V Rehabilitation of the Environment.

1. Rehabilitation of waters

1.1. Types of waters and water contaminants

(Haidley Smith 19

Oil floating on water can be restrained by booms and pumped off but nearly all other pollutants likely to get into water cannot be removed in toto within the constraints of time and the economy. Water supply systems, which take an essentially constant flow from a river, can be modified to remove some pollutants but the normal response is to close the intake pipe until the "plug" of pollutant has passed. Thus both for air and flowing water the only rehabilitation possible or necessary is to wait until the pollutant goes away.

A pollutant in flowing air or water always diluted by which in many cases rapidly reduces the concentration below dangerous levels. However, some pollutants are toxic when present at concentrations of only 10^{-9} which means that one ton of material must be diluted in more than one cubic kilometer before it becomes acceptable. Cubic kilometers of air are usually available but the flow of most rivers is insufficient to provide the required volume for dilution in a reasonable time. Furthermore, even if diluted, some chemicals are adsorbed on surfaces at high local concentrations and some may even be concentrated in food chains.

Since it is essentially impossible to remove pollutants from flowing water, efforts should be made to avoid washing pollutants into surface waters, no matter how effective such action might be in removing the immediate danger during the emergency phase.

In some cases a plug of contaminant has been traced as it moves down an aquifer and wells have been closed as the polluted water approaches to be reopened years later when it has passed.

Ground-water

Water that flow underground provides more than half of the good water used for potable purposes. Most underground aquifers are filtered very efficiently in their natural formations so that they are free from suspended matter including infectious agents. Bacteria, for example, may be removed by flow through a few meters good soil. Many dissolved substances are adsorbed on soil surfaces and precipitated or neutralized. However, some salts and some small organic molecules travel essentially as fast as the ground-water they are dissolved in. Examples of such pollutants are sodium salts of chloride, sulfate, nitrate and chromate as well as organic liquids such as gasoline and solvents used for paints and dry-cleaning. Although these solvents are not very soluble in water, a saturated solution of any one of them is far from potable and smells just as bad as the solvent itself.

Ground water flows very slowly in contrast to surface waters and velocities from meters to kilometers per year are common. Rapidly flowing ground-water in underground channels and caves is seldom purified to any degree by such flow, only slowly moving water has time for the natural purification processes we associate with good ground-water. Because the flow is usually so slow, a considerable time may elapse before pollution is noticed in wells that are only a few hundred meters from a source of contamination.

Nota: La página 106 del documento original se encuentra en mal estado.

CONTROL AND CONTAINMENT OF WATER RESOURCES CONTAMINATED BY CHEMICAL ACCIDENTS

[redacted]

The actions necessary to achieve the rehabilitation of a contaminated water resource divide into two phases. Firstly [redacted] those [redacted] designed to arrest the spread of contaminat[redacted] and secondly [redacted] to remove, [redacted] the contamination [redacted]

2. SPILLS ON THE LAND SURFACE

2.1. Physical barriers

[redacted]. The first action to be taken must be to stop the continuation of discharge whenever possible, by closing valves and stopping pumps [redacted] transferring remaining materials from damaged containers to intact vessels [redacted] and plugging obvious leaks [redacted] Spilled liquids are likely to flow towards drainage channels and the next step is therefore to impound the flow by construction of a barrier (bunding). **Liquids collected in bunded areas or in excavation should be removed by pumping to secure, intact containers as soon as possible.** [redacted] liquid. In some cases the same effect may be achieved by rapid excavation of a pit across the flow path of the spill. Obviously the impounding of liquid behind a bund wall increases the hydraulic gradient through the underlying soils, leading to greater loss by vertical percolation. If the natural soils at the site of spill [redacted]

¶ Actions suggested in the preceeding paragraph must be undertaken during the emergency phase of an acute accident and may be the opposite of what seems to be required to protect life and property. For example washing spilled gasoline off a street in front of a crowded school to prevent fire may be more important than the resulting contamination of the river and off-flavors in its fish.

2.1.2 Soil Removal

The prompt removal of contaminated soil may be appropriate if the contaminant is likely to penetrate rapidly into an important aquifer. On soils of low permeability however the possibility of in-situ biological treatment (Section V 4.5) should be carefully investigated before soil is removed.

