TOXIC EXPOSURE: THE TILTING BALANCE

By:

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INTRODUCTION

The population of the world is expected to reach some 7 billion by the year 2010, double that of the 1960's. Moreover, by the year 2050, it is projected the some 12 billion human beings will be living in the world. Yet already, the natural ecology of 75% of the total habitable area of the planet is significantly disturbed. Much of this increase in population will take place in coastal regions which are currently not heavily industrialised and there will be a concomitant intensification of agricultural and industrial activity. In turn, inevitably, human pressures on the environment will also increase. The changes are likely to be most marked in those regions within 60km of the sea. This is an obvious characteristic, for example, of the burgeoning industrial development taking place in the countries bordering the Pacific region. In such coastal areas, degradation of many critical marine and terrestrial environments is already, visibly, well advanced.

A degraded environment is not simply a matter of aesthetics or conservation although, of course, these are fundamentally important aspects to consider. Questions also arise about the quality of human life resulting from such changes. Currently, the true costs of many modern environmental impacts are hidden and externalised upon the environment itself. The economic costs of protective measures are rarely examined in the context of the onward societal costs of failing to formulate, adopt and implement them. These costs can be manifest in a number of ways. Direct loss of livelihood is often obvious and relatively easy to quantify in fiscal terms. Impacts upon human health and welfare, by contrast, are often more subtle and more difficult to recognise. They involve a formidable array of practical, philosophical and ethical issues. Nonetheless, it is clear that the impact of toxic exposures is a key determinant of human quality of life and one that is growing in importance.

TOXIC EXPOSURES DEFINED

b) Toxic metals

Early references to the harmful effects of toxic metals upon human and animal health can be found in the classical works of Xenophon, Lucretius and Pliny. Indeed chronic lead contamination is widely believed to be linked to the decline of the Roman Empire. Analysis of peat cores dating to the 17th Century has shown that the increasing scale of metallurgical processes in Europe was already being reflected in increased metal levels in remote regions of Scandinavia by this time. Other historical records such as ice cores and sediments document increasingly severe toxic metal pollution from the Industrial Revolution to the present day. Once dispersed, these metals are not degraded. Nor does technology exist to recover them. The environmental impacts of metals tend to be permanent even though they occur naturally, undergo natural cycling in the environment and indeed may be vital components of biochemical pathways. For elements like copper, zinc and selenium the balance between the essential amounts required for normal functioning of the body and the amounts producing toxic effects is an extremely fine one. Others such as lead, cadmium and mercury have no known biological function and the ability of many organisms, including humans, to regulate body levels of these is very limited.

Metals are naturally released from the weathering of rocks and from volcanoes and forest fires. Prior to industrialisation metal inputs cycled in a steady state, and these processes controlled and restricted metal distributions in natural systems. These sources, however, are now equalled or exceeded by the amounts now being released from mining, smelting and industrial processes, including oil and coal combustion. In urban areas, natural sources are now insignificant in relation to the amounts being released by human activity. Globally and regionally, the ambient levels in the environment reflect proximity to industry. Levels in the atmosphere above the South Pacific Ocean, for example, are much lower than those above the North Atlantic, while these levels in turn are exceeded substantially in the air above the Mediterranean and North Seas. These balances have been inexorably and unfavourably tilted within a comparatively short space of time.

Much of the focus upon the human health effects of this insidious increase in environmental metal levels has centred upon acute poisoning incidents. The Minimata incident involving mercury in Japan affected many hundreds of people directly and effects were carried across into the next generation. Cadmium was responsible for Itai-Itai disease in another area of Japan. What is not clear, however, is the degree to which chronic exposures may be taking place and what the effects of this may be. Impacts are likely to be subclinical in many cases and any overt clinical disease is likely to have poorly characterised symptoms. Current clinical tests are too insensitive to detect important but subtle changes in biochemistry. Indeed, metal mediated changes in vital signs may not become evident until toxicological processes are well advanced Bodily mechanisms capable of compensating for metal exposures may be overwhelmed before the damage becomes obvious.

All the evidence points to a substantial global problem with human health. Exposure to toxic metals has been implicated variously in the etiology of cardiovascular disease, reproductive disorder, allergy and some cancerous diseases. It has been estimated that between a quarter and a half million people worldwide may suffer renal dysfunction due to cadmium poisoning. Up to 80,000 people dependent on fishing may be suffering from the effects of mercury poisoning due to eating contaminated seafood. Another quarter of a million people are believed to be suffering from skin cancers caused by arsenic exposure.At least eighteen metals have been implicated in cancerous diseases in laboratory studies. The numbers of people actually at risk are inevitably much higher. In the case of lead, for example, between 130 and 200 million people are estimated to be at risk of poisoning worldwide as gauged from their blood lead concentrations. Although hard data are lacking, it seems that at least a billion people are unwittingly exposed to elevated levels of metals in the environment.

