancers argued: "the degree of proof needed to accept a causal link is strongly correlated with the vested interest of the individual or organisation in the outcome" [Williams 2001].

Consider the case of leukaemia in children who were exposed to radiation doses while still in the uterus. Past studies have established that such children are at increased risk of cancer [Stewart et al 1956]. Similar increases were found in the case of some regions subject to radioactive fallout from Chernobyl. The number of excess deaths due to leukaemia in infants, for example in Chernobyl [Noshchenko et al 2001], falls well within the range of standard estimates of leukaemia mortality from radiation exposure.[10] All published studies reviewed by the Forum found excesses, albeit of varying magnitudes. And yet the Forum dismissed them as "not entirely convincing" and concluded that "there is neither strong evidence for or against an association between in utero exposure to Chernobyl fallout and an increased risk of leukaemia" [Chernobyl Forum 2005].

Despite such efforts at minimising the impact of Chernobyl, the Forum was forced to admit to some concrete and unexpected, at least in magnitude, effects. One unanticipated consequence is the "mental health impact of Chernobyl", which according to the Forum, "is the largest public health problem caused by the accident to date". This may seem trivialising the other impacts. Nevertheless, it is testimony to the "complex web of events and long-term difficulties, such as massive relocation, loss of economic stability, and long-term threats to health in current and, possibly, future generations", unleashed by Chernobyl "that resulted in an increased sense of anomie and diminished sense of physical and emotional balance".

These, of course, are only illustrative of the health effects of Chernobyl. More such impacts will likely manifest themselves over the coming years [Williams and Baverstock 2006].

Some Lessons

Despite the nuclear industry's efforts to play down the significance of the Chernobyl disaster, there are important lessons to be drawn from the accident and subsequent events. Writing in the *Bulletin of the International Atomic Energy Agency* in June 1983, the head of IAEA's safety division claimed: "The design feature of having more than 1,000 individual primary circuits increases the safety of the reactor system – a serious loss of coolant accident is practically impossible...the safety of nuclear power plants in the Soviet Union is assured by a very wide spectrum of measures..." But, on April 26, 1986 a serious accident did occur. The first lesson, therefore, is that such assurances from those who have a vested interest in the continued operation and expansion of nuclear power cannot be trusted. Despite increased attention to safety since Chernobyl, such massive accidents cannot be ruled out even today. Indeed, some have argued that such accidents will occur despite the best of intentions, and so should be considered "normal" [Perrow 1984].

The second lesson is that safety evaluations should not be performed by organisations that operate the facility, but be left to independent agencies. Organisations that operate nuclear reactors have other pressures and requirements, most importantly the cost and ease of operation.[11] In India, the Atomic Energy Regulatory Board (AERB), which is supposed to oversee the safe operation of all civilian nuclear facilities, is not independent of the Department of Atomic Energy (DAE) because it answers to the Atomic Energy Commission, which is headed by the secretary of the DAE. Further, as a former chairman of the AERB has observed, "the AERB has very few qualified staff of its own, and about 95 per cent of the technical personnel in AERB safety committees are officials of the DAE whose services are made available on a case-to-case basis for conducting the reviews of their own installations. The perception is that such dependency could be easily exploited by the DAE management to influence the AERB's evaluations and decisions" [Gopalakrishnan 2002].

Third, the contested nature of the Chernobyl impacts means that the evaluation of health impacts of accidents, real or hypothetical, as well as routine releases of radiation from operating nuclear fuel chain facilities should be performed by individuals and organisations independent of nuclear utilities in a transparent manner.

A fourth lesson is that when accidents occur at nuclear facilities, details about the accident and its potential (even if considered low probability) impacts must be made public as soon as reasonably possible. In contrast, the first reaction to the accident by Soviet authorities was to impose enormous secrecy on the event itself and its fallout [Medvedev and Sakharov 1991].[12] This resulted in thousands of unnecessary deaths and victims of cancer and other serious illnesses. This secrecy cannot be attributed entirely to the Soviet system of government; even in India, the nuclear establishment operates largely in secret [Subbarao 1998; Ramana 2005].

Fifth, Chernobyl shows that nuclear accidents could have transboundary, potentially global, impacts; what happens in one country cannot be considered just its own sovereign matter. Thus, for example, the concern among some in Sri Lanka, that the construction and operation of the Russian designed Koodankulam reactors might pose a potential threat to their health in the event of an accident, should not be dismissed out of hand.

Finally, one is left with the all important question – what lesson does Chernobyl offer for the continued use of and further expansion of nuclear power worldwide. Deciding on the future of nuclear power depends on many considerations: environmental sustainability, economics, ethics, international security, and safety, to name some. These are all contentious and will remain so. If there is one normative consideration that can be advanced into this debate, it should be that of democratising the decision-making. Chernobyl demonstrates beyond doubt that nuclear technology poses a risk to all people, and that their consent, based on a sound understanding of the issues involved, is a prerequisite for making any decisions about nuclear power or other hazardous technologies. EPW

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Notes

1 Soviet safety philosophy focused on active safety systems, which would shutdown the reactor in cases of mishaps, but largely ignored basic design safeguards or passive safety features in order to improve performance or save costs [Dodd 1994:85].

