CHAPTER 1: INTRODUCTION

1.1 Answer

Answer varies. Sample answer provided below.

Kepone Disaster, Hopewell, VA, 1973: Life Sciences Products, a subcontractor of Allied Chemical, produced the pesticide Kepone. After several complaints of employee health problems, investigation revealed major violations of health and safety regulations by Life Sciences and Allied. Kepone was illegally discharged into the James River, chemicals were released into the sewer system, and working conditions in the plant were unsafe. As a result, drinking water, air, plant and animal life, and municipal wastes in Hopewell all recorded high levels of Kepone contamination.

Stringfellow Acid Pits, Riverside County, CA, 1977: Stringfellow Quarry Company used these pits as a surface impoundment for approximately 34 million gallons of liquid hazardous waste. Because of inaccurate hydrogeological analysis, the site was legally sanctioned for such a disposal facility. However, the site was actually over the Chino Basin aquifer, a major source of drinking water. Contamination was detected in this water supply but wrongly attributed to runoff problems from other sites. Finally, in 1977, the Stringfellow pits were identified as a problem and major remediation efforts began.

Biocraft Spill, Waldwick, NJ, 1975: Biocraft manufactured synthetic penicillin. Sometime between 1972 and 1975, pipes, running from the plant to an underground storage tank, leaked waste solvents. These solvents seeped into a storm sewer leading to a nearby creek and a shallow aquifer. Concern rose about possible contamination of drinking water at a nearby source aquifer. The leak is also believed to have caused a fish kill in a pond fed by the contaminated creek.

1.2 Answer

Answer varies. Sample answer provided below.

The two fields of engineering differ in their scope. Geotechnical engineering covers subsurface investigation, foundation design, earthworks, and land mass problems, focusing mainly on soil and rock. Geotechnical engineering is only one aspect of the practice of geoenvironmental engineering. Geoenvironmental engineering deals with the behavior of soil and rocks when they interact with pollutants. This practice is a combination of classical geotechnical skills and environmental chemistry knowledge.

1.3 Answer

Answer varies. Sample answer provided below.

Accidental releases of chemicals into the subsurface contaminate the soil and could contaminate groundwater (depending on the hydraulic characteristics). Tainted drinking water would obviously be unsafe for the public and animal habitats could be ruined. Vapors could be released, affecting atmospheric conditions and respiratory functions.

These releases can be prevented by selection of a suitable site for disposal based on hydrogeological characteristics. A proper liner system should be designed and implemented, acting as both a hydraulic and a chemical barrier. A system of closure should also be used when capacity of a site has been reached. Also, the mechanical stability of the liner and cover systems should be taken into consideration in design.

1.4 Answer

Answer varies. Sample answer provided below.

Geoenvironmental engineers possess knowledge of soil composition, stratigraphy, groundwater hydraulics, and geochemistry, which enable them to assess and implement remedial procedures for subsurface contamination problems. They are able to lead in-situ investigations of such problem areas.

1.5 Answer

Answer varies. Sample answer provided below.

Recycled materials may be used in various engineering projects. They can be used as soil substitutes in roadways, embankments, retaining structures, and other civil engineering projects. These engineering projects can utilize large amounts of recycled material. Recycled materials can also be used as soil substitute in waste containment systems and as a reactive media substitute in soil and groundwater remediation processes.

It is vital to the success of any engineering project, but especially to the ones involving the use of nonstandard materials such as recycled materials, to thoroughly evaluate the engineering properties of the materials to be used. Inadequate characterization of properties may lead to failures in the materials which could cause harm to individuals and would definitely incur additional costs in repair and/or replacement work. There is also the chance that the material may not perform the required function adequately and would then need to be replaced or modified, again resulting in more money spent. An example of this would be filter material. It may not

allow fluid to pass through at a fast or slow enough rate and would then be ineffective. The use of recycled material is definitely advantageous in engineering projects both for the environment and for the cost of the project, but the engineering properties of such materials must be accurately determined. To best utilize the recycled materials, the properties of the materials must be found to be equal to or better than the soil properties. Issues of chemical stability and physical stability are also considered important when using recycled materials in engineering projects.

1.6 Answer

Answer varies. Sample answer provided below.