Problems are likely to increase in scale and scope. Consumption of metals and the products made from them is linked to, and fuelled by, increase in population and rising gross national products. Initial markets in durable metal items expand to embrace less durable products, more frequently discarded and replaced. Rising energy consumption based upon fossil fuels also adds to the environmental burden. Moreover, observers have noted a growing trend for metal wastes and scraps to be exported from industrialised nations to those striving to develop their industrial base. They are variously disposed of or used as marginal resources employing methods which would certainly not meet environmental regulations in their country of origin. The burgeoning trade in used vehicle batteries is a well known example, the significant trade in mixed metal compounds and metal rich residues less so. Some gold wastes can contain 40% by weight of arsenic. There are significant gaps too in the international regulations governing the trade in such wastes. The current situation has already been described as a "Silent Epidemic of Environmental Metal Poisoning". If metals consumption continues to grow in line with the increasing global population this epidemic is set to grow, loudly, to pandemic proportions.

c) Organic chemicals

Of the chemicals in common industrial use, the greatest proportion are organic chemicals. Used as solvents, raw materials, chemical intermediates and as final products in their own right, these substances are manufactured from petroleum. Some idea of the scale of the problem facing the industrial hygienists and environmental toxicologists can be gauged from the fact that an estimated 63,000 chemicals are in common use worldwide, that about 3,000 account for 90% of the total production and that anywhere between 200 and 1000 new synthetic chemicals enter the market each year. The properties of those organic chemicals of greatest concern are their toxicity coupled with their persistence in the environment and a tendency to accumulate in the fat tissues of organisms exposed to them.

To a very large extent, studies on the effects of these chemicals have concentrated upon their ability to cause cancer. This represents a convenient point of reference both for the public who justifiably fear such diseases and to the medical profession who are well aware of the difficulty of treating them. Some cancers have been found to be associated with particular exposures. Indeed, cancer of the scrotum in chimney sweeps in Victorian England, was the first identified cancer resulting from toxic exposure. Since then other links have been found. Some are specific, others less so. Agricultural workers are a high risk group, presumably due to their exposure to agrochemicals. Industrial workers involved in producing vinyl chloride used to make PVC are at risk of contracting liver cancer. It would be wrong, of course, to ignore these signs of extreme disturbance of body systems. As largely incurable diseases they represent an ultimate threat to the quality of life of individual humans. Arguably, however, the investigation of cancer causing properties has tended to divert attention away from other effects of toxic exposure. Although these may not seem at first sight to be as severe, their effects extend beyond the individual to embrace the whole human population.

Levels of persistent organic pollutants (POPs) in the environment have increased markedly since the industrial revolution. Some, such as the polynuclear aromatic hydrocarbons (PAHs) are released predominantly from combustion processes. Increases in levels have been traced through archived samples of soils, and cores of peat, ice and sediment. Some of these chemicals are highly potent carcinogens. The most important group of these persistent chemicals, however, contain chlorine and for the most part these have no counterparts in nature. Members of the group include the pesticides DDT, dieldrin, chlordane, toxaphene and lindane, the polychlorinated biphenyls (PCBs) and the chlorinated dioxins and dibenzofurans. Many other organochlorines are used as bulk industrial and consumer chemicals. In general, increases in environmental levels of these chemicals are easy to follow. Quite simply, prior to their industrial production from the 1920's onward they did not exist in the natural environment.

i) Organochlorine pesticides and PCBs

Organochlorine chemicals were eventually recognised as ubiquitous global pollutants and restrictions on their manufacture and use were emplaced in many national legislatures. International legislation, however, has been slow in coming. Restrictions followed after they were found to build up in the tissues of birds and animals. Severe reproductive and infertility problems were found in species at the top of the food chain. Fish eating birds and mammals were found to be most badly affected but humans too, accumulated these chemicals from their food. Most, if not all, humans now have residues of these chlorinated pesticides and industrial chemicals in their body fat.