.2.2: Surface waters

2.2.1- Pollutant transport paths

Liquids heavier than water sink to the bed of rivers and lakes and may flow along depressions. In the case of streams this is often in the downstream direction, but not inevitably so. In the case of immiscible heavy liquids, for example many halogenated solvents, the liquid mass continues to move until it enters a closed basin of sufficient capacity to contain its volume. [redacted], Slurries eventually settle out but in high energy streams turbulence may progressively resuspend the slurry particles [redacted] and transport them in the downstream direction,

Lighter than water substances, typically hydrocarbons and some non-wetting fine particulate materials, float on the surface and are convected in the direction of stream flow. In lakes and slow moving bodies of water movement may be strongly influenced by wind directions.

Spills composed of miscible or soluble compounds spread through the body of water which they enter by the normal processes of hydrodynamic dispersion and molecular diffusion.

2.3

GROUNDWATER

Pollutants entering groundwater systems from accidental spills may [redacted] be either miscible and soluble substances that disperse into the groundwater flow or partially or wholly immiscible compounds [redacted]

Soluble (miscible) substances move with the groundwater but are retarded to some extent by adsorption on the solid particles in the aquifer (see Section D 8.1). Very soluble substances such as sodium chloride and nitrate move nearly as fast as the groundwater whereas ions such as K^+, NH_4^+, Ca^{++}, $HPO_4^=$ adsorb fairly strongly on soil solids and initially move very slowly (Young 1981). Many organic substances tend to be strongly adsorbed and are not seriously contaminants of groundwater. Highly volatile immiscible substances, such as petrol (gasoline) may move more rapidly as vapour through gas spaces than in the groundwater itself.

The principle contaminants that [redacted] differ significantly in density from groundwater are hydrocarbons (oils) which are lighter than water and many of the halogenated organic compounds which are denser. The behaviour of these types of pollutants in groundwater systems [redacted]r [redacted]n [redacted] has been [redacted] renewed by Schwille (1981) for immiscible liquids and by Young (1983) with particular attention to organo-chlorine compounds.

The movement of liquid and dissolved pollutants in soil depends on a large number of factors including density, surface tension, solubility in water and volatility of the liquid and on the pore size, adsorbative surface area degree of saturation by water and chemical nature of the soil. Water movement may be as fast as a river in underground caverns or less than one meter per year in compact clay or chalk.

2.3.1 [redacted] Physical barriers

Two types of physical barrier are commonly suggested for the containment of contaminated groundwaters, slurry walls and sheet piling. With the exception of lighter then water contamination incidents, these techniques are really only applicable when a natural impermeable barriers exists at some reasonable depth within the aquifer, into which the base of the cut-off can be sealed.

The slurry wall technique is more versatile (Millet and Perez, 1981). Ryan 1980) In essence, a slurry of bentonite clay is pumped into a trench whilst excavation of the trench is proceeding, with the slurry maintaining the wall stability through hydrostatic pressure. As excavation of the trench proceeds, it is progressively backfilled with a cement/bentonite or soil/bentonite mix which combines with the slurry to form a low permeability membrane. A permeability of not greater than 10^{-7} cm/sec is normally specified.

— The slurry wall techniques are only really applicable in unconsolidated sediments, or, in the case of direct trenching, in very poorly cemented granular materials.

Physical barriers to groundwater movement, unless completely surrounding a mass of contaminated water, may allow contamination to escape around the flanks. It is therefore necessary both for the purposes of preventing further movement and in order to remove the contaminated water for subsequent treatment to install a borehole, or boreholes within the contained mass and to remove the polluted water by pumping.

2.3.2

Hydraulic barriers

Hydraulic barriers are created by changing the hydrostatic pressure heads in the vicinity of a spill in such a way that movement of the contaminated water is abated. Two basic types of barrier exist, pressure troughs and pressure ridges.

