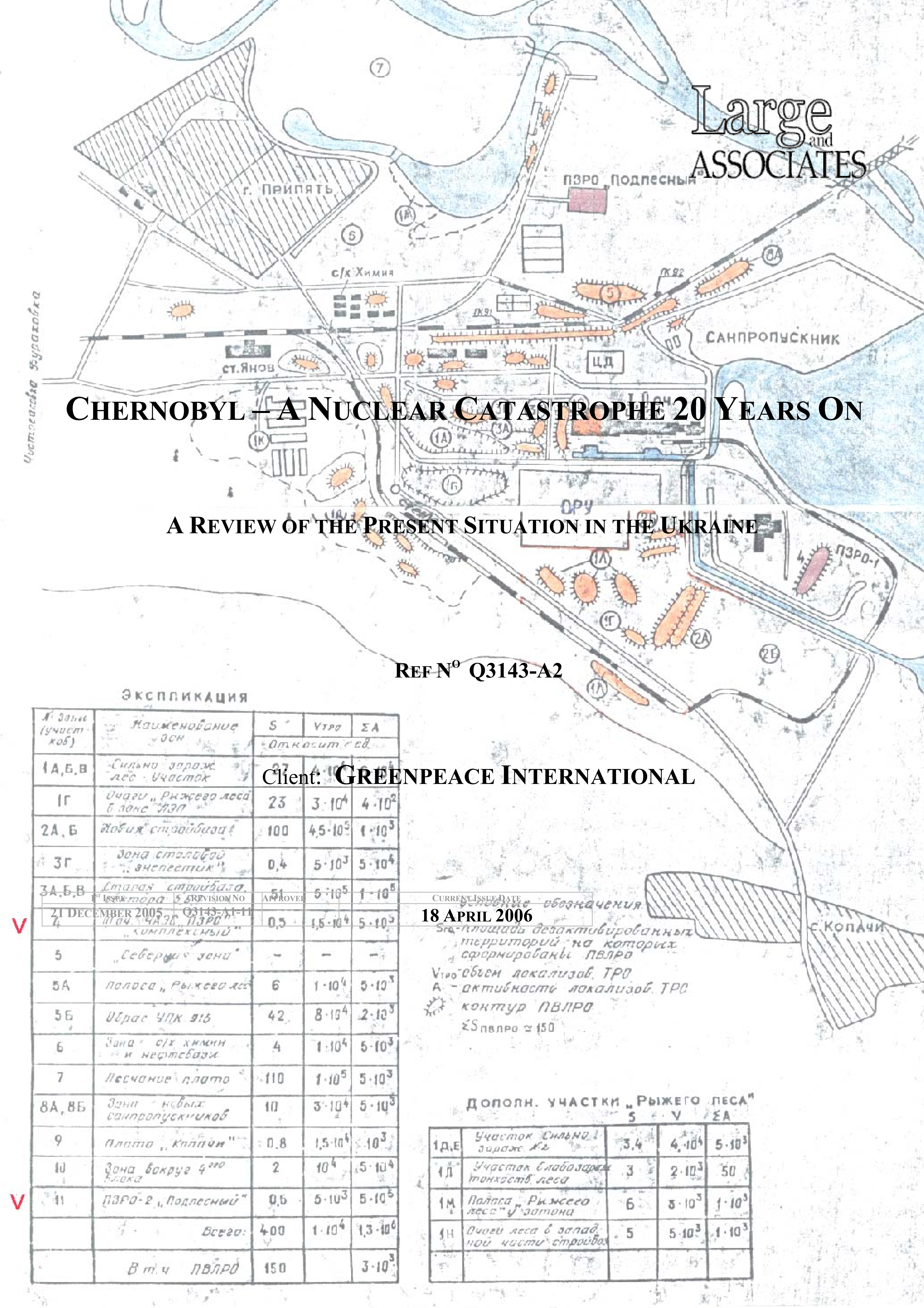

Large and ASSOCIATES

CHERNOBYL – A NUCLEAR CATASTROPHE 20 YEARS ON

A REVIEW OF THE PRESENT SITUATION IN THE UKRAINE

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SUMMARY

Twenty years ago the N° 4 reactor of the Chernobyl nuclear power station underwent catastrophic failure, spewing radioactivity into the environment for 10 or so days. The radiological consequences applied throughout most of Europe, extending as far afield as Britain and Scandinavia. Locally, in the regions of the Ukraine, Russian and Belarus, the radiological situation was very severe, in fact so bad necessitating the immediate evacuation of ninety thousand or more population from towns and villages nearby the stricken Chernobyl nuclear power plant and, as time passed, whole settlements were evacuated, demolished and ploughed into the ground, and more and more stringent controls over foodstuffs and agricultural were imposed.

Today the town of Pripyat, once home to 50,000, remains deserted along with the villages and settlements of the Exclusion Zone with the zone itself remaining evacuated save for about 7,500 people who continue to work there. These workers, who receive additional pay and employment privileges, maintain the dikes and earthworks that hold back the river defences and the spread of radioactive contamination into the River Dnieper basin serving the greater part of Ukraine's national population; they safeguard the remaining but now closed down three reactors at Chernobyl; they are responsible for the 800 or more radioactive waste dumps that were hurriedly formed in the aftermath of the accident but which remain very much in the same unmodified state today; and they are presently engaged in the construction of a number of large civil engineered projects for continuing waste clean-up and decontamination, spent nuclear fuel storage, and for the construction of roads and access to the large tracts of forest now covering previous agricultural land.

This Review considers Chernobyl as it is today and how it might be in future decades. It gives regard to past decisions on how to isolate and cope with the radioactivity and contamination, and it reviews the present approach to management and remediation being undertaken or at various stages of planning for future years. It has been compiled with the participation of individuals and organisations that have been and/or remain active in Chernobyl situation, including key scientists, engineers, non-governmental organisations, the nuclear regulator and the politician chairing the parliamentary committee for the elimination the Chernobyl consequences, with their individual contributions and inputs being collated during a week of intensive interviewing in the Ukraine during February/March of 2006. All of these individuals and their respective organisations, demonstrated a clear understanding of the overall challenges that Chernobyl presents and will continue to present in the years to come and all, without exception, showed dedication to furthering and sharing their knowledge so that the radiological, socio-economic and the other detriments arising from the Chernobyl accident of 1986 might be best managed in the years and decades to come.

The Review concentrates and ventures opinion on the following topics:

CONTAMINATED TERRITORIES

In the lands adjacent to the Exclusion Zone, the co-called contaminated territories, in total reside about 1.3M population. These *Chernobyl Sufferers* live and work, mainly as yeoman farmers growing, rearing and collecting produce that they then consume. They receive state compensation for remaining in the contaminated territories along with an array of leaflets and posters that provide elementary instruction on how to minimise their dose via self-management of their food uptake. The environment and radiation dose in the contaminated territories are closely monitored and recorded in much detail. However, year in year out, the average radiation dose to these individuals remains above that permitted elsewhere in the Ukraine, yet this aberration is tolerated and excused on the basis that they, those receiving the higher dose and risk, can choose to leave whenever they themselves wish to do so.

It might not be a full understanding to put this deadlock entirely down to the almost symbiotic relationship that has developed between those in the contaminated territories, who receive financial compensation, and the politicians who look towards this compensated group as a block vote. Correcting this overdosing via the food uptake path requires a greater degree of intervention management of the agricultural cycle and critical group habit. Put simply, it requires additional resources costing relatively small sums of money to finance, perhaps no more that €10M per year for a few successive years. In effect, this requires the budget allocation to those presently monitoring and managing the dose uptake to be increased from a meagre 0.3% to 3% of the overall Chernobyl budget.

However, finances are short with in recent years the government raising less than 30% of what it, itself, identifies to be the minimal funding requirement for Chernobyl overall, but the compensation payments always take precedent. Perhaps it is the bureaucratic inertia of paying so many individuals each no more than the equivalent of a few euros in compensation, is at the sacrifice of adequately funding those charged with managing and minimising the dose uptake of all of those in the contaminated territories. This sacrifice is made not least at protecting those children who are borne to become, in the first days of life, sufferers of the accident that occurred twenty years past at Chernobyl.

DRAINING THE COOLING LAGOON (POND)

Very large amounts of the fall-out from the Chernobyl release settled in the waters of the cooling lagoon. In addition, during the hurried clean-up operations in the immediate aftermath of the accident, further amounts of radioactive contaminated materials were deliberately dumped into the lagoon.

Leaving the lagoon in its present state is not a variable interim term option: It is leaking radioactivity into the Dnieper Basin; there is always the risk of a collapse of a section of retaining embankment and the release of a surge of highly contaminated sediment; wildfowl that nest on the lagoon are so contaminated that these represent a radiological risk if eaten; and maintaining the lagoon full at its elevated surface level and ensuring the embankments are sound costs, in all, around €630,000 per year.

A recent study has assessed a number of possible options for the future management of the cooling lagoon. The study concludes that the lagoon could be allowed to drain down naturally if the present pumping was stopped, taking between 3 to 8 years depending on the climatic conditions over the period. As the lagoon surface level recedes, the contaminated sediments nearing exposure would be sludge pumped and/or bulldozed into the depressed areas that would remain permanently waterlogged once the lagoon had drained down to the River Pripyat level. Although there are some unresolved issues on this preferred drain down option, notably that further research on the radiological impact of the fuel 'hot particles' known to inhabit the sediments and planning the longer term institutional control to ensure that at some future time the River Pripyat does not meander into the dried out areas of the lagoon, the lowering of the lagoon could have started in about 2004, that is once that the N° 1 and 3 reactors had been emptied of fuel when there should no longer have been a need for emergency cooling.

However, the defuelling of the reactors was contingent upon a new dry spent fuel facility being available for 2003. This store, designed and built by Framatome, it is now reckoned will not be

completed until 2010 which means that the Ukraine has to bear the cost of maintaining the lagoon full by pumping, running the additional nuclear risk of maintaining the fully fuelled reactors closed down and safe and, of course, keeping the 2,000 personnel specifically required for these essential duties employed within the Exclusion Zone.

MANAGING THE RADIOACTIVE WASTE AND CONTAMINATION

Of the various estimates that have been made over the years, perhaps the most straightforward reckons that to completely decontaminate just the Exclusion Zone, 21 million cubic meters of contaminated material would need to be identified, sorted, sifted and packaged for safe storage and eventual disposal. Confronted with such an impracticably large number, analysts have found reason to reduce this absolute volume to about 1.5M m^3 of wastes needs to be retrieved for packaging and storage and that a further 400,000m^3 could be disposed of via incineration. These daunting numbers have been further reduced by classifying the wastes into action priorities, the most urgent of which requires about 600,000m^3 for storage and 7,500m^3 for incineration.

This latest estimate of the radioactive waste volumes was prepared in support of a European Union funded waste processing and storage facility, *Vector*, presently under construction within the Exclusion Zone. However, there remains the oddity that to date no realistic assessment seems to have been undertaken to determine the dose burden sustained by those individuals, and because of the size the task it is likely to be several hundreds if not a thousand or so, who are to recover and package the buried wastes and contaminated soils of the Exclusion Zone, to transport the waste to *Vector*, and to remediate the sites of the original waste dumps.

EUROPEAN AND OTHER EXTERNALLY FUNDED PROJECTS

***VECTOR* Radioactive Waste Facility:** The *Vector* facility will also receive radioactive wastes from Ukraine's thirteen operational nuclear power plants and, quite possibly, take delivery of the high-level vitrified waste due to be returned from Russia in 2011. It could also be that the *Vector* site will be developed to temporarily store unreprocessed spent fuel that is now stockpiling at the operational nuclear power plants.

The final selection of the Chernobyl Exclusion Zone for *Vector* was determined from a 1996 TACIS funded study which although acknowledging the site *'not to be perfect from a technical point of view . . . the deficiencies could be compensated for by the provision of engineered barriers"*. That said, the final choice of *Vector* is surprising since it is now almost universally agreed that the siting of the Chernobyl nuclear power plants in the 1980s, at the head of such a large river basin serving as the main potable water supply of the greater part of the national population, was far from optimal but this does not seem to have been considered in the site selection process. If a major factor determining the siting of *Vector* included, as it seems to have been, that of putting radiation on radiation then it was ill-conceived because in reality it is piling risk upon risk.

Putting aside the lack of optimal siting and the apparent failure to justify the dose burden that will arise from recovering the radioactive waste throughput for *Vector*, in terms of co-operation with its Western European designers the *Vector* project, although some years later than anticipated, seems to be progressing well. This is more than can be said for some of the other European Union TACIS and G7 funded projects which are to be found across the region, for example:

Sarcophagus: Those who are antagonistic towards the plan for the erection of a second containment, the Sarcophagus Arch or Shelter Implementation Plan (SIP),[1,2] argue via a number of well deliberated studies that the maximum radioactive release within the Exclusion Zone and beyond from a sudden collapse would not result in excessive dose and, moreover, that arrangements are in place to protect those individuals in very close proximity to the sarcophagus who might be at risk of exposure to intolerable levels of inhaled dose. Furthermore, whereas it is acknowledged that the sarcophagus is in poor structural condition, the contention is that the time, effort and money to be invested in SIP would be better deployed stabilising and moving towards recovery of the radioactive materials within the wrecked N° 4 reactor building rather than, as with SIP, simply enclosing the extant mess with no features being built in to facilitate remediation at some later time.

Yet, or so it seems, these calls for caution go unnoticed with the European Bank for Reconstruction and Development (EBRD) progressing SIP through a maze of international bureaucracy in which some consider it to have lost its way and, in doing so, allowed the projected costs rise by 40% to over 1B US$. Even the involvement of the Ukrainian state nuclear regulator is limited in setting the SIP nuclear safety case to its own terms, seemingly it being subservient to the EBRD's own consultants the International Advisory Group (AIG). Throughout all of this the Ukrainian Parliament wrangled, continuing the uncertainty about the future of SIP over and past the tendering stages until, in June 2005 being subject to considerable diplomatic pressure, the Ukrainian government agreed to participate in a joint committee to see through the practicable implementation of SIP.

In the meantime, another EBRD managed project, the Framatome spent fuel store, fell behind time for its completion accumulating an enormous overspend.

Framatome Spent Fuel Store: The Framatome dry fuel store at Chernobyl is much overdue and has greatly overspent, being reckoned now to be another 5 years to completion, making it 7 to 8 years late, at a projected overspend of €100M over its original turnkey contract price of €70M or thereabouts. Reasons for this sorry state of affairs are allegedly numerous and mostly anecdotal. From the Ukrainian perspective these reasons range from the wrong railway gauge being installed, foundation subsidence, faulty concrete, insufficient space to manipulate the fuel assemblies at receipt into the store and so on and so forth. Whereas the French retort that much of the cause of the delays and overspend result from misinformation from the Ukrainians about the quality and condition of the spent fuel in the Chernobyl ponds and central store.

Whatever and from whichever perspective, the Framatome spent fuel store has become a *cause célèbre*. The delay in commissioning means that both reactors 1 and 3, although shut down, remain fully fuelled requiring a number of the front line safety and cooling systems to be maintained operational and for emergency cooling, should it be required, the cooling lagoon has to be kept pumped to its artificial level of 7 to 10m above the River Pripyat. The failure of the French to build the spent fuel store to specification and on time has been and continues to be costly to the Ukraine in maintaining the Chernobyl nuclear power plants safe.

CONCLUSION

This Review has been, by necessity, very limited in both scope and application.

The work of the scientific community in the Ukraine is, on the whole, very sound. There exists a determined group of researchers and analysts who have doggedly approached, worked at and assembled an information base and understanding that is quite possibly unparalleled for any other project anywhere in the World. However, the funding of this invaluable scientific and applications resource is miserably mean, the various core scientific bodies are

[1] The sarcophagus is to be reported by others, so it is only briefly dealt with in this Review, see *Chernobyl – 20 Years Later, the Situation at the NPP – No Solution in Sight*, Becker O, Hirsch H, Greenpeace Germany, March 2006.