2 The design of the prototype fast breeder reactor being constructed in Kalpakkam also has this unsafe feature.

3 In comparison to nuclear weapon explosions these are small yields; the atomic bomb that destroyed Hiroshima produced about 13,000 tonnes of TNT equivalent.

4 This is not to say that a containment structure is not desirable. It is certainly an additional level of safety. Yet, it should not be used to reassure the public that they would be completely safe even in the event of a nuclear reactor accident. A containment structure, of course, increases the construction cost of the reactor, thereby making nuclear energy even more expensive. The construction cost of the reactor is already the largest component of the cost of generating nuclear electricity [Ramana et al 2005].

5 The events at the Kakrapar Atomic Power Station (KAPS) in March 2004 provides an example of the difficulties in understanding even under slightly abnormal conditions. According to the Atomic Energy Regulatory Board, there were failures of the automatic reactor power control system and the automatic liquid poison addition system of Unit-1 of KAPS on March 10, 2004, and the reactor power rose gradually [AERB 2004]. Investigations by KAPS and the Nuclear Power Corporation of India (NPCIL) lasting over a month could not identify the causes of the power increase and the unit had to be shutdown.

6 This is the region where the caesium-137 level would have sufficed to cause an estimated radiation dose of about 1 mSv during the first month. The typical annual limit for radiation dose to members of the general public from anthropogenic activities is 1 mS/y.

7 The number of deaths should not be considered the only marker of importance. Each cancer patient and their families underwent immense amounts of suffering that cannot be captured through merely counting cancer deaths and incidences. The epigraph is an illustration of the suffering undergone by a survivor.

8 More recent UNSCEAR volumes, including the 2000 volume which focused on the Chernobyl accident, have not revisited this estimate. [UNSCEAR 2000] estimates that the lifetime collective dose to the inhabitants of contaminated regions of Belarus, Russian Foundation, and Ukraine to be about 60,000 man-Sv, about a tenth of the estimated global dose.

9 For the same institutional and political reasons as there are underestimates of the number of deaths, the collective radiation dose estimate itself could be a deflated one. Verifying this estimate, however, requires enormous technical and financial resources, which is well beyond the abilities of independent scientists and civil society groups.

10 While there is clear evidence of elevated leukaemia risk from in utero radiation exposure, there is some uncertainty over its magnitude. However, it is likely to be at least in the range of lifetime risk of leukaemia mortality from radiation exposure for all ages, which is roughly 0.04 for an exposure of 0.1 Sv [UNSCEAR 2000:427]. The average radiation dose to the children studied by [Noshchenko et al 2001] is 4.5 mSv. This translates to over 40 deaths over a 70-year period, roughly three times the excess observed in the study. Since [Noshchenko et al 2001] only studies children up to age 10, this is not inconsistent.

11 The design of the Chernobyl reactor is testimony to this. As recounted by Valery Legasov, who was closely involved in the planning and design of RBMK reactors of the type installed in Chernobyl, "reactor specialists considered that this was a bad one. Bad not because of safety considerations but because of economic reasons: high consumption of fuel and high capital expenditure" [Mould 2000:297-98].

12 Decree U-2617 C of the Soviet health ministry, issued June 27, 1986, states: "Secrecy is imposed upon any data concerning the accident. Secrecy is imposed upon the results of treatments for sicknesses. Secrecy is imposed upon the data about the extent of radioactive contamination of personnel who took part in the liquidation of the accident at the Chernobyl atomic power plant" [Watermann 2006].

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Indian Stock Market in Comparison

This article evaluates the impact of financial liberalisation on the growth, development and efficiency of the Indian stock market vis-à-vis other select Asian markets. Though the expansion of the Indian stock market in the post-liberalisation period is truly impressive, in terms of quality there has been a regress. Trading has become increasingly concentrated in some sectors and companies, and the higher volatility in the market, without a corresponding higher return, portends greater risk and more instability for investors.

JOYDEEP BISWAS

During the late 1980s, developing countries started liberalising their financial sectors. The concept of financial liberalisation became a new orthodoxy among the major international institutions that offer policy guidelines for developing countries, which hastened the process of deregulation of financial system in many less developed countries (LDCs). One distinguishing feature of financial liberalisation, in relation to financial sector reforms, suggests the abolition of institutional nominal interest rates that are held below their equilibrium level in order to raise savings, investments and growth.

Introduction

Financial markets, especially stock markets, have grown considerably in developed and developing countries over the last two decades. Better fundamentals (higher economic growth, more macro stability, structural reforms (notably privatisation of state-owned enterprises) and specific policy changes (notably domestic financial reforms and capital account liberalisation) have aided in their growth. Thanks to financial liberalisation, Indian stock market, like many other markets of developing countries, underwent tremendous changes from 1991, when the government has adopted liberalisation policies more seriously than ever before. As a result, there can be little doubt about the growing importance of the stock market from the point of view of the aggregate economy. Stock market liberalisation is a decision by a country's government to allow foreigners to purchase shares in that country's stock market. The standard international asset pricing models (IAPMs) predict that stock market liberalisation may reduce the liberalising country's cost of equity capital by allowing for risk sharing between domestic and foreign agents