[redacted]y., pressure trough barriers involve the construction of several wells sited so that they [redacted] divert and intercept water moving along a broad front. Successful operation of such systems have been described [redacted] by Burt (1972[redacted] De Walle and Chian, 1981

Groundwater pressure ridges, are located in such a way as to divert or restrict the flow of polluted water [redacted] either by injecting fresh water through a series of specially drilled wells, or by recharge of water through lagoons and trenches. The former technique [redacted] control the movement of groundwater polluted by solvents and acid sludges has been reported by Neely, et al. (1981). The technique is basically that of artificial recharge of groundwater resources and similar quality constraints apply to the injected water, if rapid blockage or corrosion of the injection wells is to be avoided. By contrast, the use of recharge lagoons or ditches to create pressure ridges is restricted to unconfined aquifer systems and is much less controllable than the injection well method because the water must move vertically through an unsaturated zone before reaching the water table, and may be subject to lateral dispersion. The technique does, however, offer certain advantages.

Costs and time of construction of trenches are far less than those for an equivalent array of boreholes

Maintenance of recharge performance is relatively simple, consisting of periodic dredging of the ditches to remove settled fine materials.

Unlike pressure trough systems, in which the wells directly remove the contaminated water, pressure ridge systems require [redacted] abstraction boreholes for the removal and disposal of the diverted or restricted polluted groundwater.

The actions described in the previous section are designed to prevent or restrict the spread of pollution in the aquatic environment. In all cases this involved the containment of the polluted water in such a way that it could no longer mix with and contaminate clean flows, and often implied the removal of the polluted liquid by pumping to a prepared storage area. As such, certain of the actions could be considered as a first stage in the treatment of the polluted resource.

This section, therefore, deals with those actions which may be taken after the initial isolation of the polluted water in order to improve its quality to the point where it meets quality standards appropriate to direct use, discharge to surface waters, reinjection to an aquifer or some other specified use. The techniques may be applied to contaminated water that has been isolated or removed from its original location, The level to which treatment is carried depends on the final use of the water after treatment,

The ability of physico-chemical treatment methods to remove pollutants from water have been extensively studied in various Water Reuse and Advanced Waste Treatment programmes. Culp et al.(1978) Dean and Lund (1981)

Gravity separation of suspended or floating solids is often necessary in the case of polluted surface waters,

In the case of heavier than water solids the process may be carried out as a batch process, with a series of tanks in parallel employed to ensure continuous flow to later stages of the treatment system. very finely divided

colloids settle only slowly, if at all under gravity. In such cases flocculants such as ferric chloride, alum or polyelectrolytes may be added to cause coagulation and more rapid settlement of particles.

Portable clarifiers are available as parts of prefabricated water or sewage treatment plants. The use of a properly designed clarifier can greatly improve the removal of suspended matter.

Afsluttet Fortsættes

3.2 Filtration.

Water filters consist of columns of granular material (filter media) through which the polluted water flows. Flocculated particles adhere to the surfaces of the media and are subsequently removed by back washing.

Portable filters used for swimming pools are available and may be modified for treatment of limited quantities of contaminated water. They are rapidly exhausted if fed with very turbid water, but are useful for polishing after clarification by sedimentation.

3.3 Activated Carbon and Ion Exchange

Adsorption on activated carbon is an effective treatment for the reduction in concentration of many organic compounds in solution.

Both granulated (GAC) and powdered activated carbon (PAC) are produced. GAC is most commonly used in continuous treatment to remove organic pollutants (e.g. odours, phenol, pesticides) etc. from water because it can be thermally regenerated. PAC is less expensive but regeneration is generally not possible. PAC is usually added to water before coagulation and is removed and disposed of as a sludge along with other suspended matter in the water. PAC can also be removed in disposable filter filled with straw or peat moss. For clean-up of a limited quantity of water PAC will usually prove to be more economical than GAC.

Ion exchange systems rely on the exchange of ions held by electrostatic forces to functional groups on the surface of porous solids (resins and silicate minerals) by ions of a different type in solution.

Ion exchange is useful to remove metal salts from dilute solutions in water, but concentrated solutions e.g. more than 1 molar, and solutions of simple salts, eg $NaCl$ and NH_4NO_3 ~~[illegible]~~, are not economically treated by ion exchange.