[2] In general on citation, all of the tables, figures and diagrams have been taken from the work of others – but for brevity and clarity only the main paper or source is cited early in the text of each section dealing with that subject – a full citation list is available upon request.

still organised on the 'soviet' institutional model which is almost completely mismatched to, and cannot effectively communicate with the emerging democratic systems of the Ukraine. All of this is eking away at the confidence of the scientists and engineers whose ongoing interest and input is vital if the continuing aftermath Chernobyl is to be safely managed.

In this respect, it might be argued that the input of the European Union, G7 and other international donors has not eased the organisational and funding crisis that is enveloping the scientific and engineering community in the Ukraine. Joint ventures, such as those funded by TACIS and managed by the EBRD, in some instances have resulted in fragmentation of previously coherent teams of researchers because time fixed overseas projects carry discontinuities in funding. Some joint ventures offer separate funding to individual researchers, thereby enabling them to supplement their meagre (by western standards) institution salaries, but this can result in individuals being drawn away from work directly related to Chernobyl to joint ventures that may not have, because of the sometimes ineptitude of the sponsor, meaningful bearing on what is actually needed to safely manage the Chernobyl situation. Also, there are the anomalies whereby overseas organisations become involved in and offer advice on and/or project manage subjects which they themselves have little experience and expertise, much to the chagrin of those in the Ukraine who may know better. And, of course, there is the *brain drain* of scientists and engineers with all of their invaluable experience and expertise of Chernobyl being drawn away overseas.

Of course not all is bad about joint ventures but all is not well with this system which was, after all, initially superimposed upon the Ukraine to avoid a further radiological disaster spreading to the West. Although presented then as generous altruism from the international community to the people of the Ukraine and its neighbours, the joint venture activities now seem to be so highly commercialised one might drawn into the observation that, as one Ukrainian commentator wryly put it *". . . the Chernobyl project overall seems to have developed into little more than a money laundering facility for countless millions of Euro . . ."*. That said, and indeed without that much evidence of its veracity, there is no doubt that, overall, it is an unfair and, perhaps, ungrateful exaggeration of the assistance provided by overseas donors and the high degree of cooperation and positive work that has been achieved by these partnerships.

And what to do about Chernobyl?

First, any ambition to entirely decontaminate the Exclusion Zone and the contaminated territories must be recognised to be overly ambitious and practicably unobtainable

It seems sensible and an absolute prerequisite that all actions and measures that are taken or planned to be taken in and about the Chernobyl Exclusion Zone should be aimed at stabilising a given situation. Thus funding greater intervention of food uptake and habits of those inhabiting the contamination zones, say to about €10M per year, would lower and stabilise the individual dose uptake; the proposed drain-down of the cooling lagoon would remove the element of radioactive leakage into the River Pripyat, it would eliminate the risk of surge transfer of radioactive sediments should an embankment breach, and it would remove the dose path to beyond the Exclusion Zone via contaminated ducks nesting on the lagoon so, overall, it would stabilise and remove the uncertainty of maintaining a full lagoon; and progressing the Vector storage facility, albeit the choice of siting in the Exclusion Zone itself is somewhat doubtful, will provide interim term storage for wastes generated by Ukraine's 13 operation nuclear power plants, and for the decommissioning of the Chernobyl nuclear plants, which otherwise would not have been made available to an agreed international standard of containment and safety.

But there have been projects that have not resulted remediation or a stabilisation of an undesirable situation. For example, it might be argued that the failure to provide the spent fuel store in time for the Chernobyl shut down has destabilised the nuclear power plant safety regime, has introduced a new safety concern over leaving two of the three shut down reactors full of fuel for at least a further five years; installing the *Vector* storage sufficient capacity to receive wastes recovered from the Exclusion Zone dumps without first determining the dose burden of the waste recovery seems neither sustainable or stable; and the yet to be built sarcophagus arch, at an estimated US$1B is not sustainable because it puts off the clearing of the high level wastes to another day, indeed to another generation and, moreover, the enormous sum allocated might be money better spent on resolving other more practicable and pressing needs.

The enormity of the aftermath of Chernobyl is that really very little can be done other than to maintain the status quo and wait out the natural decay of the radioactive contaminants – providing and managing a safe radiological situation in the region of Chernobyl is challenging enough in itself. The projections are that this natural decay process will mean continuing isolation and rigid institutional controls having to be maintained in the evacuation zone and beyond for at least another 100 to 300 years but, even then, the presence of the longer lived fission products and actinides will require restrictions on the habitation and use of the land perhaps for ever and a day. It is not at all clear how it is justified that adventurous and highly iconic projects such as the sarcophagus arch, which many consider not to be entirely necessary at least in the very grandiose form proposed, can be allocated such enormous sums whereas the children born in the contaminated territories, through no choice of their own, immediately become sufferers of an accident that happened twenty years ago for want of, by comparison, a mere bagatelle of aid being diverted their way.

Finally, I thank all of those who have participated in this Review (see APPENDIX II) many of whom took the time and trouble to read through and correct the draft, making useful suggestions on how the Review might better reflect the situation in the Ukraine. Although their individual contributions to this Review should not be taken as endorsement of its observations and findings, I hope that I have somehow reliably reflected their unstinted dedication and enormous personal effort to address the continuing challenges of the Chernobyl accident some twenty years past.

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CHERNOBYL – A NUCLEAR CATASTROPHE 20 YEARS ON

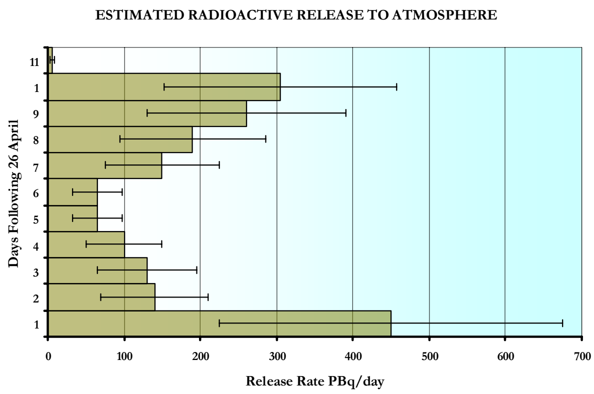
Twenty years ago, early in the morning of 26 April 1986 the N^{o} 4 RBMK nuclear power plant at Chernobyl (ChNPP) underwent a catastrophic containment failure. Two successive explosions shattered the reactor containment, spewing fragmented fuel, pieces of graphite moderator core, and parts of the reactor structure into the atmosphere, the result of which was that large tracts of the environment nearby and beyond were contaminated by radioactive fall-out.

The early response of those confronted with the catastrophe, obviously working under great stress, was to avert conditions whereby the melted fuel could commence spontaneous criticality and then to smother the flames of the reactor core.[3] Rather than letting the crippled reactor run its own course, with the risk of a continuing chain reaction, on 27 April through to 10 May, helicopters commenced dropping five thousand or so tonnes of dolomite, sands, lead and boron on the exposed reactor core and, at the same time, nitrogen was pumped into the cavity of the reactor pit to cool and stabilize the convection of air through the reactor core.

Radioactive Release Phases

The initial radioactive release was very energetic, within the core in the few seconds preceding the first explosion fuel temperatures are estimated to have exceeded 3,000^{o}C, well beyond the fuel melting point, thereby releasing fine oxides of the irradiated fuel, along with volatile radionuclide compounds of caesium, iodine, tellurium and noble gases. This first phase of the accident is reckoned to have released about 450PBq (~12MCi)[4] activity during the first 24 hours.

Thereafter and in response to the smothering and cooling of the core, the radioactive release progressively reduced, lowering to a level of about 75PBq per day mostly in the form of finely dispersed fuel and graphite particles. This second phase of release carried on through 2 May until the core temperature began to rise releasing increasing amounts of fission product aerosols and graphite up to a rate of 300PBq/d on 6 May, after which the release collapsed to a level of 2-6PBq/d.[5]



Total Release to Atmosphere

The totality of the radioactivity ejected to the atmosphere remains the topic of much debate, although even now some 20 years following, as further information becomes available, the total source term released is regularly updated from the very first, and possibly politically sensitive estimates, undertaken by the Soviets:[6]

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3 The extent of the burning (air reactivity) of the remaining graphite moderator core has never been established or, indeed, if the heating of the core was due continuing reactivity and/or, releasing Wigner energy from the graphite core.

4 1 PBq = 1 Pera Becquerel = 1.10^{12} Bq - 1 Curie = 1 Ci = 3.7 10^{10} Bq also used elsewhere in text 1 PBq = 1.10^{15} Bq

5 There are many published accounts of the events leading up to the Chernobyl accident and its release, but for a concise explanation of the release phases see *Analysis of Radioactive Contamination in the Near Zone of Chornobyl NPP* Alexander Gaydor, Oleg Nasvit *Institute of Nuclear Research, NASU, (http://www.rri.kyoto-u.ac.jp/NSRG/reports/kr79/kr79pdf/Gaydar.pdf). Release of Radioactivity from Destroyed Unit of the Chernobyl NPP* Borovoy A, Gegerinsky A, Atomnaya Energia. 2001, v.90

6 *The Accident at the Chernobyl Nuclear Power Plant and Its Consequences*, USSR State Committee on the Utilization of Atomic Energy; August 1986

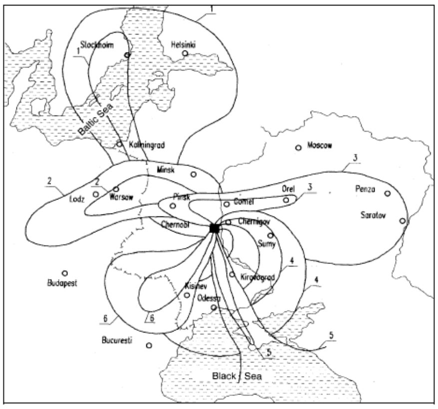
TABLE 1 ESTIMATES OF RELEASED RADIOACTIVITY OF MAJOR NUCLIDES BY THE CHERNOBYL ACCIDENT[7]

		ESTIMATED RELEASED ACTIVITY - PBq [% CORE INVENTORY]					
ISOTOPE – HALF LIFE	INVENTORY PBQ	USSR 1986	SEO[8] 1988	IMANAKA[9] 1993	UKRAINE[10] 1996	BOROVI[11] 2001	UN FORUM[12] 2005
I^{131} – 8.05d	1,350	270 [20%]	945 [70%]	661 [49%]	743 [55%]	743 [55%]	1,800 [?]
Cs^{137} – 30.2y	285	37 [13%]	162 [57%]	88 [31%]	86 [30%]	94 [33%]	85 [30%]
Zr^{95} – 64d	4,400	140[3.2%]	207 [4.7%]	220 [5.0%]	154 [3.5%]	-	-
Sr^{90} – 28y	21	0.8 [4.0%]	2 [9.6%]	-	1.1 [5%]	-	1 [4.8%]

The estimates of Table 1 can be compared with the opposite approach of assessing how much of the original ~192 tonne fuel core load remains in the sarcophagus containment that was hurriedly thrown up to enclose the debris in the weeks following the accident. This exists in the form of i) fuel fragments, ii) lava-like solidified fuel slurry and iii) dusts and general building/engineering debris. Sampling the solidified fuel slurry suggest that about 60% of the Cs^{137} escaped so, with the fuel fragments retaining the Cs^{137} content, the postulate is that 33% of Cs^{137} was released from the core.[11]

Radioactive Contamination

The radioactive disposition from the Chernobyl accident was widespread, extending over a vast area of Europe and reaching into Scandinavia. In the Ukraine and Belarus region the disposition of radioactivity was intense in the areas around the reactor.



ATMOSPHERIC DISPERSION TRAJECTORIES

The highly energetic explosions at the onset of the accident, followed by the burning reactor core, pushed the radioactivity to sufficiently high altitudes for the plume to be carried west across Europe, thereby contaminating vast tracts of land. In terms of caesium (Cs^{137}) being the dominant long-term contamination, a total of about 1,300,000 km^2 of land was contaminated to varying degrees:[13]

TABLE 2 ESTIMATE OF LAND CONTAMINATION EUROPEWIDE >1 Ci/km²

	Cs^{137} LAND CONTAMINATION LEVELS - kBq/m^2 - TOTAL LAND AREA km2					
kBq/m^2	10 - 20	20 - 37	37 - 185	185 - 555	555 - 1480	>1480
Europewide*	309,100	180,100	45,260	-	-	-

* Excludes Belarus, Russia and Ukraine.

In the local region the spread of land contamination (as indexed by Cs^{137})[14] was determined by the wind conditions and changes in direction during the ten days of release (26 April through to 5 May).[15] In terms of

7 *Current Topics about the Radiological Consequences by the Chernobyl Accident*, Imanaka Tetsuji, Research Reactor Institute, Kyoto University

8 *Released Radioactivity by the Chernobyl Accident*, Seo T, Imanaka T & Koide H. Kagaku, 58 N° 2 (1988)

9 *The Final Report of the Research Grant of the Toyota Foundation*, Imanaka T. et al 1993

10 *Minchernobyl - Ten years after the accident at Chernobyl NPP*: National Report of Ukraine, 1996

11 *Release of Radionuclides from the Destroyed Reactor at Chernobyl NPP*, Borovoi A. A.& Gagarinsky A. Atomnaya Energiya, 90 No.2 (2001)

12 *Environmental Consequences of the Chernobyl Accident and Their Remediation: Twenty Years of Experience* Report UN Chernobyl Forum Expert Group ‘Environment’ (EGE) August 2005

13 *Atlas on Caesium contamination of Europe after the Chernobyl Nuclear Plant Accident*, EC/CIS international scientific collaboration, M De Cort & Yu S Tsaturov.EUR 16542 EN (1996).

14 The dominant radionuclide is caesium but, of course, other fissions products and transuranics from the irradiation of the fuel are present. Of these, the strontium (Sr^{90}) was generally bound or fused into the fuel or ‘hot’ particles by the high temperatures of the reactor core heat-up phase of the immediate aftermath of the release sequence and, depending on the geo-chemistry of the local environment, strontium remains in the land deposited hot particles with a generally leisurely rate migration into plant roots, but those particles in the peaty bogs and, particularly, the cooling lagoon sediments have long washed out – for a fuller discourse on strontium uptake see *Dynamics of Redistribution of Radionuclides in Soils and Plants in Chernobyl Exclusion Zone*, Ivanov Yu National Academy of Science of Ukraine. Kyiv, 2001 and see also *Dissolution Kinetics of Chernobyl Fuel Particles: I. Dissolution of Fuel Particles of Various Genesis in Model Experiments*. Kashparov V. A et al 2000, see also Ref 16

the proportion of national territory contaminated at, for example, levels in excess of 1 Ci/km^2 (>37kBq/m^2) Belarus suffered worst with about 22% of its territory so affected, less at about 7% in the Ukraine and >1% in the Russian territories to the North.[16]

TABLE 3 ESTIMATE OF LAND CONTAMINATION LOCAL REGION >1 Ci/km^2

	Cs^{137} LAND CONTAMINATION LEVELS - kBq/m^2 [Ci/km^2] - TOTAL LAND AREA km2					
kBq/m^2	**10 - 20**	**20 - 37**	**37 – 185 [1 – 5]**	**185 – 555 [5 – 15]**	**555 – 1480 [15 – 40]**	**>1480 >40**
BELARUS	60,000	30,000	29,900	10,200	4,200	2,200
RUSSIA	300,000	100,000	48,800	5,700	2,100	300
UKRAINE	150,000	65,000	37,200	3,200	900	600

Ukraine Individual Radiation Dose

In the Ukraine (and also in the adjacent states of Russia and, particularly, Belarus) the Chernobyl accident resulted in intolerable contamination of the environment to the extent that it was not practicable to continue normal human activities, a situation that remains much the same today in the Exclusion Zone that surrounds the power station site. By 10 May following the accident a generalised radiological survey of gamma radiation over the Ukraine and neighbouring territories which enabled the then USSR Ministry of Health and Goskomhydromet to set out control zones. These zones were defined at the time in terms of i) and *'estrangement'* area at >0.2mSv per hour, ii) *evacuation* of all population at dose rates >0.05mSv/h,[17] and iii) *'hard control'* requiring the temporary evacuation of children and pregnant women at 0.03 to 0.05mSv/h.

