溶解,或者发生火灾，那么就地处置的废弃物将会带来潜在的危险。核设施退役场所一旦发生火灾或者洪涝灾害，也将会向空气、土壤和地下水中释放放射性物质，构成一定的风险（如废物处理或存储场所）。如果水渗入处理场中,放射性同位素可被溶解，并进入水系。但退役过程中产生的大多数同位素难以溶解或半衰期较短。

核设施退役时大量释放放射性物质的风险低于反应堆运行期。然而,低剂量的辐射可通过空气、地表和地下水进行近距离传播。精心规划、采取隔离、局部和周边监控措施,可以防止放射性物质的释放。

对于已经运行了几十年的核设施，在其退役的过程中可能会发生意想不到的情况。乏燃料残骸常存在于研究堆和其他除发电堆以外的反应堆中，但发电堆中也可能意外出现乏燃料。有时，直到设备拆除之后，才有可能监测到反应堆下还存在放射性污染，所幸的是底层地下水没有受到污染。尽管这些仅仅是个例，但如若发生，将会大大增加安全处理的费用。例如，当美国康涅狄格州的洋基核电站被拆除时（图11），工作人员发现33000立方米的土壤因受核辐射污染需要清理处置（EPRI 2008）。退役中的开采或其他活动可能会增加放射性污染从土壤转移到地表水或地下水的风险。

在运行期间,核电站中反应堆芯周围的组件具有放射性。核设施退役工作中，如需使工作人员遭受的辐照量尽可能低于可接受水平（即规定的最大量），则需要制定大量的工作规划、进行管理和物理控制,穿防护服,并设计一个完备的监测方案。应用机器人和其他远程技术，能够进一步降低人员因近距离处理放射性废物而接收的辐射量。迄今为止,核设施退役时的辐射暴露水平一直处于规定以下。

因事故遭到损坏的核电站，如切尔诺贝利和福岛核电站，其处理方式不同于那些正常退役的核电站。当污染物质需要远距离运输时,应采取应急处理措施阻止其进一步扩散。一旦放射性物质停止泄露,核电站进入稳定状态,核燃料就必须从可能已有毁坏的反应堆中移除。之后，核设施退役工作和核电站及周边地区的清理工作才可以展开。

图11：康涅狄格州的洋基核电站顺利退役并且已成功恢复成绿地。照片显示了核电站在每一阶段取得的进步：运行初期(2003年6月),运行中(2006年1月)和退役后(2007年9月)。
图片来源: Connecticut Atomic Power Company

纵观历史,核活动（包括核设施退役）的环境影响分析主要聚焦在对人类健康的威胁上。1991年,国际放射防护委员会（ICRP）提出,“环境控制的标准是在一种理想的程度下，既保护人类也不影响其它物种的生存。”最近该委员会又指出该观点有些狭隘，重新提出我们不能基于为人类设定的标准，来判断退役和其他活动是否给生物多样性和生态系统带来威胁（Higley等 2004）。

自2007年以来，国际放射防护委员会为12种动植物，从鸭到鹿，从海藻到蚯蚓，建立了辐射剂量参考标准（ICRP 2007）。参考标准并不是一种限制,而是作为进一步研究的起点（Andersson 等 2009），其目的是“预防或减少辐射效应对生物多样性、物种保护、自然栖息地良好环境的影响”而不是消除对某种生物造成的全部威胁（ICRP 2007）。

经验总结

核设施的退役不仅仅是简单的拆除，而是对组成核反应堆的受污染的、复杂的核设施系统的解构过程。这些设施包括反应堆压力容器,蒸汽发生器,水泵和贮存池,以及包括由数千米管道组成的配套系统——甚至连同大量的建筑材料。这种解构过程和建立核设施一样，需要投入相当多的时间和资金,进行详细规划和精确控制,此外，它还需要同样高水平的专业知识和监管控制。

全球核设施的退役技术仍在不断成熟,快速发展。但是专业知识的掌握程度有很大的地域差异。少数国家已有几十年的经验，而对另一些国家,还未曾有这样的专业技能。关键知识也已掌握,但是这些经验教训尚未体现在国际标准中。为加强各国经验交流，国际原子能机构（IAEA）建立了一个国际核设施退役网络（IAEA 2012b）。

在可预见的将来,很多核设施将会退役,而确保核设施退役的经验能够及时地在全球范围内应用是至关重要的.国际机构、核设施的所有者和工作人员更需从承包商获得有效信息。国际和国内法律也有必要规定相关的信息共享，包括从失误中获得的专业知识,因为这通常是最重要的经验。而“商业机密”不应该成为阻碍这方面信息共享的托词。

核工业需要不断创新，采取新方法和技术,推动核设施退役过程的“智能化”，即更安全、更快捷、更廉价。此外,为了更好地面对核设施退役带来的挑战，我们需要制定政策和措施来支持退役进程的不断完善。科学研究可以更好地为核设施退役奠定知识和科学基础。

未来十年内，耗资数百亿美元的核设施退役活动将快速增长。核设施退役技术的发展对于核能发电的前景至关重要. 但我们仍面临多方面的挑战,不仅是技术上的,还包括政治、经济、社会和环境上的挑战。

经验表明,核设施退役可以通过安全、及时和高效的方式来进行。同时，核电站的设计一开始就应考虑安全高效退役、安全运行、事故防范及其对公众健康和环境的潜在威胁。由于第一代核电站在设计时并没有考虑到退役问题,产生了大量本可以避免的资本投资。如今，许多运营商和监管机构在设计新的核电站时均考虑了这些问题,从而更益于简化退役过程。

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