3.4. Chemical and Biological Treatment.

Some pollutants can be altered or destroyed by chemical reaction. Acids and bases can be nutralised, cyanides, nitrites and sulfites can be oxidized to harmless products, chromates can be reduced to chromic salts that are easily removed by precipitation. Few organic pollutants can be removed by external ~~chem~~ chemical treatment. In contrast biological treatment at a waste water treatment plant can deal with a wide variety of organic substances especially if they are readily biodegradable and are not present at too high a concentration. However, a certain number of compounds are so seriously antagonistic to the operation of biological waste water treatment plants that they are generally unacceptable (Table V. 1).

A few halogenated compounds related to chloroform, especially 1,1,1, trichloroethane, a dry-cleaning compound, are specifically toxic to the anaerobic process and concentrations as low as 10 to 20 mg/l can seriously reduce the production of methane from sewage plant digesters. (Swanwick and Foulkes 1971).

Table V.1 - Compounds antagonistic to aerobic biological treatment

(after Huibregtse, 1977)

Water soluble salts of:	Organic compounds:
Antimony	Benzonitrile
Arsenic	Brucine
Beryllium	Carbon disulfide
Cadmium	Dinitro benzene
Chromates and bichromates	Chlorophenols
Cobalt	Nitrophenols
Copper	Resorcinol
Lead	Strychnine
Mercury	Tetraethyl lead
Nickel	
Uranium	Most pesticides
Vanadium	
Zinc	
Zirconium	

Almost all of the ~~processes~~ treatment that will remove pollutants from water will occur in soil, albiet at a slower rate. Neutralization by calcium carbonate, as chalk or limestone, removes acids. CO_2 from bacteria neutralizes strong alkali. Many metal salts are converted to ~~[illegible]~~ insoluble basic carbonates by calcium carbonate. Soil is a very effective filter even for particles as small as viruses Ion exchange was first recognized in soils and a measure of cation exchange capacity is a standard analysis. Biological activity can also oxidize or reduce simple chemicals such as sulfites, nitrites, chlorine and chromates as well as use organic substances as food eg phenol, formaldehyde (See Parr et al 1983)

In each of these cases an excess of pollutant will use up the reactive capacity of the soil. However the contaminated zone will be surrounded by a layer of soil ~~through wich~~ in which the diffusing molecules ~~will~~ can be degraded. Only when the pollutants escape to flowing aquifers or are completety resistant to natural degradation will it be necessary to install external treatment systems.

4 2. Rehabilitation of soil

Relatively little has been published on rehabilitation of soil following chemical accidents but there is a substantial body of information developed by the US Environmental Protection Agency (EPA) in their Hazardous Waste programme. The behaviour of chemicals in the soil is essentially the same whether they are leaking from improper dumps or spilled in an accident.

Sediments from contaminated lakes and streams share many characteristics in common with contaminated soils and may require similar treatments.

A presentation of [redacted]-remedial action unit operations has been published (Ehrenfeld and Bass 1984) based on the [redacted] EPA's Handbook [redacted] Evaluating Remedial Action Tehcnology Plans" by the same authors. A second edition by Wagner et al. (1986) offers additional data. The EP work is limited to North-American [redacted] legal frameworks but it provide useful guidance particularly in areas where other work is lacking.

The various types of remedial action that have been used at hazardous waste sites was summarised by the EPA in 1984. Nearly four hundred sites were examined and detailed case histories of 23 successful & rehabilitations were reported in detail (EPA 1984). Some of these were accidents or fires although most were at landfills. Contaminated material was removed from over forty percent of the sites. Groundwater control was the next most frequent rehabilitation technique. Table V2 lists the processes used for rehabilitation. The main report on the 23 sites, presents carefully reviews the methods actually used ~~and~~ the costs incurred and compares them with standard cost estimates. Variations in costs between different locations exceed several fold in almost all examples.

A more international approach to soil rehabilitation has been published by NATO (Smith 1984, 1985). Much work has been done on the rehabilitation of land that has b n contaminated as a result of normal manufacturing operations

The details of rehabilitation vary greatly because they depend both on the chemicals and the local soil characteristics. The literature on this subject is rapidly advancing and should be consulted when the nature of a new chemical accident is apparent.

An EPA document that deals with decontaminati of buildings structures and equipment also include

TABLE 3. RESPONSE TECHNOLOGIES EMPLOYED ~~AT SURVEY SITES~~

*Note: Percentages do not total 100 since more than one remedial action technique has been used at many sites.