The decision to evacuate the 50,000 or so population of Pripyat was taken on 27 April and all but a few stragglers had been evacuated by that same evening. The evacuation zone was extended to a 10km radius around the reactor site with evacuation of about 10,000 persons during 2 to 3 May and then, on 4 May, evacuation was extended throughout the 30km zone, including areas in Belarus, which was completed on or about 7 May 1986.[18] Smaller scale evacuations continued through to August 1986 so, in total,[19,37] about 90,800 Ukrainian individuals, including the entire populations of the towns Pripyat and Chernobyl (Chornobyl) and 80 or so villages, were permanently evacuated during the days and weeks following the accident in 1986 with, simultaneously with the evacuation of farming communities, about 60,000 livestock were removed.

For the purposes of radiological management in the longer term, the cumulative individual radiation dose was set at 100mSv whole body and 300mSv for the thyroid over the first year following the accident and, for the second year, this limit was reduced to 30mSv.[20,21] However, in December 1987 the permissible

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following. For the transuranics, plutonium remains generally immobile but there is, with time, the increasing dose burden of plutonium daughter americium (Am^{241}) which is to peak over the next 40 or so years, although its radiological significance remains small compared to the caesium.

15 Of course, the wind changes during the 10 or so days of high release, have resulted in a dispersion pattern characterised much by the conditions within the stricken reactor at any particular time. For example the fallout from the narrow fallout plume to the west over the first day of 26 April is dominated by non-oxidised UO_2 and zirconium U-Zr-O fuel particles, whereas the later release phases include oxidised UO_{2+x} fuel particles – an example of a specific release phase source term can be found in *Chernobyl Case Study Increases Confidence Level in Radionuclide Transport Assessments in the Geosphere,* Bugai, D, Dewière L, Kashparov V et al

16 For an exhaustive and authoritative review of the regional contamination see *Territory Contamination with the Radionuclides Representing the Fuel Component of Chernobyl Fallout*, Kashparov V A, Lundin S, Zvarich S I, Yoschenko VI, Levtchuk SE, Khomutinin Yu V, Maloshtan I N, Protsak V P, The Science of The Total Environment, vol.317, Issues 1-3, 2003 (я посылаю pdf файл этой статьи)

17 The *estrangement* zone rates of radiation dose should be compared to the actual dose active in the immediate aftermath of the accident. For example, in the town of Pripyat about 3km from the reactor site, radiation levels towards the evening of 26 April were at 0.14 to 1.3mSv/h and by the morning of 27 April the dose rate had climbed to 1.8 to 5mSv/h, thereafter rising sharply that evening to 4 to 10mSv/h in different areas of the town within, in some places, peaking at 15mSv/h. At the reactor site dose rates as high as 10,000mSv/h were recorded

18 The average external dose of the evacuees in the Ukraine is reckoned at 17mSv with a maximum individual dose of 380mSv – see Ref 27. However, *The Map-scheme of Radiation Damage of Coniferous Forests in the Region of Accident on the Chernobyl Nuclear Power Plant*, Kozubov G M et al Institute of Biology, Komi Scientific Centre, 1991 suggest that individual evacuees from the village of Usov (north of Pripyat) may have received very high radiation dose averaged at 2Sv.

19 *Countermeasures After Chernobyl Impact, Evaluation and Lessons*, Davychuk V, Annales de l'Ass Belge de Radioprotection, v24 No 4, 1999

20 From the *Sanitary Rules for the Operation of Nuclear Power Plants SRNPP-79* – these emergency limits might be compared with the emergency reference aversion limits (ERLs) adopted in the UK of 3 to 30mSv for sheltering and 30 to 300mSv for evacuation, although a radiological emergency has to be declared in the UK if the one-year projected dose exceeds 5mSv at which countermeasures must be implemented – see *Radiation (Emergency Preparedness & Public Information) Regulations 2001*

emergency radiation internal dose uptake was revised to a maximum limit of 8mSv per year and then, with a stabilising radiological situation, a census was undertaken in 1991 projecting the following combinations of internal and external dose uptake:

TABLE 4 PROJECTED POPULATION AVERAGE INDIVIDUAL INTERNAL & EXTERNAL RADIATION DOSE IN 1991 (1 YEAR)

	POPULATION NUMBERS		
EXTERNAL DOSE mSv	INTERNAL DOSE <0.3 mSv	INTERNAL DOSE <0.5 mSv	INTERNAL DOSE >0.5 mSv
>1	312,400	399,700	470,000
1 to 5	306,400	393,000	415,300
>5	6,000	6,700	54,700

At or sometime following these projections, for members of the public of the Ukraine, a universal annual dose limitation of 1mSv/annum and a 70mSv cumulative lifetime (70 years) dose was adopted broadly in line with ICRP 60,[22] although there was then and remains to this day considerable numbers of population that are exempted from these national limits via legislation exclusively applied to territories contaminated by the Chernobyl accident.[23] This exemption is based upon residence in areas where the levels of contamination could result in exposure in excess of the 1mSv/annum limit, specifically determined zones as a measure of the soil contamination, as follows:[24]

TABLE 5 CATEGORIES OF CONTAMINATION ZONES ACCORDING TO UKRAINIAN LEGISLATION FOR CONTAMINATED TERRITORIES[25]

ZONE	Cs^{137} Ci/km^2	Sr^{90} Ci/km^2	Pu etc Ci/km^2	DOSE mSv/annum
1) EXCLUSION	Zone of permanent evacuation established days after the accident in 1986 [26]			
2) MANDATORY EVACUATION	>15 [5 - 15]	> 3 [0.15 - 3]	0.01 - >0.1 [0.01 - 0.1]	can exceed 5
3) VOLUNTARY RESETTLEMENT	5 – 15 [1 – 5]	0.15 – 3 [0.02 – 0.15]	0.01 – 0.1 [0.005 – 0.01	can exceed 1
4) RADIOLOGICAL CONTROL	1 – 5 [0.2 – 1]	0.02 – 0.15	0.005 – 0.01	can exceed >0.5

Note: a) Limits shown […] apply to soils conducive to transfer of the nuclides to plant roots.
b) This 10 year data is reckoned to consist 60 to 70% of the total 70 year to which the first year (1986-7) contributed 23 to 28%.

Estimates of the effective (whole body equivalent) dose[27] for the first ten years following the accident for the population living in the contaminated territories (>1 Ci/km^2) provide sufficient data for the 70 year effective dose (1986 – 2056) to be forecast for the 1.3 million population of the contaminated territories of the

21 Those engaged in emergency and decontamination works in the highly active areas were set a dose limitation of 500mSv and there was also a somewhat poorly defined total dose of 100mSv exception for children under 14 years, pregnant women and breastfeeding mothers were limited to 100mSv.

22 1990 Recommendations of the International Commission on Radiological Protection, ICRP 1990

23 The Commission of the Supreme Soviet of Ukraine

24 However, note that in accordance with *Concept of Chornobyl Exclusion Zone on the Ukrainian Territory*, the Exclusion Zone itself is now divided into 5 individual zones, taking into account activities in its different parts, non-uniformity of contamination, location of industrial facilities and infrastructure elements - these are *Zone 1* applied 5km radius from the reactor site, *Zone 2* the far zone of 5 to 30km, excluding the Chornobyl residential area, *Zone 3* residential comprising adjacent territory where hostels and dormitories are located, *Zone 4* the territories of Zeleny Mys where the shift teams live, and *Zone 5* comprising isolated areas which were and remain evacuated such as Polissya, Narodichy and Ovruch – these zones comply with the legislation for *Basic Reference Levels, Exemption Levels, and Action Levels Concerning Radioactive Contamination of Exclusion Zone Objects* (GN 6.6.1.076-01).

25 In greater detail the Zones are defined as:

ZONES		CRITERIA TO ESTABLISH THE ZONES
1	Exclusion Zone	30 km radius around ChNPP
2	Unconditional (obligatory) Resettlement	Where D_{eff}>5 mSv/yr - ^{137}Cs > 555 kBq/m^2 or ^{90}Sr > 111 kBq/m^2 or Pu> 3.7 kBq/m^2
3	Guaranteed Voluntary Resettlement	Where D_{eff}>1 mSv/yr - 185 < ^{137}Cs <555 kBq/m^2, 5.5< ^{90}Sr < 111 kBq/m^2, 0.37 < Pu < 3.7 kBq/m^2
4	Enhanced Radioecological Monitoring	Where D_{eff}>0.5 mSv/yr - 37<137Cs< 185 kBq/m^2, 0.74 <^{90}Sr< 5.5 kBq/m^2, 0.185 <Pu< 0.37 kBq/m^2

26 The *Chernobyl Exclusion Zone* is defined as that area which is under the responsibility of the Administration of the Ministry of Chernobyl Affairs. The Exclusion Zone extends over an area of approximately 200,000 Ha.

27 *UNSCEAR 2000 Report*, United Nations Scientific Committee on the Effects of Atomic Radiation, Annex J (2000)

Ukraine. For this group the projected total collective dose is 14,000 man-Sv which yields an average individual dose of 10.8mSv, comprised 4.7mSv external and 6.1mSv internal components.[28,29] The above natural incident cancer fatalities for this collective dose can be projected to be about 500[30] in addition to the thyroid cancers which peaked in the early years following 1986.

However, more recent data[31] gives a possibly more disturbing projection for the rural group:

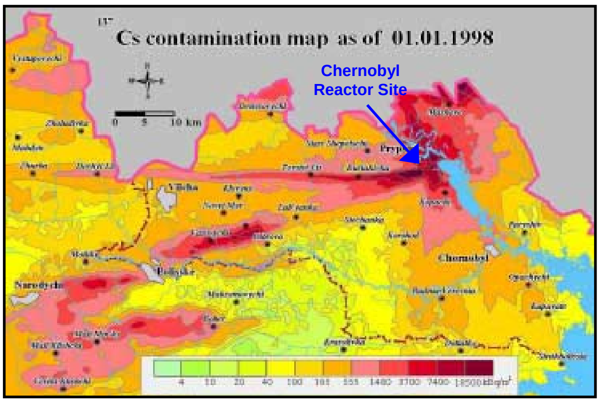
TABLE 6 ESTIMATES OF AVERAGE INDIVIDUAL AND COLLECTIVE DOSES TO RURAL GROUPS IN THE UKRAINE

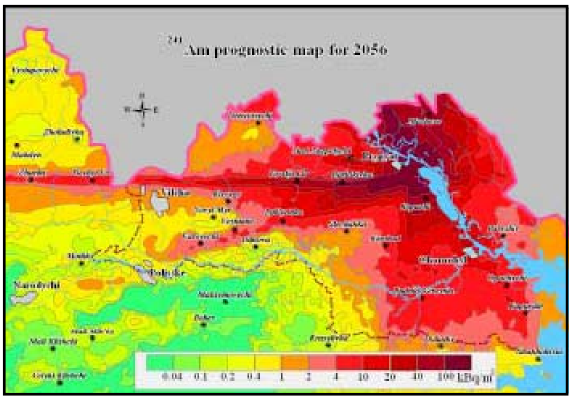
Cs^{137} kBq/m^2	[Ci/km^2]	GROUP SIZE	AVERAGE INDIVIDUAL DOSE mSv			COLLECTIVE DOSE manSv		
			1986	1986-2000	1986-2055	1986	1986-2000	1986-2055
<37	[<1]	21,742,200	0.36	1.2	1.5	7,785	25,356	32,694
37 – 74	[1 – 2]	892,200	2.1	11.5	14.0	1,902	10,302	12,485
74 – 185	[2 – 5]	423,400	4.5	20.1	24.9	2,907	8,516	10,542
185 – 370	[5 – 10]	39,600	10.8	33.8	43.9	426	1,337	1,737
370 – 555	[10 – 15]	8,400	21.0	54.4	73.1	176	457	614
>555	[>15]	3,200	25.6	74.1	96.4	83	241	313
TOTAL		**23,109,000**	**0.70**	**2**	**3**	**16,251**	**46,210**	**58,385**

So, comparing the results of TABLE 6 for the equivalent group of the earlier data[27] the collective dose of 25,691 manSv yields about 1,300 cancers over (0.63%) the natural incidence of cancers expected in that group, again neglecting the excess thyroid cancers in the earlier years. The projected average individual dose is 18.8mSv with the highest exposed group (>555kBq/m2 or >15 Ci/km2) expected to receive a lifetime dose of 96.4mSv which is in excess of the required norm.

Monitoring and Managing the Contaminated Territories

Obviously, the management of radiological protection approach adopted for the exclusion zone and contaminated territories of the Ukraine requires a comprehensive monitoring system.





There is now an established and systematic monitoring approach for the long-lived radionuclides, including Cs^{137}, Sr^{90} and the transuranics $Pu^{238,239+240}$ and Am^{241} daughter product, comprising more than 1,500 specific stations shown the data from which is used to construct the Cs^{137} and projected Am^{241} radiological maps shown left and right above.[5]

28 ICRP 60 mortality factor of 5E-2 per Sv.

29 Following the early phase of the accident, during which external exposure dominated, there has occurred a steady transmogrification of the dose receipt balance with internal dose uptake contribution increasing. This is because uptake of radionuclides through plant roots from soil became increasingly important and showed strong time dependence. Cs^{134} and Cs^{137} were the nuclides which led to the largest problems, and after decay of Cs^{134}, Cs^{137} remains the dominant dose source. In addition, Sr^{90} is expected to increase its dose contribution in the near field but at longer distances from the reactor its deposition levels were too low. Other radionuclides such as plutonium isotopes and Am^{241} were either in so low deposition levels, or not very available for root uptake, to cause real problems in agriculture.

30 Although 500 is a significant number itself, when compared to the present rate of cancers caused by other non-radiological factors (about 15% of the population) such a small percentage (0.24%) would be difficult to detect by epidemiological survey.

31 Note provided by Valeriy Kashparov, Director of the Ukrainian Institute of Agriculture Radiology, on data of I Likhtarev

Confronted with such widespread contamination, the (principled) approaches initially determined by the then Soviets and which has been generally adhered to but developed by the Ukraine, being:[19,32,33,34,35,36]

1) **Minimisation of Dose to Populations in Contaminated Territories**

   By mass evacuation, such as from the towns of Pripyat and Chornobyl in 1986 and other communities years later;[37] by recovering and placing in repositories (trenches, dumps etc) radioactive contamination and wastes from the land and building surfaces, etc.; remedial clean-up and decontamination of settlements where occupation was to remain; and management of human activities and food uptake.

2) **Dose Control in the Exclusion Zone**

   Minimising the numbers of persons in the exclusion zone to those required for essential maintenance and contamination management works, and for the safe continued operation of the remaining three nuclear power plants at Chernobyl; providing close radiological monitoring of all individuals involved and adhering to a dose investigation-justification scheme.

3) **Containment of Radioactivity within the Exclusion and Contaminated Zones**

   Effectively, ring fencing the zones, particularly the exclusion zone for migration of radioactivity in the soil, flooding and watercourses to the Dnieper basin, and atmospheric dispersion via forest and field fires, from other natural resuspension events such as typhoons, etc., and the potential for collapse of the sarcophagus and resuspension of the dusts within.

CHERNOBYL 20 YEARS ON - PRESENT SITUATION

This section collects together and discusses the outcome and overall impressions of individuals in the Ukrainian scientific, engineering and applications sectors, and non-governmental organisations (NGOs) all presently involved in the Chernobyl project – the individuals are listed in **APPENDIX I**.