Paradoxically, populations in some of the most remote regions of earth may eventually become the most severely affected. In many cases, chlorinated pesticides which are banned or severely restricted in industrialised nations remain in intensive use elsewhere. As agricultural systems also intensify to feed the growing population, so this balance of toxic exposure will tilt inexorably towards the nations of the southern hemisphere. One very recent discovery is that persistent organic pollutants can also be transported in the atmosphere over long distances. Their physical properties mean that they tend to "condense" out at cold, high latitudes. This means that Arctic ecosystems are particularly vulnerable but temperate areas will be affected too. This transport is a stepwise process. Before ending in the remote cold areas, these chemicals will pass through the more temperate regions where population densities in the Northern Hemisphere are highest.

The various regulations put in place initially appeared to restrict the growing environmental levels of some persistent organic chemicals. Tissue burdens fell and threatened wildlife populations appeared to recover. Bald eagles, a national symbol of the United States, together with a host of less well known wildlife species appeared to have been saved from terminal decline. After an initial sharp fall in the level of these chemicals, however, the downward trend levelled off. Even after a decade of regulating PCBs and other organochlorines, they were implicated as toxic contributors to the mass mortality of seals in the North Sea in 1988 when 18,000 animals died from a viral infection, and in the die-offs of dolphin species in the Mediterranean and North Atlantic ocean which seem to be still continuing. Fish from the Baltic Sea, contaminated with organochlorines, were fed to seals. The immune systems of the animals quickly became suppressed, endangering their defences against infection.

It was thought initially that the organochlorine pesticides and the PCBs were relatively non-toxic to humans. True, there had been at least two direct poisonings due to contamination of rice oil with PCBs, one in Japan (the "Yusho" incident) and one in Taiwan (Yu-cheng disease). In addition, widespread toxicity problems in livestock were reported in the US due to contamination of animal feed with a fire retardant similar to PCBs. While these events were closely studied, they were regarded as exceptional. The chronic problems with wildlife attributed to toxic exposures were regarded as a peculiar consequence of them only eating contaminated fish. Humans, it was reasoned were only exposed to contaminated fish under exceptional circumstances and these exposures could be controlled. This assumption has proven to be ill founded. Although the amounts required to produce a lethal response in humans are relatively high, the more subtle effects have only become evident after much close scrutiny. For example, extensive studies were made of children born to mothers who consumed organochlorine contaminated fish meals just twice a month from the Great Lakes. The children born to these mothers were smaller at birth and showed poorer cognitive development, indicating neurological damage before birth.

As a result of the poleward migration of persistent chemicals, dangerous levels have been found in the bodies of indigenous populations in the North of Alaska who depend upon marine resources. Faroe Islanders who consume blubber from pilot whales caught in the supposedly clean waters of the North Atlantic are exposing themselves to levels of organochlorines which exceed international advised daily intakes in some cases. Toxaphene, more dangerous than the PCBs is found in fish and porpoises in the North Sea and is thought to originate from Caribbean cotton fields where it is used in pest control. Traces of many organochlorines can also be found in fish oils produced from fish taken in waters far distant from industry. Given that organochlorine pesticides are still being produced and used, that PCBs are still being released to the environment, that PAH emissions are increasing from our consumption of fossil fuels, these findings do not augur well for the future.

ii) The chlorinated dioxins

The chlorinated dioxins and dibenzofurans, known collectively as "dioxins" were only identified as important environmental contaminants in the early 1980s although their toxic properties had been made evident by the Seveso accident in 1976, which released large quantities of the highly toxic chemical known as 2,3,7,8-TCDD, and by their discovery as contaminants in Agent Orange to which many Americans were exposed in South East Asia. The regulatory issues attached to this group of 210 individual chemicals are complex since they are not deliberately produced but appear as by-products in industrial processes, particularly the manufacture of other organochlorines, and through the combustion of chlorine containing wastes. Waste incineration is an important source, as is the production of steel, non ferrous metals and the plastic PVC. The dioxin group of chemicals also build up in the food chain and can be transported to remote regions. Greater human exposure to these compounds will inevitably follow from increasing industrialisation. Again, the balance of these increasing exposures will tilt towards the developing countries.