Remedial Action	Number of Sites	Percent of Total 395 Sites
Capping/Grading/Revegetation	69	17.5
Surface Water Diversion/Runoff Controls (including spill containment controls, e.g., dikes)	34	8.6
Leachate Collection (e.g., underdrains)	19	4.8
Lining (clay or synthetic)	13	3.3
Drum Removal/Recontainerization	55	13.9
Waste/Contaminated Materials Removal	107	27.1
Waste Recovery/Recycling (solvents, metals)	8	2.0
Contaminant Treatment/On-site Treatment	66	16.7
Encapsulation/Solidification	10	2.5
Ground Water Pumping	29	7.3
Ground Water Containment (e.g., slurry walls)	17	4.3
Ground Water Monitoring	73	18.5
Gas Control	5	1.3
Dredging	5	1.3
Incineration	5	1.3
Other Methods (e.g., new water supply)	28	7.1
Combined Techniques	126	31.8
Unknown (remedial actions planned, but unspecified)	60	15.2

.1 Soil properties

Soil is not only one of the most diverse natural substances in terms of the range of properties of natural soils but also one of the most complicated. Soil is the natural product of weathering, vegetation and other forms of life on the rocks that form the bulk of the earth's free surface. One of the most important properties of soil is its surface area, which is related to its fineness. Sand of about 1 mm in diameter has a surface area of about 60 cm^2/cm^3 or about 20-25 cm^2/gram. Clay has surface areas up to 100 m^2/gram (10 ha/kg). Organic matter in soil, humus, may have comparably high surface areas. The importance of surfaces is that almost any contaminant molecule may be adsorbed on surfaces and the quantity adsorbed depends upon the area and not on the weight or volume of the adsorbant.

When a substance is adsorbed from solution, for example a pesticide in water adsorbed on soil, the concentration adsorbed on the solid is always greater than in the solution at low concentrations. The same phenomenon can be observed with low quality dyes on cotton fabrics. When washed enough dye will come off, to stain white fabrics in the same wash, but the original fabric looses very little of its colour and it is essentially impossible to wash all the dye out.
solution of pesticide is spilled on soil.

concentrations of many substances, including pesticides, are as low as one part per million or even less, it is obvious that attempts to wash soil clean are doomed from the start. Only in the case of a few very soluble salts including NaCl, nitrates, sulfates and chromates is it possible to wash out all of a pollutant with reasonable quantities of water.

.2. Removal of soil versus teatment in situ

When dealing with contaminated soils, remedial action may be either to remove and dispose of it or to treat it in situ.

Physical removal and disposal of contaminated soil constitute the best known and most widely practised method for rehabilitation after chemical spills on land. Standard excavation techniques such as manual and mechanical shovelling and scrapers may be used.

Such a procedure is straight forward and relatively simple if a suitable landfill is available within a reasonable distance. The major cost can well be for transport of the excavated material.

For small spills that have not had a chance to penetrate very far prom; removal of all of the contaminated soil may be the most economical rehabilitation method. Such removal should not be allowed to wait until pollution shows up at distant wells for by then the volume of polluted soil may be too great to handle within the available budget. In some cases, such as Seveso (Noe 1983) the initial dispersions has taken place through the air over a large area. In such a case if it is possible to remove the top layer of soil rapidly before rain washes pollutants deep into the soil, rehabilitation could be much less expensive. Ideally the surface removal should be carried out as part of the emergency action and the polluted soil could even be stored in a pile on the site pending final treatment and disposal.

Removal of contaminated soil requires the use of containers or covered trucks, protection of operators depending on the nature of the chemical spill, equipment for decontamination of tools and plant after use, and precautions against fires and explosions.

Transportation of the contaminated soil must comply with environmental regulations of the province, state or country (if such exist).

prevention of spillage enroute to the treatment or disposal site by total enclosure
avoidance of contamination of roads by material that adheres to any part of the vehicle or container, and drops off. A "wash" area may be necessary to avoid this hazard.

Possible disposal methods are secure landfill, landspreading, treatment (physical, physico-chemical, chemical and biological), incineration, dumping at sea, [redacted] The most environmentally acceptable method is treatment and landspreading as a part of restoration.