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32 Analysis of the Efficiency of the Countermeasures on Prevention of the Radioactive Contamination Spread, Sobotovich E et al, Chernobyl Catastrophe, ed Baryakhtar V, 1997

33 Some very large scale water-protection works have been undertaken in the exclusion zone: First, in the years immediately following the accident (1986-87) a number of areas and catchments were dammed but these, generally, proved ineffective and were removed in 1988. In 1993 the north-west bank flood meadows of the River Pripyat were protected by about 20km of dikes and another dike section was introduced on the south-west flood plain in or about 1998 – these dikes provide for the controlled pumping and weir sluice drainage of the flood plains to mitigate transfer of ground contamination into the Dnieper basin are planned to operate for at least 60 years henceforth – in detail see the work of Oleg Voitsekhovich..

34 On Dose Efficacy and Social-Economical Expediency of Modern Water-Protection Activity in the Exclusion Zone, Voitsekhovitch V et al 1998

35 *Radioactive Contamination of Food in Stepanivka Village, Zhytomyr Region, Ukraine: in 1992 and in 2001* Tykhyy V, Institute of Mathematical Machines and Systems, the National Academy of Science of Ukraine.

36 The implementation and effect of this approach have been well reported so here it is appropriate only to briefly outline this immense past effort by the Ukraine to have included (not all of which had an entirely beneficial outcome):

- the complete evacuation and resettlement away from the exclusion zone of about 91,000 individuals in the few days following the accident in April 1986
- the cutting back, removal and controlled disposal of 580 hectare of pine forest (the *Red Forest*) in 1986 to reduce the dose to personnel attending the nuclear power plant
- the preparation for and construction of the sarcophagus
- cessation of use of 2,100km^2 of arable land in the exclusion zone
- the decontamination of villages and, in some cases, the demolition and disposal of settlements by burial
- the construction of dikes to control the flood plain
- implementation of agricultural countermeasures, such as liming, sorption layers introduction, ploughing of lands in continuing use in the adjacent inhabited zones of about 2,300km^2 and 200,000 population

37 Quite large scale evacuations continued in the Ukraine in the years following 1986 with, for example, despite many efforts to improve the radiological situation in Poliske of about 10,000 population. First, in December 1989 families with children under 14 could leave the town, in February 1990 the decision on mandatory resettlement from Poliske of families with children and pregnant women was taken but this was delayed, because there was insufficient accommodation, but followed a decisive Resolution of the Council of Ministers (23.08.90) on *mandatory resettlement* of all population of the town was evacuated. This decision was repeated in the Resolution of CMU № 106, 23.07.1991 in which the town of Poliske was listed among other 86 Ukrainian communities as destined for *'mandatory evacuation'* - see *Solving the social problems caused by the Chernobyl catastrophe: 20 years is not enough*, Volodymyr Tykhyy in *Many-sided Approach to the Realities of the Chernobyl NPP Accident: Summing-up of the Consequences of the Accident Twenty Years After*, funded by the Toyota Foundation.

In essence, the ***Principled Approach 3)*** above, that is containing the radioactivity within the exclusion and contaminated zones, is a balance between the detriment of higher dose exposure within the zones -*v*- the benefit of minimising the collective dose to the greater Ukraine population beyond the exclusion zone.[38] Maintaining a favourable balance of this composite requires quasi-stability within the exclusion and contaminated zones and, where changing circumstances are envisaged over time, full account of these and a reliable assessment of how the collective dose beyond the zones might be affected. Also, within this balance the contingency of reasonably foreseeable events, accidents and external events, including malevolent acts, has to be assessed in terms of acceptable risk (probability) and tolerability of the consequences (transfer of collective dose).

Aspects[39] of the present circumstances of the aftermath of Chernobyl relate to this detriment-benefit as follows:

1) INHABITANTS OF THE CONTAMINATED ZONES – RADIATION DOSE AND FUTURE WELLBEING

Valeriy Kashparov (Institute of Agriculture) expressed great concern that a significant population group (about 270,000 individuals) continued to receive higher than maximum 1mSv annual dose primarily because of insufficient controls and discipline on their food uptake (TABLE 6). Part explanation was that, originally, the Soviets applied a system of controls on the then more readily acquiescent society comprised large collectives of farms, food processing and manufactories over which state controls could be effective. For example, then, in 1986 and the few years following, the major delivery pathway of Cs^{137} milk could be readily controlled by dilution, conversion to butter, and pasturing controls over the cattle, etc., but following independence the collectives were largely replaced by yeoman farmers[40] for whom such centralised controls cannot be effectively applied. Specifically, the most effected regions are Rovno and Zhitomir with the 15 or so villages in Rovno averaging individual dose of 2 to 5mSv/year in 2004 and, overall, about 200-300 villages in Rovno, Zhitomir, Volyn, Kiev and Chernigov regions with individual dose from 1 to 2 mSv/year in 2004. Generally, *Kashparov* would like to have the existing 4 zones redrawn because they were originally set up subjectively, that is redefining each zone in terms of effective individual dose (internal + external).

Kashparov argues that increasing the meagre budget, from the present 0.3% of the state Chernobyl allocation, say by the equivalent of 10M US $ to 3%, would be sufficient to bring the exposed group of his concern to within the 1mSv/annum whole body dose equivalent limit using relatively straightforward intervention measures, whereas his present resources generally confined his efforts to dose monitoring, observing and the distribution of educational/information leaflets. Given adequate funding, the main thrust of *Kashparov*'s intervention would be increased use of ferrocene or Prussian Blue (PB)[41] and he gives example of the effectiveness of PB dosing to cattle in that cessation of is application would increase the number of villages at risk from the present 160 to 300 with levels of Cs^{137} in milk rising to 1,000Bq/l.

Even when subject to severe financial constraints, *Kashparov*'s work has steadily etched away over exposure by countermeasures, conjoined with natural processes, that have resulted in a decrease in the number of the settlements in Ukraine where the milk contamination with ^{137}Cs exceeds the State action level (PL-97) of 100 Bq/l, from 400-500 in 1994-2001 to 166 in 2005 (including 87 villages in Rovno region, 60 in Zhitomir region, 13 in Volyn region, 1 in Kiev region and 1 in Chernigov region). The most affected settlements are 15 villages in the Rovno region, where the catalogue effective dose to population exceeds 2 mSv/year, and the levels radiocaesium contamination of milk is 3-10 times higher now than the action level. However, exceeding of PL-97 is observed for Cs^{137} in the vegetables and potato from peat bogs (about 10 villages), and for Sr^{90} in grain (about 50 villages), which was never observed before.

On his part, *Volodymyr Tykhyy* (Institute of Mathematical Machines and Systems) noted that his recent study[42] for the village of Stepanivka, some 120km west of the Chernobyl reactor site, recorded a nine-fold

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38 Albeit with some very significant exceptions to this.

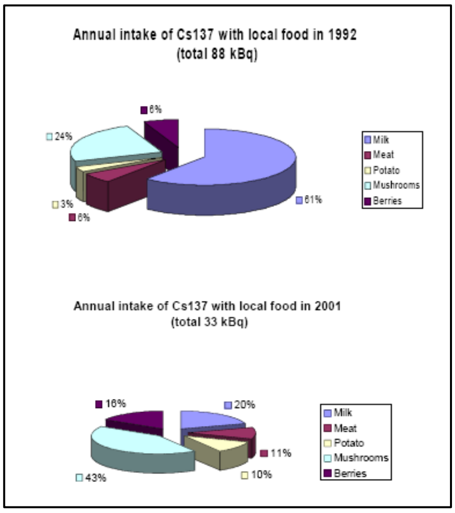
39 Obviously in the limited time available not all aspects relating to the Chernobyl situation are covered by this review and some of the judgement reached are based on anecdotal and possibly incomplete information.

40 *Kashparov* gives 80% for collective farm production in 1986 which ha now reduce to about 20%, and milk production is now dominated by individuals who generally have no work, they produce what they eat with much of this being contaminated.

41 The term *Prussian Blue* refers to a number of ferric hexacyano ferrates having distinct properties. Ammonium ferric cyanoferrate, or AFCF, is perhaps the most studied caesium-binding compound. In solutions such as those found in the gastrointestinal tract, AFCF is in a colloidalsoluble form and reacts with ionic caesium forming a complex that does not penetrate biological membranes.

42 *Radioactive Contamination of Food in Stepanivka Village, Zhytomyr Region, Ukraine: in 1992 and in 2001* Volodymyr Tykhyy, Institute of Mathematical Machines and Systems

reduction in Cs^{137} contamination milk pathway in 2001 over 1992. However, this reduction had been offset because the consumption of wild forest products, such as mushrooms and berries in which the Cs^{137} component had not markedly decreased, now played a greater part in the overall diet. This unpredicted change of diet has resulted in the overall Cs^{137} uptake by the Stepanivka population through food products and water to be about 3 and not 9 times lower in 2001 than in 1992,[43] although *Tykhyy* considers that Stepanivka is *'in rather a good area'*, because in many of the other villages the milk and other food Cs^{137} levels remain significantly higher.[44,45]



Cs^{137} INGESTION UPTAKE - AFTER *TYKHYY*

Tykhyy argues that the effects of Chernobyl apply to a much larger and more diverse group, including those 600,000 liquidators[46] who participated in emergency activities in the exclusion and control zones over 300,000 of whom remain in the Ukraine, the total 350,000 who were resettled and the several millions that have lived on contaminated land since 1986. The numbers of *Chernobyl Sufferers* are large but subject to uncertainty, according to *Yuriy Urbanskiy* (non-governmental organisation *'NECU'*) who reckons about 6 to 8% of the Ukraine population were and/or remain effected but the system of compensation, and particularly the identification of ailment and illness that can be officially attributed to Chernobyl exposure is almost wholly insufficient and unfair with, for example, 6% of those registering for liquidator status being denied.[37]

Both *Kashparov* and *Tykhyy* concur that the Ukrainian State budget for Chernobyl could be better managed and that such small individual payments of a few Euro (€) equivalent per year to so many thousands of claimants might be better diverted to bolster resources for direct state intervention to improve food quality and radiological control. *Tykhyy* goes so far as to opine that many of the claimants themselves undermine the system, so much so that the compensation scheme overall is open to abuse,[47] and that the budget allocation for radiological management can only diminish further, with the State failing to meet its own fiscal targets.[48]

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43 Contrary to the reducing Cs^{137} trend, activity of Sr^{90} in milk and dried berries was significantly higher in 2001 than in 1992.

44 In 1998 19.7% of 34,233 milk samples were Cs^{137} were higher than the permissible 100Bq/l - see *Control of content of main dose-forming radionuclides in Ukraine.* Tsyprian V & Myshkovska. A, Higiena Naselennyh Mest (Hygiene of Populated Localities). Vol.36, Part 1. Kiev, 2000

45 But note that the long-term internal doses to residents of rural settlements strongly depend on soil properties. Contributions due to internal and external exposure are comparable in areas with light sandy soils, and the contribution of internal exposure to the total (external and internal) dose does not exceed 10% in areas with dominantly black soils. The contribution of 90^{Sr} to the internal dose regardless of natural conditions is usually less than 5%.

Both accumulated and predicted mean doses in settlement residents vary in the range of two orders of magnitude depending on radioactive contamination of the area, dominating soil type and settlement type. In 1986-2000 the accumulated dose range comprised from 2 mSv in towns located in black soil areas up to 300 mSv in villages located in areas with podzol sandysoils. The doses expected in 2001-2056 are substantially lower than already received ones, ie, in the range of 1 to 100 mSv.

46 The largest group of liquidators participated in clean-up operations for variable durations over a number of years after the accident and were subject to controls and dose limitations, they received significant doses ranging from tens to hundreds of millisieverts, although there persistent claims, by *Vladimir Usatenko* (Expert of National Committee of Radio Protection) and others, that dose monitoring and records were corrupted and/or never released. The liquidators were initially subjected to a radiation dose limit for one year of 250 mSv. In 1987 this limit was reduced to 100 mSv and in 1988 to 50 mSv, although *Usatenko* notes that these assessments and limits only applied to the working period and dose increments received travelling to and from the working area were not taken into account in the dose registry. The registry data show that the average recorded annul doses in the national registries of Ukraine, Belarus and Russia decreased from year to year, being about 170 mSv in 1986, 130 mSv in 1987, 30 mSv in 1988 and 15 mSv in 1989.

47 Those living in the contaminated territories receive several forms of compensation which is linked to minimum earnings, at about 60 €/month and this includes compensation for restrictions on locally produced food, increments for living and working in the contaminated area, and additional increments for public servants (teachers, medics, etc) engaged in the zones. Often, these compensation sums amount to a greater grant than the wage that can be earnt by an average person in the locality.

48 The decline in iv) funds available to the *Chernobyl 'sufferers'* run contrary to i) the needs identified by government and the ii) amount actually allocated, and the iii) funds actually provided:

Funding for Social Protection of Chernobyl Sufferers – Hryvna Million after ***Tykhyr*** citing from data from the web site of the Ministry of Ukraine of Emergencies quoted

YEAR	EXCHANGE RATE HRYVNA = $USD	i) NEEDS SET BY LEGISLATION	ii) PLANNED STATE BUDGET	iii) PLANNED % OF NEEDS	iv) PROVIDED FUNDS % OF NEEDS
1996	1.83	2004.1	1150.8	57.4	49.8
1997	1.86	3291.7	1799.3	54.7	36.0

Urbanskiy laments with his damning summation of the reasons for the fate of the *Chernobyl Sufferers*, this being *" . . Unfortunately, several different organisations are responsible for their separate bits and there is no co-ordination between them - it is a cocktail of incompetence, populism and dishonest politics".*

On her part, *Olena Mykolaichuk* (Chair, State Nuclear Regulatory Committee) expressed an eagerness for areas of the exclusion zone to be made open for reoccupation and, although her nuclear safety regulatory responsibilities do not permit direct involvement, her influence over such things must be significant. Parliamentarian *Gennadiy Rudenka* (Chairman, Committee on Environmental Policy, Natural Management and Chernobyl Catastrophe Consequence Elimination) recognised the radiological plight of the group of *Kashparov*'s concerned, but noted that very little could be done about it and that, moreover, the occupiers were not only compensated but were entirely free to move away from the contaminated territories if they so wished.

In summary: The data of *Kashparov*, *Tykhyy* and others suggest that, as time passes, there is a decreasing dose detriment to those subsistence farmers occupying the contaminated territories.[49]

However, two aspects of this are disturbing and give cause for concern: The first is that the collective dose pathway remains significant thereby violating ***Principled Approach***. The second aspect is intergenerational, with those being born into this undesirable situation having no say about the State's commitment of them individually and collectively to a higher radiation exposure regime, so much so that the *Rudenka*'s basis of justification for the practice continuing might be argued to be entirely invalid because, it follows, it is simply unsustainable to the second and third generations now in and for those coming into occupation of the contaminated territories.

As shown by both *Kashparov* and *Tykhyy*, the primary uptake path is food consumption so it would be relatively straightforward, as *Kashparov* has outlined,[50] to reduce the exposure to levels below the national regulatory limit of 1mSv/annum. However, such would require either additional state funding and/or diversion of a relatively small increment of the total amount set aside for compensation of the *Chernobyl sufferers* but this, in itself, will require unravelling of the symbiotic dependency between the *sufferers* and national politicians – a somewhat unhealthy alliance that serves only to frustrate improvement in this and other areas.

Overall, the impact of Chernobyl on agricultural practices, food production and use and other aspects of the environment has been and continues to be widespread. The impression gained is that about as much as can be done to control and remediate this situation has been done, although some slippage has and continues to occur with respect to radiological controls over farming practice and food uptake for a large population group in occupation of the contaminated territories. Large areas of agricultural land are either subject to restrictive controls or remain excluded from use and are expected to continue to be so for a long time. Although contamination levels followed a decreasing trend for some years after the accident, it now appears that ecological stability has been reached. The decrease now seems to be following the decay period for the foremost radionuclide Cs^{137} which, with a 30-year half-life, will be the dominant source of contamination for a further 10 or so half-lives, or about 300 years.[14]

1998	2.45	3474.9	1953.5	56.2	30.2
1999	4.13	4408.0	1310.1	29.7	27.4
2000	5.44	5771.9	1578.4	27.3	27.3
2001	5.37	6731.5	1559.6	23.2	23.2

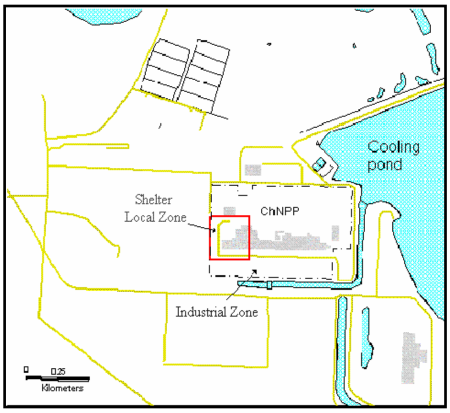
49 Ref 12 reaches the conclusion that the *'Application of agricultural countermeasures in the three more affected countries [Belarus, Ukraine and Russia] has substantially decreased since the middle of the 1990s, because of economic problems. In a short time, this resulted in an increase of radionuclide content in plant and animal agricultural products'*.