Unsurprisingly, a great deal of effort has been directed at investigating the toxic properties of dioxins. For many years it was believed that the only real effect was a disfiguring skin disease known as "chloracne". More in depth research, however, has shown that they can affect the immune system. Indeed, such interferences may be taking place at the levels to which people are already exposed to these chemicals. They can be passed on in breast milk to nursing infants and may cause interference with the function of the thyroid gland and vitamin K metabolism to produce a life threatening syndrome. They are carcinogenic and there does not appear to be a threshold for their effects. Any exposure could, therefore, cause cancers to appear many years later. These effects can be identified when levels of chlorinated dioxins in the blood and body fat reach part per trillion levels. There is now also strong evidence also that dioxins and other organochlorines may, together with some of the PAHs, interfere with oestrogen and other hormonal pathways at extremely low concentrations.

d) Hormonal effects

Of all the subtle effects of toxic exposures, chemical interference with body hormones is, with hindsight, an effect that should have been foreseen and the effect with the most profound implications. For instance, this property of the pesticide DDT has been known for some years in the laboratory, yet the significance of this finding was not translated into real environments despite the fact that the most often observed effect in wildlife populations was reproductive failure. The implications to human populations are now becoming clear. In areas of Europe, research has shown that sperm counts have been declining at around 2% per year over the last 20 years, a trend which can traced back over at least the last 50 years. The most likely cause is thought to be exposure to toxic chemicals.

Plausible links have made between low level exposure to organochlorine chemicals and cancers of the reproductive tract in humans of both sexes. Exposure of unborn children at critical stages of their development in the womb may have repercussions of equal importance to the intellectual disadvantage already identified in the Great Lakes studies. Genital abnormalities may occur, as may lowered fertility in adult life. It is, of course, not simply the POPs which could be responsible for these effects. Breakdown products of commercial detergents, for example, are suspected of causing male fish to develop female characteristics when discharged in rivers in sewage. Nonetheless, the majority of chemicals exhibiting these properties are persistent organic pollutants which can be transported by natural process across the globe. In turn the greatest proportion of these is the group of organic chemicals containing chlorine.

As scientists have come to appreciate the power of these chemicals to interfere with the systems that crucially underpin the workings of the body, so they have realised that the whole science of toxicology now requires a fundamental reappraisal. No longer can threats to the quality of human life be justifiably reduced to a number which simply describes the risk of contracting cancer. The problems must now be investigated on a broader base. If it is true that the survival of vulnerable species is at stake, that the world faces a series of chemical extinctions due to toxic exposure, then why should these predictions not extend to humans?

THE TILTING BALANCE: AN ALTERNATIVE?

Toxic exposures to human society depend upon a series of balances. As the industrial base broadens and deepens in the developing world, so the exposure of the population to metals through contamination of natural systems. Equally, increased use of agrochemicals and control agents in health programmes is likely to both increase toxic exposures on a local basis and to exacerbate the problems due to the transport of chemicals to remote areas in the atmosphere. The potential magnitude of the effects of chemicals on hormone systems are quite simply unknown.

For many groups of chemicals, the scale of the problem could grow substantially. Emissions of PCBs, for example, are widely perceived to be under control and a problem of the past. Yet even with this well studied group it is possible that emissions and hence human exposure will increase despite regulations and controls. Total world production figures for PCBs are estimated at between 1 and 2 million tonnes since they went into production in 1929. Of this, it is estimated that around 35% have escaped into the environment, while only 4% have been destroyed. The balance, some 60%, is in dumps and landfills or still being used in electrical transformers and capacitors the world over. Most of the equipment containing PCBs will reach the end of its useful life by the year 2005.

Hence, the scope of problems involving PCBs, one of many chemicals of concern, could well increase by two or three times unless concerted efforts are made to prevent this happening. These chemicals need to be systematically collected and detoxified using an environmentally benign technology. More radical measures are required to control levels of PAHs reaching the environment. A substantial decrease of human dependence upon and consumption of fossil fuels is required. Similarly, control of chlorinated dioxins can only take place by decreasing human dependence upon the diverse processes which generate them including primary chlorine production.

Obviously, the problems cannot be allowed to grow and intensify. Equally, no one measure will suffice to address these problems of toxic exposures, what is needed is a profound adjustment of philosophy. Instead of only regulating chemicals when their ill effects become obvious, a precautionary approach is required, one that gives human and environmental health the positive benefit of any doubts that may exist. We must come to regard regulations as staging posts on the road to zero emissions and develop alternative clean technologies for both industrialised and non-industrialised nations. Agricultural practices must move towards an ideal of ecological agriculture, seeking ways to minimise and eliminate the use of agrochemicals. Health programmes will need to be supplied with alternatives to persistent organochlorines. There are also economic considerations which must be made. A global effort is required.

The alternative seems to be a simple one: To allow the balance to tilt further, allow toxic exposures to increase, allow the environment to continue to degrade and to let the human race collectively bear increasing chemical compromises to it's good health and to it's secure future.

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