4.3 Physical Barriers used to retain contaminated ground-water (Section 2.3.1) will also retain chemical pollutants such as oils that are not dissolved by the ground water. It is usual to cap any enclosed area of contaminated soil to prevent infiltration of rain water and the cap will also greatly retard the escape of volatile substances. Long term stabity of caps and barriers is difficult to maintain (Johnson and Urie 19[illegible]

R 4.3.1 Surface sealing is easier if the surface is elevated and shaped so that rainfall runs off and does not accumulate in puddles and sink in.

The design of surface seals and other cover systems has been investigated in considerable detail Ehrenfeld and Bass (1984) and Wagner et al (1986) include extensive tables of chemicals and proprietary substances that can be added to cover soil to improve the seal. The EPA (1984) found that capping, grading and revegetation were used as response technologies at only 17% of the sites surveyed but eight of the 23 sites studied in detail used some form of capping procedure. Both clay (bentonite) and asphalt were used with no significant cost differences. Clay caps were sometimes covered with soil and plant to vegetation. see Gilman et a 1985)

4.3.2 Complete containment, which is also known as encapsulation, involves surface, lateral and bottom sealing and, in essence, the chemical spill area becomes a permanent disposal site and its reuse is unlikely. Several different types of sealants may be used such as clay, asphalt and organic based compounds. Bottom sealing is the most difficult process and therefore the sealing is usually pumped. A bottom seal would not be necessary if the walls can be sealed to solid bedrock

There are a number of barrier techniques that have been developed to isolate the sides of hazardous landfills. The type of barrier that can be installed depends very much on the nature of the soil. If the soil is loose sand and gravel and an impermeable clay barrier or bedrock is not too far down, it is possible to completely surround an area of polluted soil so that there will be no leakage to groundwater. The cheapest and best understood method is to use interlocking sheet piles. These are constructed by driving web sections of sheet piling permanently into the ground. Each section interlocks with its neighbours and infiltrations of clay and fine soil particles into the joints soon complete the seal. Sheet steel piling is commonly used but has an expected life of less than half a century. Sheet

-4.4 Injection of water, which may contain neutralizing chemicals, may sometimes be used to remove pollutants from a confined block of soil. As noted earlier it is not practical to wash out substances that are strongly adsorbed. In some cases it may be possible to wash out a salt or neutralize a strong acid. Oxidizing environments can be supplied with dissolved oxygen or hydrogen peroxide. Attempts to precipitate a heavy metal will usually lead to blocking of the injection wells or trenches.

In some cases it is possible to fix the pollutant in the soil by introducing a cement or geling agent that makes the whole body of soil impermeable. Such treatment is usually combined with surface sealing and frequently with side barriers as extra safety feature.

The main advantage of treatment in situ is that the contaminant remains in place, special transportation equipment is not required and costs ~~are~~ may be reduced.

Mobile treatment equipment may be brought in with appropriate personnel to undertake the rehabilitation. The equipment may be relatively simple ~~such as spraying units, pumps, plastic sheeting, and~~ to pump air into the soil or it may require digging the soil to mix in neutralizing chemicals. In some cases plowing, fertilizing and watering could be sufficient. A major cost could be adequate fencing to keep the public off the area until natural degradation is completed.

4.5 Biological in-situ treatment makes use of natural soil bacteria and other micro organisms that are capable of degrading a very large variety of chemical compounds. Simple aromatic and aliphatic substances are degraded rapidly if the soil is kept moist, aerated and well fertilized with N and P. Aerobic degredation can destroy as much as 15 cm of oil sludge in six months on a field during warm weather (CONCAWE 1980). Chlorinated compounds decompose more slowly because few organisms posses the enzymes to attack them. Gene spliced organisms with enhanced ability to digest chlorinated compounds are being investigated to degrade such substances as the pesticide 2,4,5T. (Ghosal et al 1985)

Biological treatment in the soil may be as simple as letting the soil alone, either fallow or planted to a disposable crop. In such a case it could be called "Natural degradation" or even "Doing nothing". Never-the-less such natural biodegradation may be by far the most efficient and safe method. The addition of special microbial cultures could of course be tested experimentally but in most cases they are unable to compete with the Native Flora.