50 Among long-term remediation measures, radical improvement of pastures and grasslands as well as draining of wet peaty areas is of high efficiency. The most efficient regular agricultural countermeasures are pre-slaughter clean feeding of animals accompanied by *invivo* monitoring, application of *Prussian Blue* to cattle and enhanced application of mineral fertilisers in plant growing. Restricting harvesting of wild food products, such as game, berries, mushrooms and fish from 'closed lakes,' by the public still may be needed in areas where their activity concentrations exceed national action levels. Advice on diet aiming to reduce consumption of highly contaminated wild food products and on simple cooking procedures to remove radioactive caesium still is an important countermeasure in reducing internal exposure.

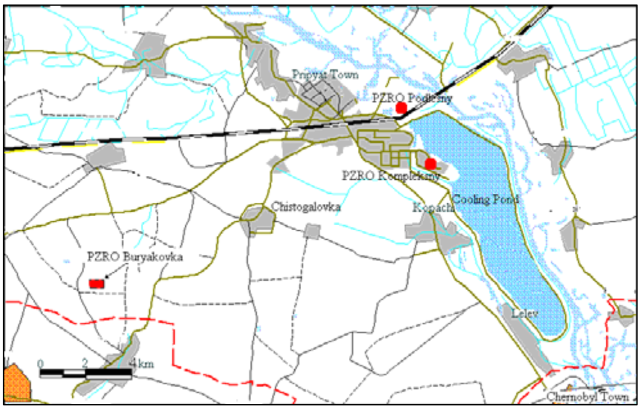
2) Radioactive Waste and the Waste Recovery and Disposal Project

In the Ukraine (excluding Belarus and Russia) the post accident recovery and clean-up operations resulted in the production of very large quantities of radioactive wastes and contaminated equipment which are currently held in about 800 dump sites within and outside the 30-km exclusion zone around the reactor site.

Some areas of land and expanses of water, such as tracts of forest and the cooling pond (lagoon), were abandoned without any attempt to recover the radioactive contamination, remaining so to this day. Other radioactive contaminated material and wastes were hurriedly disposed into unlined and ill-prepared pits, trenches and heaps and, at least two locations, entire villages were demolished and dug into the ground. As the clean-up programme developed a number of engineered disposal sites were prepared for the longer term management of the wastes with the waste, to the limited extent that was practicable at the time, being segregated for disposal into custom-built facilities featuring concrete and/or clay liners and capping. At the stricken reactor site, highly active reactor components and irradiated fuel debris were dug into the ground and, where practicable, the intensely active debris was pushed back into the reactor building to be subsequently enclosed within the sarcophagus where it remains today.



Shelter Local and Industrial Zones



PZRO Radioactive Waste Dumps

The sites of radioactive waste disposal are categorised in the exclusion zone generally to be the *Shelter Local Zone* within and immediately about the Sarcophagus, the *Industrial Zone* outside the Sarcophagus, three 'engineered disposal' sites (the so-called PZRO), non-engineered near surface trench dumps (PVLRO), contaminated soil and sites of 'unauthorised' disposal within the *Exclusion Zone*. The location and contents of these various waste facilities was recorded, sometimes inadequately, during the few years following 1986 when the clean-up and decontamination operations were underway in earnest.

PZRO Dumps Podlesny, Kompleksny and Buryakovka: These are the so-termed 'engineered' waste repository dumps located to the 2km north, 3km east and 12km west of the power station site respectively.

The waste inventories given on the following table are estimates drawn from necessarily limited sampling. For example, sampling at Buryakovka was from sampling of just one of twenty-seven trenches; that at Kompleksny was from sampling just several tens of containers out of a total number of 18,000; and at Podlesny the assessment is taken from an investigation undertaken in 1995.[51] On the basis of the average specific activity for free release the wastes in Podlesny and Kompleksny are defined to be long-lived under the IAEA classification system. Although the heat rating is not provided, the wastes at Podlesny would most probably be classified as High-Level Waste, particularly because the dump is reckoned to hold about 104 tonnes of fuel mass.

[51] Energoproekt *Working Design. PZRO Podlesny. Sealing*. Energoproekt. Kiev, 1995

Table 7 PZRO Dump Radioactive wastes

		Podlesny	Kompleksny	Buryakovka 1998
		HLW (Ukrainian Regs)	Long-Lived (Ukrainian regs)	Short-Lived + 150m^3 long
Total volume	**m^3**	3,960	26,200	590,000
Total activity of waste				
Cs^{137}	**Bq**	0.420×10^{15}	0.0320×10^{15}	0.061×10^{15}
Σ Cs^{137}, Sr^{90}, Pu^{241} + trans	**Bq**	1.000×10^{15}	0.0750×10^{15}	1.500×10^{15}
Σ $Pu^{238-239-240}$ Am^{241}	**Bq**	0.014×10^{15}	0.0011×10^{15}	0.002×10^{15}
Average specific activity of waste				
Cs^{137}	**Bq/g**	52,000	757	77
Σ Cs^{137}, Sr^{90}, Pu^{241} + trans	**Bq/g**	125,000	1,780	183
Transuranics	**Bq/g**	1,800	26.6	2.5
Maximum specific activity of waste				
Cs^{137}	**Bq/g**	-	1,280	-
Σ Cs^{137}, Sr^{90}, Pu^{241} + trans	**Bq/g**	-	3,000	-
Transuranics	**Bq/g**	-	45	-

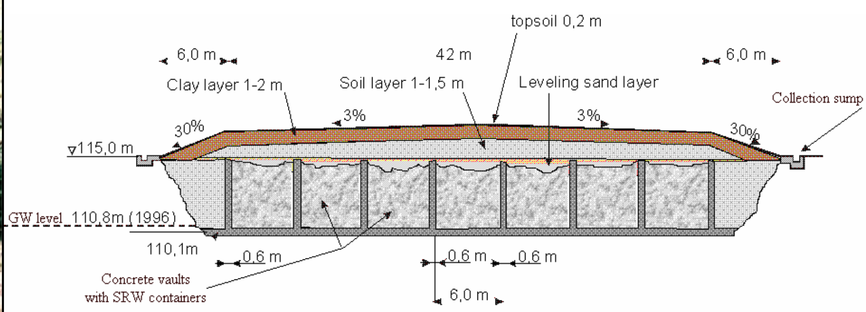
All three PZRO dumps are in poor condition.

The above ground containment vaults of **Podlensky** comprises concrete blocks of 1.1m and 2.4m thickness (for the A and B compartments respectively) of 1 to 9m high rising from in situ cast concrete slabs of 1.5m thickness, with an earth bund of about 4.5m height laid around the external periphery. In 1990 following the discovery of settlement and cracking of the vault walls, further filling was suspended and the two loaded vaults were sealed with about 2,400m^3 of cement grout overlain with a mix of sand and crushed stone. There are no electricity supplies to the site, the loading crane is derelict and entirely unserviceable, and security to the specific site is virtually none existent.[52]

Vault A1 Podlensky

PZRO **Kompleksny** (below) comprises seven compartments formed by a shallow underground reinforced concrete cellular structure, each 6m wide by 5m deep. When closed, the compartments were topped with sand, soil and capped with a 1m thick compacted clay liner.

Kompleksny – Vault and Pit through Clay Cap

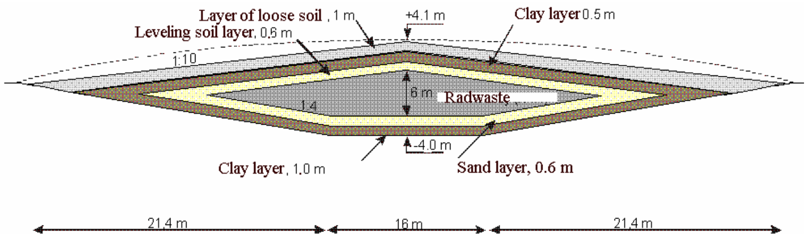


52 Although it is argued that the policed borders of Exclusion Zone itself provides sufficient security.

This dump is filled with fabricated steel waste containers which, over the years, may have extensively corroded and collapsed, resulting in the localised subsidence in the surface depressions and pits that penetrate through the clay cap. Radiation dose rates at the surface register up to 34μSv/h and at the walls of the buried waste containers now exposed by subsidence form 10 to 500 μSv/h.[53] The bottom of the cells are flooded, depending on the season, to a depth of 0.5 to 0.7m resulting, it is assumed, from the blockage of the drainage system once the facility ceased receiving wastes in 1988. Groundwater flows to the cooling lagoon about 150m to the North.

PZRO **Buryakovka** is the largest of the engineered dumps comprising 30 clay lined trenches.

There are 4 empty trenches (2000) which continue to receive radioactive waste at, on average, 30,000 to 40,000m^3 each year. Each trench contains about 20,000 to 35,000m^3 which in situ compacts down to about 3,000m3 using heavy earth moving machinery. There is also an open air storage area holding vehicles, machinery, etc.

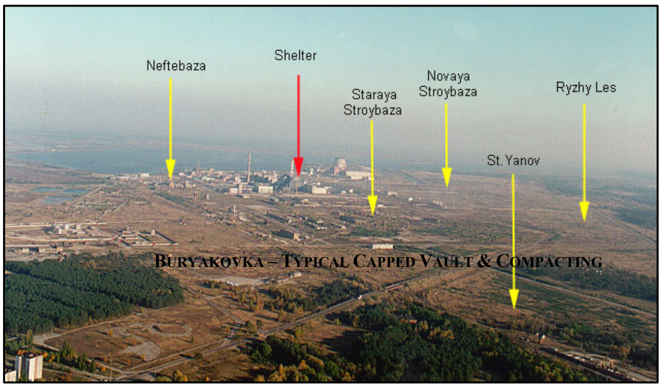


CONTINUING DUMPING AT BURYAKOVKA

Temporary Dumps – PVLROs: There are a number of temporary waste dumps (PVLROs) that were formed between 1986 and 1987 around the power plant and in the surrounding areas. These waste dumps have no engineered barriers and seemed to have been constructed without any regard whatsoever to the local soil and hydrological conditions with, in some in areas, the dump sites being subject to flooding.

About 28% of the total area of PVLROs (about 1,100 Ha) have been surveyed to date in the Near Zone[54] which comprises about 1,200 distinct trenches and mounds, although where these have been radiologically surveyed the soil covering the general area of the sites exceeds the Ukraine contamination levels at which management (decontamination and removal) is required.

SURFACE FLOODING AT THE NEFTEBAZA PVLRO



THE MAIN PVLROS IN THE NEAR ZONE

53 Development of conservation projects for PVLRO within the 30-km Exclusion Zone. Phase 1.3. Completion of characterisation of PVLRO sector Yanov, collation of field and laboratory measurements, compilation of the data. Chernobyl, STC KORO 1993

54 In addition to the unsurveyed PVLROs in the Near Zone, there are PVLROs Chistogalovka and Pripyat that remain unsurveyed.

Radioactive Wastes Inventory – Exclusion Zone:

Over the years there have been a number of attempts to assess the quantities and types of radioactive waste, compiling these into a consistent inventory.[55] The most recent inventory is the painstakingly detailed work of *Dmitri Bugai* (Institute of Geology, National Academy of Science) and colleagues[56] which endeavours, so far as is practicable, to classify the waste in terms of the standards set by International Atomic Energy Agency (IAEA),[57] although there remains some doubts and unresolved issues on whether all of the waste volumes and inventories are even now fully accounted for. In fact, *Emlen Sobotovich* (National Academy of Science) recalled his experience when surveying some of the known trench disposal sites in the early years, noting that the total number of trenches over again had probably not been recorded on the original records, thereby expressing doubt about the accuracy and applicability of both earlier and the latest inventory audits. *Sobotovich* also noted that the original records and record keeping since 1986, had been poor with much being lost during the transition to independence from the Soviets and, indeed, since that time, with the reorganisation of the various government ministries and institutes in the Ukraine itself.

The ultimate objective of *Bugai*'s work is for this latest inventory of the Exclusion Zone wastes is to provide the basis of the extent of retrieval for subsequent processing (sorting and packaging) for incineration, disposal and longer term storage under the CTD *Vector*[58] project based within the Exclusion Zone. However, the *Vector* project is behind schedule still remaining largely at construction stage, with the first of three radioactive waste above-ground storage facilities currently completing its foundation works the project seems to be about 4 years behind schedule.[59]

As a baseline reference *Bugai* cites an earlier assessment of the Exclusion Zone inventory giving total throughputs of various wastes streams at *Vector* to be, if achieved, impressive as shown by the schematic diagram of APPENDIX I:[60]

These *Vector* throughput projections do not include the volumes arising from other dumps, if and when further dumps are discovered in the Exclusion Zone, for waste dumps and contaminated soils outside the Exclusion Zone and, importantly, soil cover and subsoil that exceeds the present free release (radio)activity levels. If all of these sources are taken into account then the total volume of waste arisings exceeds 21,000,000m^3 being so large as not to be feasible for remediation.

EXTENT OF WORK AT VECTOR SITE 2004

Discounting the 21,000,000m^3 and referring to the above *Vector* throughput diagram of APPENDIX I, the volume reduction target of

55 For example ISTC Shelter (1998a). Inventory taking, summarization, and analysis of data on types and volumes of radioactive material, concentrated at the Industrial Zone of the Shelter. Task 1. Project No. B7-5200/97/000077/MAR/C3. ISTC "Shelter", Marchenko V I, Doroshenko V I (1997) - Radiological State of the Exclusion Zone. Bulletin of ecological state of the Exclusion Zone. Volume 10, 1997, pp4-13, NIPIPromtechnologii (1992). Research report: Study of radwaste disposal sites, development of technologies and measures to localise and redispose the wastes, implementation of radiological and hydrogeological monitoring in the area of disposal and adjacent territories, Chernobyl NPP Archive.№A-01.10-92ЧНИПС. Moscow- Chernobyl (in Russian), TACIS (1995) Management of Radioactive Waste in Dumps in the Chernobyl Exclusion Area. TACIS UR/029.

56 DG Environment Project N° B7-5350/99/51983/MAR/C2, *Review and Analysis of Solid Long-lived and High Level Radioactive Waste arising at the Chernobyl Nuclear Power Plant and the Restricted Zone*, Antropov, V. M.. Bugai, D A, Dutton, L. M. C. Gerchikov, M. Y. Kennett, E. J. Ledenev, A. I. Novikov, A. A. Rudko, V. Ziegenhagen J

57 IAEA (1985). *Acceptance Criteria for Disposal of Radioactive Wastes in Shallow Ground and Rock Cavities*. IAEA Safety Series No 71, 1985., IAEA (1990). *Qualitative Acceptance Criteria for Radioactive Wastes to be Disposed of in Deep Geological Formations.* IAEA-TECDOC-560. IAEA (1991). *Conditioning of Alpha Bearing Wastes*, Technical Report Series N° 326, IAEA, 1991, IAEA (1994a). *Classification of radioactive waste*. *A safety guide.* Safety series No 111-G-1.1, IAEA (1994b). *Siting of near surface disposal facilities.* Safety Series No. 111-G-3.1, IAEA (1996). *Requirements and Methods for Low and Intermediate Level Waste Package Acceptability*. IAEA-TECHDOC-864. IAEA, IAEA (1999). *Near surface disposal of radioactive waste. Requirements. Safety Standards Series* No WS-R-1

58 Vector – Industrial Complex, Treatment and Disposal Facility (CDC) which is a design and build project contracted to the German group RWE GmbH at a cost of about €50M for the first phase 3 or 4 interim stores, for the original Vector site selection see *Site Selection for Radwaste Disposal in Ukraine*, Final Report, TACIS U 4.02/93 Contract 95-1118-WW 93.06/02 02/B006, CASSIOPEE, 1996.

59 *Comprehensive Programme for Radioactive Waste Management,* approved by the Ukrainian Cabinet of Ministers Decree N° 480 of April 29, 1996, amended by decree No.542 of April 4, 1999

60 The two 'untreatable' entries on both sides of the diagram may be a double entry – see Report on NNC contract C6063/F4695 *Review and Analysis of Solid Long-lived and High Level Radioactive Waste arising at the Chernobyl Nuclear Power Plant and the Restricted Zone Treatment and Disposal of Radwastes Vector Complex*, Novikov A A (2000)

achieving a reduction of 455,900m^3 from a total input of 1,510,500m^3, particularly the assumption of compaction down by eightfold including for packaging and shield containers, seems overly ambitious. Even if these overall compaction and over-packaging rates are accepted, the present RW1, RW2 and RW3 single store projected capacities of 18,000, 18,000 and 13,000m^3 respectively, will require 27 RW1, 40 RW2 and 25 RW3 to deal with the projected waste remediation programme.

Revised Inventory & Waste Recovery and Prioritisation: The most recent inventory compilation prioritises the management of the wastes into three categories derived from an amalgam of factors centring around the IAEA waste classification system,[61] although there is considerable leeway provided, although not quantified, in account of flooding, the practicality of in situ remediation, and so on.

Essentially, the prioritisation classification system rationale is as follows (see APPENDIX I for a diagrammatic explanation):

TABLE 8 WASTE PRIORITISATION CLASSIFICATION

CLASSIFICATION	CONDITION
A	Retrieval is required as soon as possible following the completion of remedial option studies and detailed safety assessments.
B	Retrieval is required prior to the termination of institutional control. Storage is only possible for as long as conditions are considered safe. A detailed risk assessment of the site and remedial option analyses are required.
C	Further study of the radiological risk from the site and remedial option analyses are needed to determine whether waste retrieval is required. Waste disposal at the site may be possible following remediation, providing the conditions comply with international and Ukrainian requirements for near surface disposal.

The application of these criteria results in a considerable redistribution and reduction in the amount of radioactive waste qualifying for the *Vector* management facility. The most recent Exclusion Zone assessment allocates the waste streams and locations (dumps, etc) to these priorities:

TABLE 9 WASTE PRIORITISATION DESIGNATION

SITE	TYPE OF DISPOSAL	% VOLUME - CATEGORY		
		A	B	C
Industrial Zone	Man-made soil layers	100		

61 At this time the Ukraine does not seemed to have fully developed a radioactive waste categorisation system that is compliance with the IAEA standards and the standards and good practices that exist in the Ukraine differ in derivation from the generally accepted IAEA norm. Essentially, the Ukrainian radioactive waste classification system based on dose receipt:[61]

WASTE TYPE	EXPOSURE IN 300 Y mSv/year	EXEMPTION POSSIBLE IN 300 YEARS	ACCEPTABLE DISPOSAL MODE IN 300 YEARS
Short-Lived	<1	Ultimate - Limited	Surface & Near Surface
Agreed with Regulator	>1 <50	Limited is Permitted	Case-by-Case
Long-Lived	>50	Not Considered	No Surface/Shallow Disposal

although the Ukrainian system is bolstered by additional limits such as the acceptance criteria for wastes going to shallow trench disposal in terms of a dose constraint at 0.04mSv/y during the period of institutional control and 0.01mSv/y thereafter.[61] The Ukraine seems to continue with the former Soviet system of free release limits of 10Bq/g for all radio-emitters and 0.37Bq/g for alpha emitters.[61] This compares with the IAEA standard of:

WASTE CLASS	TYPICAL CHARACTERISTICS	DOSE CONSTRAINTS
Exempt waste	Activity levels at or below clearance levels which are based on an annual dose to members of the public of less than 0.01mSv	
LLW & ILW (LILW)	Activity levels above clearance levels for exempt waste and thermal power below about 2kW/m^3	
Short-lived	Restricted long-lived radionuclide concentrations (limitation of long-lived alpha emitting radioisotopes to 4000Bq/g in individual waste packages and to an overall average of 400Bq/g per waste package)	Near-surface disposal with ICRP risk constraint for members of public at 0.3mSv/y
Long-lived	Long-lived radionuclide concentrations exceeding limitations for short lived waste	
HLW	Thermal power above about 2kW/m^3 and long-lived radionuclide concentrations exceeding limitations for short-lived waste	

In both dose constraint and specific activity respects, the Ukrainian standards are more stringent that IAEA and ICRP although, that said, the radioactive wastes disposal sites and dumps in the exclusion zone and in the contaminated territories are mainly non-compliant with either standard. Thus, it might be considered that compliance with the Ukraine's regulatory framework for the radiological management and disposal of radioactive waste can only apply to future holding and disposal facilities.

PZRO Podlesny	Fuel, Graphite, Core		100	
PZRO Buryakovka	Trenches		0.03	99.97
	Contam machinery		100	
PZRO Kompleksny	Engineered dump	100		
PVLRO Staraya Stroybaza	Waste dumps, top soil	29		70.7
PVLRO Neftebaza	Waste dumps, top soil			100
PVLRO Ryzhy Les	Waste dumps, top soil	0.5		99.5
	Waste dumps, top soil			100
PVLRO Stantziya Yanov	Waste dumps, top soil			100
PVLRO Peschannoe Plato	Waste dumps, top soil			100
PVLRO Stantziya Semikhody	Waste dumps, top soil			100
PVLRO Novaya Stroybaza	Waste dumps, top soil			100
PVLRO Kopachi	Waste dumps, top soil			100
PVLRO Pripyat	Waste dumps, top soil			100
PVLRO Chistogalovka	Waste dumps, top soil			100
Soils	Top soil			100
Unauthorised dumps	Various	100		
Rassoha 1 & 2	Contam machinery		100	
	PRIORITY	**A** **AS SOON AS POSSIBLE**	**B** **EVENTUAL RETRIEVAL**	**C** **REQUIRES RE-ASSESSMENT**
LONG LL-LILW RW3 STORE	m^3	**8,330**	**4,100**	-
SHORT LL-LILW RW1/2 STORE	m^3	**~600,000**	**~9,000**	-
TOTAL FOR ACTION AT VECTOR	m^3	**~608,500** **1 RW3 + 34 RW1/2** **LESS INCINERATION**	**~13,000** **1 RW3 + 1 RW1/2** **LESS INCINERATION**	-

This latest forecast of the radioactive waste transfers to the *Vector* CTD facility represents a considerable reduction to the previous estimate for specific management modes at the CTD:

TABLE 10 REDUCING WASTE VOLUMES VIA PRIORITISATION

		INCINERATION	COMPACTION	OTHER
PREVIOUS ESTIMATE	**TOTAL** m^3	400,000	35,000	1,500,000
LATEST ASSESSMENT (2000)	**TOTAL** m^3	7,500	27,000	585,000

There are, however, a number of uncertainties and omissions relating to this latest assessment and, particularly, how this relates to future *Vector* operations, essentially:

Setting of Priority Waste Streams: It is not absolutely clear how the various waste streams were actually prioritised into the classifications of A, B and C. Although a comprehensive range of parameters of the priority classification is identified, just how these are factored into the process is not explained.

The suggestion is that the ICRP dose constraint of 0.3mSv/y dominates the classification order but, if this was the case, then very much more waste would be classification '**A**' because this dose constraint is readily exceeded by continuous presence of a human receptor in the exclusion zone and large sectors of the contaminated territories.

Means of Waste Recovery & Worker Dose: The role of the CTD is receiving wastes that have been, assumedly at the site of retrieval, partly processed and suitably packaged for safe transportation to the *Vector* site.

Obviously retrieving the waste at the individual sites will require specialised handling equipment customised to the locality and type of dump. Working certain of the sites will require dust suppression measures, at others groundwater pumping and treatment services will be essential, and those engaged in the recovery activities will require on-site isolation and decontamination amenities. Once the methodology has been established for each particular waste stream under consideration for recovery then, and only then, will it be possible to formulate a reliable forecast of the individual and collective doses of the individuals involved.

Recovery and remediation work dose forecasts do not seem to have been completed and taken into account at the prioritisation stage (above), nor has this essential work been undertaken since the completion of the latest inventory (2000). In other words, it is not at all clear how a reliable prioritisation classification of the dump sites and wastes streams could have been arrived at in the absence of dose forecasts.

Podlesny High-Level Waste: The high and long-lived wastes held in the Podlensy A and B vaults, known to contain possibly upwards of 100 tonnes of reactor fuel, are considered not to be suitable for receipt into the CTD facility. However, the contents of the Podlesny dump score moderately '**B**' on the priority scale even though a cursory inspection of this site suggests that both filled vaults are in poor structural condition and have been little maintained over the years.[62] There are no signs of the works, proposed in 2000, to improve the weatherproofing, additional external bunding, and land works to inhibit surface water run-off into the storage areas[63] have been completed or, at least, are now at any stage of preparation.

Reactor Decommissioning Wastes: According to *Anatoliy Novikov* (Chief Engineer – Chernobyl Nuclear Power Plant) decommissioning of the now closed down Chernobyl reactor Units 1, 2 and 3 is to be delayed for at least 100 years in accord with the so-called *'Safestore'*[64] so the bulk of the decommissioning wastes, say about 15,000m^3 per reactor unit, are presently omitted from the *Vector* inputs.[65] There are also considerable volumes of liquid (~20,000m^3) and solid radioactive wastes deriving from the operational of the remaining Chernobyl nuclear plants and, currently, a liquid waste treatment plant under construction on the site.

High Level Wastes: Information on the condition and volumes of high level wastes is scant, indeed *Novikov* seemed a little reluctant to provide any great detail on the condition of the HLW stocks (spent fuel) at Chernobyl, although he was genuinely cooperative on all other subjects discussed. Framatome claim that the mechanical condition of the spent fuel assemblies is poor and that it had been misinformed by the Ukraine on this and other aspects critical for its completion of the design of the spent fuel store.[66] *Mykolaichuk* noted that her recent enquiries to Framatome on matters relating to the delays of the spent fuel storage project, received the unexpected response of a demand for fees from Framatome for it to provide the required response.

According to *Shestopalov*, other high level waste issues include the expected receipt of vitrified HLW (about 1,350m^3) awaited from Russia in 2011, spent fuel form the operating nuclear power stations (3,300m^3), Chernobyl stored spent fuel (220m^3)[67] and the fuel fragments and debris held in the Podlesny and, possibly, the other PZRO dumps.

In summary: There is much discussion as to whether a clean-up of all of the contaminated land and trenches is at all practicable (a consideration which, incidentally, was entirely beyond *Bugai*'s brief).[56] The general consensus amongst those participating was that any further significant degree of clean-up was an unobtainable artificial target and, indeed, some ventured to suggest embarking upon another clean-up phase might result in a greater spread of loose contamination.

Vasyl Davydchuk (Institute of Geography) reckoned that the diverse nature soil conditions precluded complete decontamination and he doubted that this was necessary or justified when the strong geo-chemical binding and slow migration of radionuclides were considered; *Sobotovich* considered that other than a continuing program of intrusive management, that is dealing with 'hotspots' here-and-there as these arose was the sensible and pragmatic way to contain the situation providing, that is, sufficient funding and resources were made and continue to be made available; and *Vyacheslav Shestopalov* (Radio-Environmental Centre)[68] much

62 VNIPIET (1991a) *Design for sealing PZRO 'Podlesny'*, 91-2070 and VNIPIET (1991b). *Post-closure safety justification for PZRO Podlesny*, Interim Report. 2118

63 Report on NNC contract C6063/F4695 *Review and Analysis of Solid Long-lived and High Level Radioactive Waste arising at the Chernobyl Nuclear Power Plant and the Restricted Zone*, Summary of information on PZRO Podlesny, Antropov V M, Ledenev A I, Ovcharov P A, Budai D A (ed) (2000b).

64 The term *'Safestore'* may have been adopted from a now-abandoned UK decommissioning strategy for its Magnox graphite moderated reactors. This is likely to have arisen from the UK Department of Trade and Industry assistance programmes (NSP 012) which was to *'To assist Chernobyl Nuclear Power Plant justify its long term decommissioning strategy by training Ukraine staff in how to understand and apply engineering substantiation techniques to assess equipment, plant and facilities that will be required during a period of care and surveillance of the site.'* The Chernobyl *Safestore* involves a delay to final dismantling of the rector cores for 100 years whereas in the UK, Japan and Italy where there are the Magnox graphite moderated nuclear power stations, the decommissioning periods are 25, 17 and 14 years respectively

65 Similarly the decommissioning wastes from Ukraine other 13 light water reactors, although each smaller in waste volume that the graphite moderated RBMK, are also excluded from the Vector quantities.

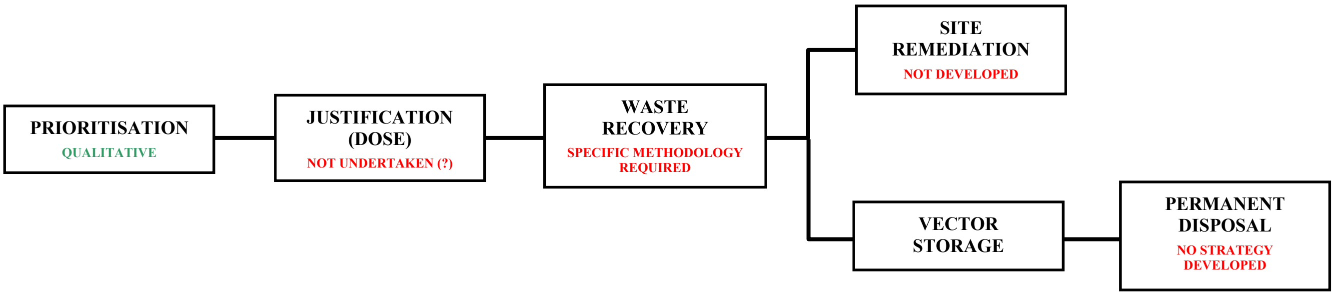
66 Nucleonics Week, September 15, 2005, 'Ukrainians say they will ditch Framatome from spent fuel project'.

67 Present State of the Art in the Development of a Geological Radioactive Waste Repository in Ukraine, Shestopalov V, presentation undated, c2004.

68 Voitsekhovich also expressed concern about the uranium tailings of the uranium conversion plants at Zhevti Vody town and other sites of Kirovograd and Dniepropetrovsk regions where, in total, some 42 million tones of uranium tailings and other radioactive wastes were generated and which today are largely uncontained – see *Uranium Mining and Ore Processing in Ukraine and its radioecological effects on to the Dnieper River Water Ecosystem and Human Health,* Voitsekhovitch, O, Soroka, Y, Lavrova T – to be published.

promoted moving directly towards deep disposal of wastes, that is leapfrogging the dose-laden interim storage stage offered at *Vector*. Others, including *Oleg Voitsekhovich* (Head, Department of Radiation Monitoring of Natural Environment), *Mark Zheleznyak* (Institute of Mathematical Machines and Systems Problems), *Oleg Nasvit* (Institute of National Safety) and *Kashparov* all expressed confidence in their respective (and collective) abilities to reliably predict the transfer of radionuclides into and through the groundwater and watercourses,[69,70] so much so that their wealth of knowledge and resourcefulness of modelling were held to be sufficient to maintain ongoing control over the safe management, resources permitting, of the exclusion and contaminated zones of Chernobyl.