The final step is restoration of vegetation. Complete restoration of a climax forest will take centuries but reasonable vegetation, including some trees, can be accomplished in a few years. The U.S State Agricultural Service has prepared Standardized Proceedures for Planting Vegetation on Completed Sanitary Land Fills (Gilman et al 1985). Local agricultural specialists should be consulted for any specific site.

considered when all other options fail. Although a numb of external treatments of a chemical or biological natur have been suggested incineration remains the only practical method for removing organic compounds that are toxic at very low concentration.

4.5.1 Incineration of soil contaminated with PCBs has been done in rotary kilns, (Wagner et al 1986) using auxilliary fuel. Costs depend on the quantity of soil incinerated and are nearly independent of its content of hazardous organic substances. incinerated. High temperatures which are necessary to destroy organic pollutants also destroy the soil leaving ashes or brick dust. Thus incineration does not rehabilitate contaminated soil although it should prevent further pollution from the initial site.

High temperature incineration in a rotary kiln was the method of choice for decontamination of soil at Sevaso. Initial plans called for a kiln to be built in the most contaminated near the factory. Strong pub'c opposition, based on the fear that some dioxin might escape from the incinerator stack and also that Sevas would become a dumping ground for all of Italy forced abandonment of these plans. (Esposito et al 19.

5. Rehabilitation of Buildings and Facilities (Equipment

The EPA has published a guide for Decontamination of Buildings, Structures and Facilities at Superfund Sites (Esposito 1985). It contains some of the most up to date information available on 21 specific decontamination methods. Some of the methods are innovative but in each case the status and costs of the method is given. See Table V-3

In the case of houses in Sevaso no single decontamination method was universally applicable.

"Thirty-six houses in the area of highest soil contamination, which were considered too polluted to be cleaned, had to be demolished; new replacement homes were constructed nearby. One hundred and twelve houses in the less contaminated areas ~~(Subzones A6 and A7)~~ were extensively decontaminated. Roof tiles were replaced, and both interior and exterior walls were vacuumed. Smooth, nonabsorbing surfaces were washed with surfactants and common solvents, whereas wall plaster and wooden floors were subjected to various degrees of scraping. Linoleum floors, wallpaper, furniture, and loose objects that could not be cleaned were removed and placed in concrete-lined pits in Subzone A5, along with the contaminated roof tiles. Many interior surfaces were subsequently coated with paint or varnish. Toxic waste that had been washed from the interior walls was collected in concrete-lined tanks placed outside the houses being cleaned. The tanks then were taken by truck to be emptied elsewhere, or the waste in them was pumped to a field lying just within ~~Subzone A5~~. the highly contaminated area.

In the case of the plant careful dismantling was followed by direct disposal of the contaminated equipment was chosen over 1) the entombment of the entire plant in a giant monolith or 2) comprehensive decontamination before dismantling and disposal of the cleaned equipment. The cost of decontamination of factory buildings can exceed the cost of removing the building entirely. Many of the decontamination methods are not applicable to Public buildings, national monuments or even substantial dwellings. The exact nature of the contamination determines as always the method to use

EPA ~~methods for~~ Decontamination Methods for Buildings (Esposito 1985)

Absorption
Demolition
Dismantling
Dusting/vacuuming/wiping
Encapsulation/enclosure
Gritblasting
Hydroblasting/waterwashing
Painting/coating
Scarification
RadKleen (Freon Extraction)
Solvent washing
Steam cleaning
Vapor-phase solvent extraction
Acid etching
Bleaching
Flaming
Drilling and spalling
K-20 Sealant
Microbial degradation
Photochemical degradation

While many contaminants can be sealed-in under a surface coating it is difficult to eliminate diffusio of vapors and sifting of dust particles that may cause reactions in sensitive individuals. Furthermo the knowledge that a building was once polluted may cause "imaginary alements" even-though analytical measurements fail to detect any significant pollutant

Facilities that have been contaminated in an accide will be rehabilitated only if the cost of cleaning and servicing is less than the cost of replacement. Tanks pipes and some pumps may be easy to clean. Electric motors and heav mechanical tools will be more difficult while meters, gagues and associated control equipment may be impossi to return to service. Bromley et al (1983) discusses official plans for the decontamination of the factory responsible for the Sevaso explosion.

D.f.B. | References
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Dato

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