Overall the approach to managing, in situ and/or by recovery and remediation, and eventually disposing of the Chernobyl wastes is incomplete with a number of undeveloped and missing elements:



Relating to adherence to the **Principled Approach** introduced earlier, the transfer of radioactive wastes from one dump site to another (*Vector*) will only be satisfied providing that the recovery and remedial dose burden received by the workforce equates to or is lower than that presently being generated by the undisturbed surfaces of the existing waste dumps. Only if this is achievable, which is doubtful, will there result no significant increase in the collective dose within and beyond the perimeter of the Exclusion Zone.

3) DRAINING OF THE COOLING LAGOON (POND)[71]

The cooling lagoon is free standing water area of about 22km^2 located on the right-bank flood plain of the River Pripyat. The lagoon is of about 10m average depth and 5 to 7m above the river level retained behind land terracing and a retaining dike of about 22km length. Leakage and evaporation losses are compensated by continuous pumping from the River Pripyat.

In 1986 the lagoon was contaminated by radioactive fallout, mainly dispersed fuel particles settling on the water surface.[72] In the immediate aftermath of the accident about 5,000m3 of heavily contaminated water from the reactor basement was released to the lagoon and, as decontamination activities got underway in earnest, a massive amount of heavily contaminated soil removed from the nearby sites was dumped into the lagoon. Estimates of the amount of radioactivity in the lagoon range from 2,200 to 13,000TBq and a later survey (1991) for long-lived radionuclides in the sediments gave a total content of 170TBq Cs^{137}, 35TBq Sr^{90} and 0.8TBq $Pu^{239,240}$.

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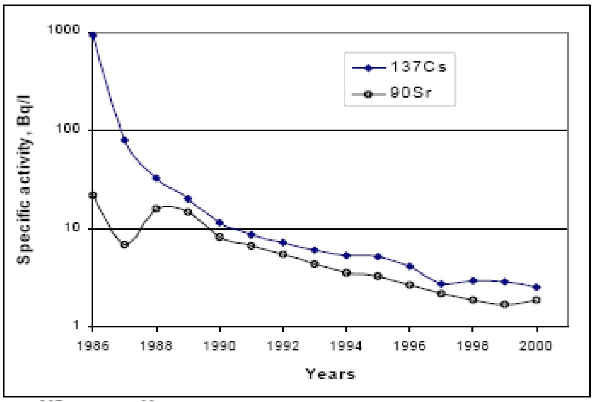
69 Indeed, this has been amply demonstrated by powerful past work by these individuals and others, together with the effectiveness of the physical protection systems so far installed comprising, principally, dikes and pumping on the River Pripyat floodplain, preventing remobilisation of radionuclides, especially Sr^{90}.

70 *Risk from Radionuclide Migration to Groundwater in the Chernobyl 30 km Zone*, Bugai D A, Waters R D, Dzhepo S P, Health Physics Society, 1996 - *^{90}Sr Migration to the Geo-Sphere from a Waste Burial in the Chernobyl Exclusion Zone*, Dewaire L, Bugai D, Grenier C, Kashparov V, Ahamdach N, J Env Radioactivity, 74 2004 – *Radioecological Study of the Chernobyl Cooling Pond and Options for Remediation*, Smith J, Murphy J, Cailes C, Adma C. Voitsekhovitvh O V, Bulgakov A, Konoplev A, Kudelsky A V, Nasvit O I, Belova N, INTAS-200100556, 2005 - *Experimental studies of radionuclide washout from Pripyat floodplain soils in conditions of flooding*, Laptev, G V, Voitsekhovich, O V Proceedings of UHMI, 245, 1993 - *Aquatic countermeasures in the Chernobyl zone*: *Decision support based on field studies and mathematical modelling* Voitsekhovich, Oleg; Zheleznyak, Mark. Washington, D C, US; Sept. 1998.

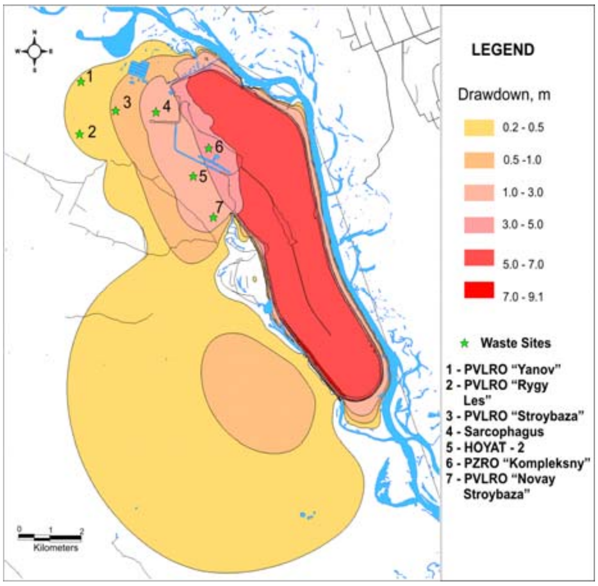
71 To avoid confusion, here the *cooling pond* is referred to as the *cooling lagoon* because this relates to the turbine condenser cooling water mass rather than the reactor spent fuel ponds inside the reactor buildings.

72 *Radioecological Situation in the Cooling Pond of Chornobyl NPP*, Nasvit O

There is a current proposal[73] for the draining of the cooling lagoon, reducing the level of the lagoon water surface overall by about 7m down to the natural level of the River Pripyat. If undertaken by entirely natural means (ie isolating the uplift pumping from the River Pripyat) this drain down is expected to take under normal climatic conditions about 8 years or, if there is an exceptionally dry spell, about 3 years. However, at this time, no decision has been made to proceed with drainage of the lagoon because of the fuel remaining in the reactors of units N° 1 and 3 requires reactor safety systems and cooling to be available and, in addition, the lagoon serves as a source of firefighting water for the Industrial Zone. The reason that fuel is being held in the reactor cores is directly linked to the delays in completion of the Framatome spent fuel dry store, so the lagoon is likely to remain undrained for at least another four to five years until the dry store issues are practicably resolved.[74]



SPECIFIC ACTIVITY LEVELS IN THE LAGOON WATER



GROUNDWATER DRAW-DOWN FROM LAGOON DRAINING

One outcome of draining the lagoon is to reduce the influence of local groundwaters in the area of the devastated Unit N° 4 and the spent fuel store by about 1 to 2m, and in the area of PZRO Kompleksny by 2 to 4m. This would significantly reduce a number of the groundwater migration routes from the PZRO and the Sarcophagus into the River Pripyat. Another but possibly negative outcome is that the contaminated silts and sediments of the lagoon would be exposed and, in dry periods, fuel particles and other radioactive contamination could become resuspended to provide a dose uptake pathway.

The lagoon drainage scheme has been subject to considerable study, particularly the introduction of the hitherto suppressed dose pathway from what will be exposed sediments and silts.

These studies suggest that i) the groundwater dose pathway, ii) external exposure to workers in the exclusion zone to the 20mSv per annum constraint, iii) that airborne resuspension doses from severe typhoon and dried up lagoon bed fires, will all be tolerable for workers in the area should the lagoon drain down proceed. However, there are either doubts and/or further work is required to determine iv) the human uptake (by chance) of a large 'hot' particle resuspended from the exposed sediments and, v) the remains ambiguity over the definition and classification of the sediment as *radioactive waste* or *contaminated material* because, if the latter, then the ICRP intervention dose restraint levels apply. In this final respect, the forecast is that the foodstuffs produced on the dried out bed of the lagoon will continue to result in a 13mSv annual dose in 100 years hence, that is above the current ICRP intervention level of 10mSv/y.

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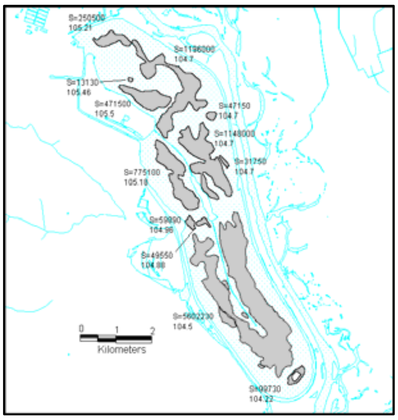
73 European Commission Service Contract N° B7-5230/2000/306958/MAR/C2 *Drawing Up and Evaluating Remediation Strategies for the Chernobyl Cooling Pond*, Buckley M J, Bugai D, Dutton L M C D, Gerchikov M Y, Kashparov V A, Ledenev A, Voitzehovich O, Weiss D, Zheleznyak M C6476/TR/001 September 2002

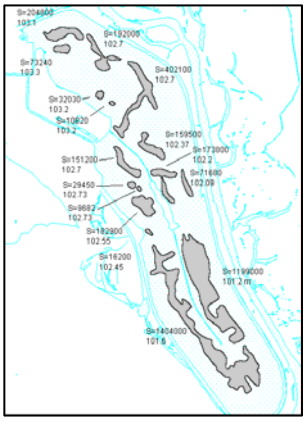
74 Currently the cooling lagoon provides water for the Chernobyl Nuclear Power Plant for both fuel cooling and fire fighting on site. Unless water is provided by alternative means, the current level of water in the Cooling Pond has to be maintained. This requires continued operation and maintenance of the existing pumping system costing ~€630,000 per year. Provision of an alternative water supply for the station and termination of the pumping to support the water level in the Cooling Pond has been estimated to cost about €400,000 in initial investment, and that the annual expenditure in maintaining the lagoon dikes, etc will be reduce ~€200,000. Obviously, with the French spent fuel store likely to be delayed another four to five years before the Unit 1 and 3 can be defuelled, it might now be justified in embarking upon the alternative water supply scheme. It may be that some fuel has been unloaded from the shut down reactors although the tonnages are unknown.

This composite of outcomes and uncertainties for proceeding with the drain down of the lagoon has to be balanced against maintaining the lagoon levels (apart from the cost of maintaining the lagoon) for which 1) a sudden collapse of a section of the lagoon embankment (dike) will be below the 1mSv limit and 2) that members of public outside the Exclusion Zone could exceed the regulatory dose constraint by eating waterfowl that has nested on the Lagoon.

Even when the lagoon is drained down the remaining wet areas will retain the original quantities of contaminated sediments. In fact, these remaining wet areas could finish up with enhanced levels of contaminated sediment if the scheme is adopted to transfer, by a combination of sludge pumping and bulldozing, sediments from the drying areas to the permanently wet areas progressively during the prolonged drain down period. The risk here is twofold: First, during abnormally dry periods banks of concentrated sediment could be exposed for resuspension and windborne dispersion and, second, in future years the River Pripyat could change its course, meandering to the west and possibly passing through the areas of high contaminated sediments. In effect, and irrespective of the proposed sludge pumping, there is no *'Do Nothing'* option because both the drained down area of the lagoon bed and the River Pripyat will require some element of institutional control if these potential transfer pathways of excessive levels of radioactivity into the Dnieper basin are to be blocked.

The recent and, indeed, most comprehensive study of the options for the future of cooling lagoon identifies and scores a number of options for the future of the cooling lagoon against each of three *timeframes*. For the *post-institutional control timeframe*, the option weighting is:





REMAINING WET AREAS IN THE DRAINED DOWN LAGOON FOR NORMAL AND DRY PERIODS

TABLE 11 POST-INSTITUTIONAL CONTROL COOLING LAGOON OPTIONS

		OPTIONS							
		KEEP OR DRAIN LAGOON		DEAL WITH DRAINED DOWN LAGOON SEDIMENTS				REMEDIATION ACTION	
		MAINTAIN LAGOON	STOP PUMPS DO NOTHING NATURAL DRAINDOWN	PLANT OUT DRIED OUT LAGOON BED	SPRAY DRIED OUT LAGOON BED WITH DUST SUPPRESSANT	SLUDGE PUMP ETC SEDIMENTS FROM DRYING OUT AREAS	CAP SEDIMENTS WITH SAND RECOVERED FROM PRIPYAT FLOOD PLAIN	REMEDIATION REMOVE MOST CONTAMINATED SEDIMENTS TO REPOSITORY	COMPLETE REMEDIATION REMOVE ALL CONTAMINANTS TO REPOSITORY
A	PUBLIC DOSE – NORMAL	Not feasible	2	4	4	4	5	5	5
B	PUBLIC DOSE – ACCIDENT	Not feasible	4	4	1	1	5	5	5
C	WORKER DOSE – NORMAL	Not feasible	5	5	5	5	5	5	5
D	WORKER DOSE – ACCIDENT	Not feasible	5	5	5	5	5	5	5
E	IMPLEMENTER DOSE – N ORMAL	Not feasible	5	5	5	5	5	5	4
F	IMPLEMENTER DOSE – ACCIDENT	Not feasible	5	5	5	5	5	5	4
G	ENVIRONMENTAL IMPACT	Not feasible	4	4	4	4	4	3	1
H	EASE OF IMPLEMENTATION	0	5	4	4	4	4	4	0
I	SUSTAINABILITY	0	5	5	5	5	5	5	5
J	UKR REGULATORY REQUIREMENTS	5	3 Uncertain - relevant Ukrainian regulations are being reviewed						
K	COST	4	5	3 significant uncertainty in the current estimates					0

Which indicates, albeit by this somewhat qualitative[75] approach, that the *'Do Nothing'* option is preferred. However, as noted previously, there remains uncertainty about the possible contribution of 'hot particles' which could have significant bearing upon the radiation dose attributes A to F. Also, an assessment is required of the need undertake remediation action to limit the detrimental contribution of hot particles, particularly in respect to the sustainability justification (which seems to be rather weakly scored in the above table).

75 The method of weighting the multi-attribute analysis seems somewhat crude and out of kilter with the very detailed and meaningful analysis of the remainder of this work

In summary: In view of its importance in providing a means of bypassing the ***Principled Approach*** it is surprising that the matter of the cooling lagoon has not be addressed earlier but, that said, the present body of work is strong and provides a compelling case for future management of a drained-down lagoon. This is because draining down the lagoon removes the risks of embankment failure and a future change in the course of the River Pripyat. However, in both these areas further work is required before the final future management option for the cooling lagoon can be determined. Because of the growing uncertainties about the final, if ever, commissioning of the Framatome spent fuel store the scheme to provide an alternative supply of water for emergency cooling and firefighting might be considered justified.

Sobotovich considered that dealing with the lagoon to be a most pressing problem, he shrewdly identified it to have been the missing link in the scientific community's understanding and management of Chernobyl overall, seeing it to be, until it was satisfactorily resolved, the last possible ill-defined pathway for transferring the collective dose to the Ukrainian population beyond the Exclusion Zone. Those who had been actively involved in the lagoon project, *Voitsekhovich*, *Zheleznyak*, *Bugai*, *Nasvi*, *Kashparov* and others, all expressed confidence that their collective knowledge was sufficient to enable the lagoon draining to progress once, that is, the cooling requirement for the remaining two fully fuelled reactors had been overcome. On this point, *Usatenko*'s concern was with the run down state of the remaining reactor safety systems, expressing caution about leaving the fuelled reactors, so to speak, *high and dry* adding wryly that parts of the safety systems had been pilfered, although *Mykolaichuk* refuted this stating that the five full-time regulatory inspectors at the site ensured that all of the Nuclear Regulatory Committee's requirements were in place.

Aspects of *Voitsekhovich*'s recent work are disturbing[76] inasmuch that i) there are continuing fluxes of Sr^{90} and Cs^{137} passing into the River Pripyat even though all of the needed flood plain enclosure dikes have now been completed; ii) there will be an ongoing net increase of Sr^{90} flow into the River Pripyat via groundwater flow over the next 100 years, peaking about 130GBq per year (*Bugai*); and iii) that abnormalities of body shape and organs of fish have been recorded in parts of the Dneiper Basin waters suggesting that the malforming contaminant was moving through the river system, with marked influence developing as late as 2002-2004 from normal levels in 1999-2001 (River Tetrev).

Shestopalov and *Marina Naboka* (Ecological & Hygienic Investigations, Radiological Centre) described the role of '*preferential depression-focussed recharge*' or zones of high permeability that frequent not more than 10% of the Chernobyl area but which account for 60% of the surface water runoff.[77] According to *Shestopalov*, these relief depressions provide for rapid vertical transport of radionuclides which may account for the levels of Cs^{137} that have developed and continue to rise at a depth (80m) below the locality of greater Kiev.

4) EXTERNALLY FUNDED PROJECTS

Much overseas aid has been invested in Chernobyl on a diverse range of projects and for infrastructure support so it is, perhaps, unfair to concentrate on just the few such as the *cause célèbre* of the Framatome spent fuel store.

Framatome Spent Fuel Store: However, it might be that the Framatome project, with all of its shortfalls and the failure to build it to specification and on time (as claimed by many of those participating in this Review) illustrates a weakness of how some the overseas aided projects are being managed in the Ukraine.

Essentially, Framatome undertook to construct and commission, on an EBRD funded design-and-build contract, a dry spent fuel store nearby the Chernobyl reactor site. Each spent fuel assembly is to be delivered to the packaging reception of the new store where is disassembled into the two fuel element components, inserted into capsules which are then packaged into a second stainless steel, multi-capsule storage canister. The store has a capacity for 256 of the multi-capsule canisters or 25,000 fuel elements in total.

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76 The Cooling Pond of the Chernobyl Nuclear Power Plant: A Groundwater Remediation Case History, Bugai, D A, Waters R D, et al, Water Resources Research, V 33 1997

77 *Critical Zones in Geological Environment and their Role in Groundwater Contamination (Experience of Chernobyl)*, Shestopalov V M, Bublias V N et al, Am Soc Ag & Biological Engineers, Proc 2nd Int Symp, Honolulu 2001

The original contract with Framatome was signed in late 1999 and commenced in 2000 with the time to completion being two and one half years to match in with the post-closure operations of the first stages of decommissioning the reactors. However, the Framatome project is much overdue and has much overspent, being reckoned now to be another 5 years to completion, making it 7 or 8 years late, at a projected overspend of €100M or thereabouts on the original capital of first €70M (which increased to €90M then €120M). Reasons for this sorry state of affairs are allegedly numerous and mostly anecdotal: From the Ukrainian perspective these reasons range from the wrong railway gauge being installed, foundation subsidence, faulty concrete, insufficient space to manipulate the fuel assemblies at receipt into the store and so on and so forth. Whereas the French retort that much of the cause of the delays and overspend result from misinformation from the Ukrainians about the quality and condition of the spent fuel in the Chernobyl ponds and central store.

Whatever and from whichever perspective, the delay in commissioning means that both reactors 1 and 3, although shut down, remain fully fuelled which itself requires a number of the front line safety and cooling systems to be maintained operational and, for emergency cooling should it be required, the cooling lagoon has to be kept pumped to its artificial level of 7 to 10m above the River Pripyat and, of course, this ongoing attendance to the Chernobyl reactors commits personnel to working in the Exclusion Zone (about 2000 out of the 7,500). The failure of the French to build the spent fuel store to specification and on time has been and continues to be costly to the Ukraine in maintaining the Chernobyl nuclear power plants safe. For example, just to hold the cooling lagoon level by pumping and to preserve the structural stability of the dikes and earth embankments incurs an annual cost of around €630,000 in addition to the cost, time and trouble that these delays in the spent fuel management route and decommissioning of the three remaining reactors at Chernobyl.

An important caveat of overseas funded works seems to be that these large capital projects, such as the Framatome spent fuel store and the proposed sarcophagus arch, are design-approved by authorities outside the Ukraine and, apparently, without that much involvement of the Ukrainian nuclear safety regulator. This is exampled by the distancing of the State Nuclear Regulatory Committee from detailed involvement in the Framatome spent fuel store, else why would *Mykolaichuk* have to make enquiries only to be rebuffed by Framatome. Another example is that the nuclear safety case for the prestigious sarcophagus arch proposal seems to have specified not by *Mykolaichuk*'s state committee but by the banker underwriting the costs and who has engaged retired nuclear safety personnel, mostly drawn out of retirement in the donor countries, for this purpose.

Perhaps the most telling comments on certain of these overseas projects are the asides coming from the Ukrainians themselves, although not necessarily from any of the individuals cooperating with this Review:

> " . . . *We [the Ukranian input to a TACIS funded project] did more than 90% of the work, for which received less than 10% of the money. . .* "

although quite to the contrary and equally, there was praise for TACIS projects in that ". . .*usually the money was split 50-50% between Ukranian and Western teams and that it was a fair and transparent fund distribution . . . and the Western partners always provided important and adequate technical inputs.*"

Much of the vitriol is reserved for the most recent projects:

> "*. . . The French spent fuel store is a disgrace, it was built so that we could close the remaining Chernobyl reactors down – we closed the reactors down, completing what was our side of the bargain, but because the French failed on their side we now have another nuclear safety issue of having the closed down reactors full of fuel . . .* "

so much so that no Ukraine national seemed prepared to provide even an inkling of how this project might eventually be completed to advantage.

Of the latest and perhaps most grandiose of all the donor funded projects the sarcophagus cover, there was little confidence

> " *. . . The new sarcophagus cover, the Arch, in neither necessary nor wanted – it is an adventurous piece of engineering architecture which serves to boost the prestige of the donor countries but which, will leave us in the Ukraine with responsibility to meet the untold costs of its upkeep if, that is unlike the French spent fuel store, it is ever finished . . .*"

Large and ASSOCIATES

other than, irrespective of its technical purpose and functional success, it would be " . . *in the perception of the public a good thing and a moral booster* . . . ", there was little support forthcoming for the proposed sarcophagus cover.

Of course not all is bad about joint ventures but all is not well with this system which was, after all, initially superimposed upon the Ukraine to avoid a further radiological disaster spreading to the West. Although presented then as generous altruism from the international community to the people of the Ukraine and its neighbours, the joint venture activities now seem to be so highly commercialised one might drawn into the observation that, as one Ukrainian commentator wryly put it ". . . *the Chernobyl project overall seems to have developed into little more than a money laundering facility for countless millions of Euro* . . .". but, again, some stoutly defend the management of international Chernobyl funding, although acknowledging weaknesses and difficulties with the system they would not accept the implications of criminal corruption being rife as suggested by the term *'money laundering'* .

There is no doubt that a few of these projects have sullied the reputation of the donor schemes overall but, that said and indeed without that much evidence of its veracity, overall it is an unfair and, perhaps, ungrateful exaggeration of the assistance provided by overseas donors and the high degree of cooperation and positive work that has been achieved by these partnerships.

Finally, if it takes a politician to spot a failing political strategy then *Rudenko* in his capacity as Chairman of the Chernobyl Parliamentary Committee, grasped the nettle by describing what he considered to be Ukraine's political weaknesses noting that government

> *". . . gave great attention to and spend a lot of money on social protection, but gives very little on technical aspects of the problem . . ."*

adding that

> *" . . .we do not have time to take this matter seriously – we have elections all the time, very few if any civil servants who would have been working on this problem continuously for at least three years because, under the conditions when the minister is replaced every six months along with his staff, it is very difficult to maintain continuity and effort, and thus arrive at any solution of the problem. . . ."*

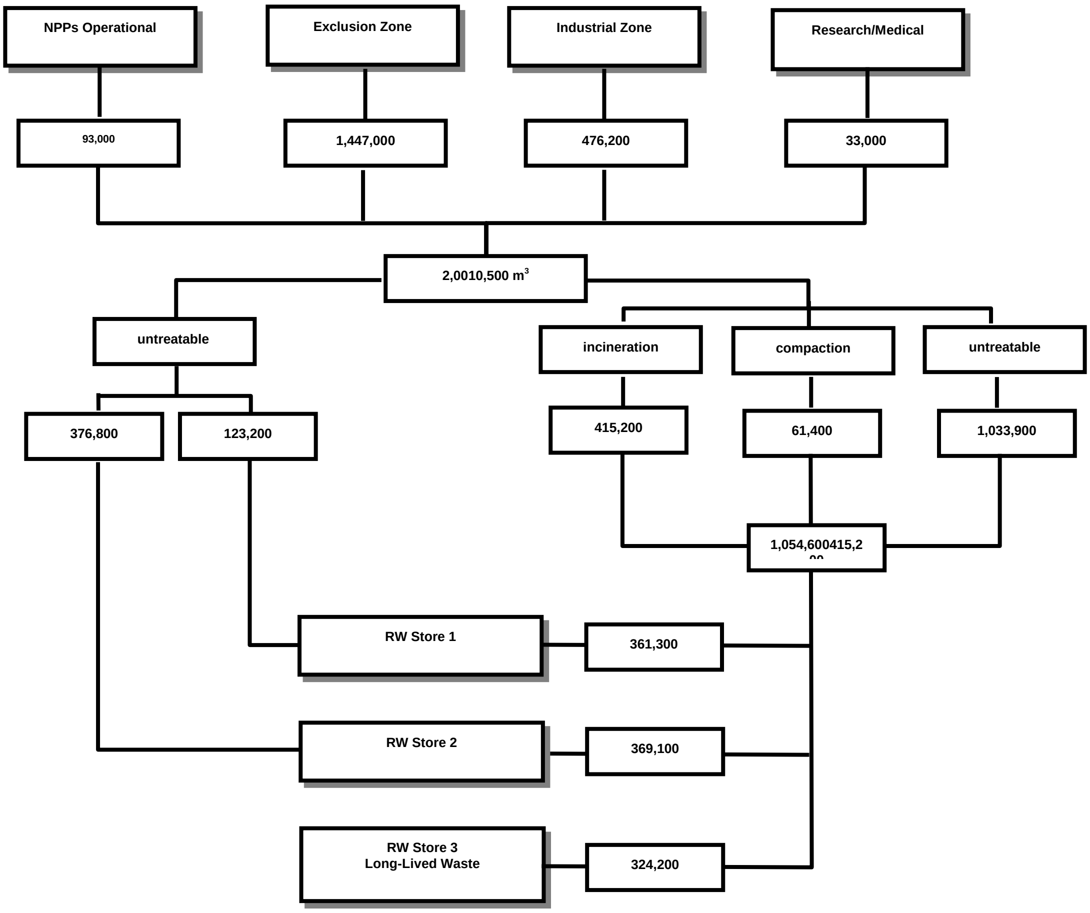
Indeed, one might muse such is the sacrifice of the *sufferers of Chernobyl* to the new democracy.

JOHN H LARGE
LARGE & ASSOCIATES

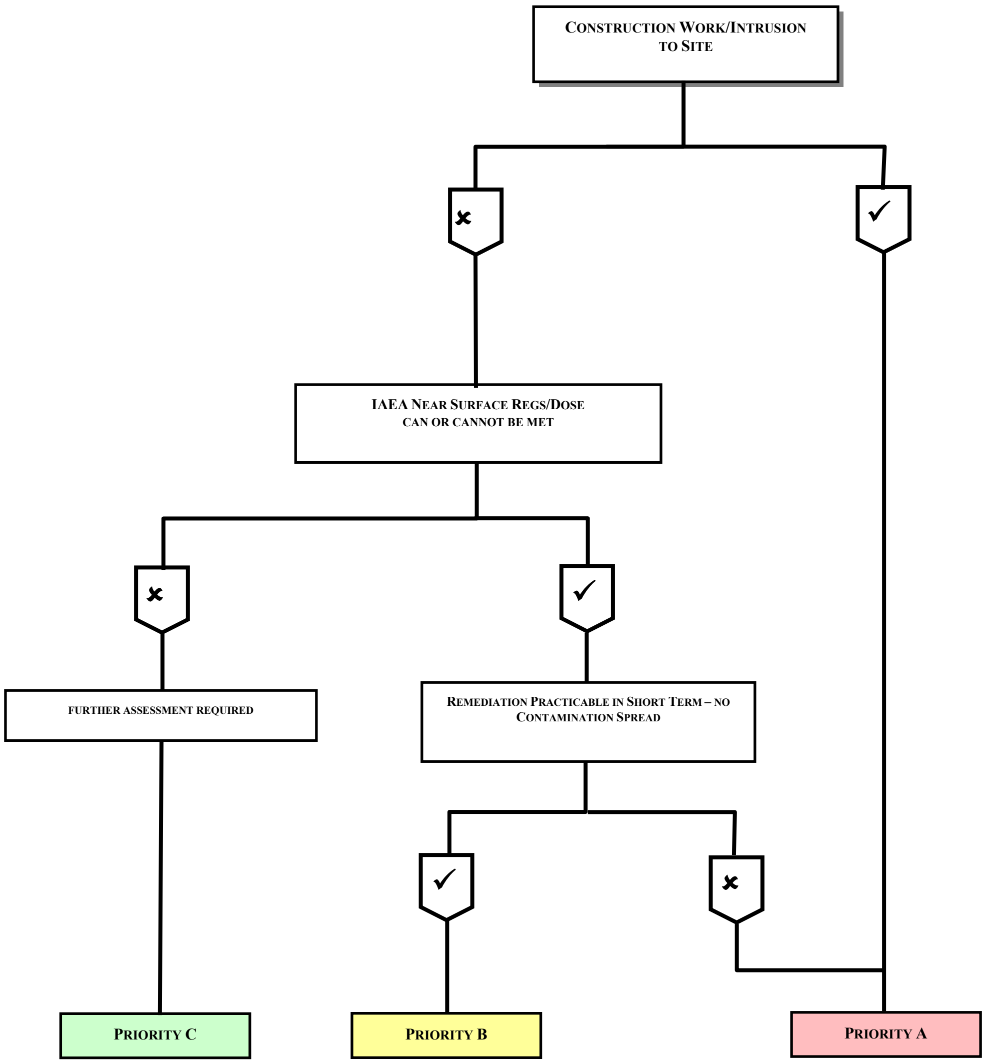
Large and ASSOCIATES

APPENDIX I

WASTE PRIORITISATION CLASSIFICATION SCHEME & VECTOR THROUGHPUTS



FIRST WASTE THROUGHPUT PROJECTIONS FOR *VECTOR*



WASTE PRIORITISATION CLASSIFICATION SCHEME

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APPENDIX II

INDIVIDUALS MET FOR DISCUSSIONS IN KIEV AND CHERNOBYL DURING THE WEEK COMMENCING 25 FEBRUARY – 5 MARCH, 2006

	Vasyl Davydchuk	Institute of Geography, National Academy of Sciences
	Academician Emlen Sobotovich	Institute Environmental Geochemistry, National Academy of Sciences
	Yuriy Andreev	NGO “Souz Chernobyl of Ukraine”
	Chernobyl Exclusion Zone	
	Vladimir Usatenko	Expert of National Committee of Radio Protection
	Anatoliy Novikov	Chief Engineer – Chernobyl Nuclear Power Plant
	Oleg Voitsekhovich	Director Centre for Monitoring Studies and Environmental Technologies, Head of Environment Radiation Monitoring Department of the Ukrainian Research Hydrometeorological Institute, National Academy of Sciences
	Dmitri Bugai	Institute of Geology, National Academy of Sciences
	Oleg Nasvit	Institute of the National Safety
	Valeriy Kashparov	Director of the Ukrainian Institute of Agriculture Radiology
	Yuriy Urbanskiy	NGO ”NECU” - “Nature Voise”
	Anna Golubovska-Onisimova	NGO “MAMA-86”
	Tetyana Murza	NGO “Chornobyl 20”
	Sergey Fedorinchik	NGO “Zeleniy Svit”
	Natalia Vishnevskaya	
	Academician Vyacheslav Shestopalov	Radio Environmental Center, National Academy of Sciences
	Marina Naboka	Ukraine Radioecological Center, National Academy of Sciences
	Gennadiy Rudenko	Chairman of the Committee on the Envyronmenatal Policy Natural Managment and Chernobyl Catastrophe
	Mark Zheleznyak	Head of the Department of the Institute of Mathematical Machine and System Problems, National Academy of Sciences
	Olena Mykolaichuk	Chairmen, Regulatory Nuclear Committee
	Academician Victor Bariakhtar	National Academy of Sciences
	Volodymyr Tykhyy	Institute of Mathematics Machines and Systems