Some of the geoenvironmental issues/tasks involved in this project can be as follows:

- Determine if the site characterization data is adequate and valid. Identify if additional subsurface characterization is needed.
- Determine if the risk assessment is performed. Review the assessment methodology and findings.
- Review all of the information available on the construction and operation of the landfill.
- Determine the final grading requirements and design a cap system.
- Estimate the leachate production currently and with the construction of the cap. Determine the most effective way to collect and remove the leachate.
- Construction of impermeable slurry wall will retard the migration of the groundwater plume. Determine the geometry and depth of the wall. Determine the type of slurry that will be effective for the containment of the site contamination.
- Groundwater extraction wells essentially should be treated as pump and treat system. Location and pumping rates should be determined.
- Treatment of extracted leachate and groundwater with air stripping method should be carefully reevaluated. This method will take care of benzene, but what will happen to lead?
- Determine if the concentrations of the contaminants in the treated leachate and groundwater can be discharged into streams. What are the allowable concentration limits? What are the regulatory requirements?
- Determine monitoring requirements to assess the effectiveness of remedial approach. What are the contingency plans?

CHAPTER 2: RELEVANT ENVIRONMENTAL LAWS AND REGULATIONS

2.1 Answer

The main objective of environmental laws and regulations is to ensure the protection and safety of human health and environment without putting an unreasonable burden on industry or on the taxpayer.

2.2 Answer

Major laws that relate to remediation of contaminated sites:

- Occupational Safety and Health Act (OSHA 1970)
- Resource Conservation and Recovery Act (RCRA 1976, 1980)
- Hazardous and Solid Waste Amendments (HSWA 1984)
- Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA) or Superfund 1980
- Clean Air Act (CAA 1970, 1977, 1990)
- Clean Water Act (CWA 1977, 1981, 1987)
- Toxic Substances Control Act (TSCA 1976)
- Superfund Amendments and Reauthorization Act (SARA 1986)
- Small Business Liability Relief and Brownfields Revitalization Act (SBLR&BRA 2002)

2.3 Answer

Major laws that relate to design of landfills:

- Resources Conservation Recovery Act (RCRA 1976, 1980)
- Hazardous and Solid Waste Amendments (HSWA 1984)
- Clean Air Act (CAA 1970, 1977, 1990)
- Clean Water Act (CWA 1977, 1981, 1987)

2.4 Answer

Environmental laws that aim at protecting groundwater:

- Resource Conservation and Recovery Act (RCRA 1976, 1980)
- Hazardous and Solid Waste Amendments (HSWA 1984)
- Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA) or Superfund 1980
- Clean Water Act (CWA 1977, 1981, 1987)
- Superfund Amendments and Reauthorization Act (SARA 1986)

RCRA and HSWA help to design and operate landfills and impoundments in a way to prevent groundwater contamination. CERCLA and SARA aim to remediate contaminated groundwater. CWA aims to protect all waters from pollution.

2.5 Answer

Environmental laws that control the underground injection of wastes:

- Safe Drinking Water Act (SDWA 1974, 1977, 1986)
- Resource Conservation and Recovery Act (RCRA 1976, 1980)
- Hazardous and Solid Waste Amendments (HSWA 1984)

Underground Injection Control (UIC) regulations control underground injection of wastes.

2.6 Answer

Environmental laws and regulations that relate to the disposal of contaminated dredged sediments:

- Rivers and Harbors Act (RHA 1989)
- Marine Protection, Research and Sanctuaries Act (MPRSA 1972)
- Safe Drinking Water Act (SDWA 1974, 1977, 1986)
- Clean Water Act (CWA 1977, 1981, 1987)
- Resource Conservation and Recovery Act (RCRA 1976, 1980)
- Hazardous and Solid Waste Amendments (HSWA 1984)

2.7 Answer

The Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA), also commonly known as Superfund, was promulgated to address abandoned or uncontrolled hazardous waste sites, which require immediate cleanup to ensure protection of human health and the environment.

2.8 Answer

The Hazard Ranking System (HRS) was established to rank contaminated sites and prioritize cleanup. This system takes into account the degree of risk to human health and the environment posed by each suspect site and considers population, contaminants and potential pathways. The National Priorities List (NPL) is prepared based on the hazard ranking score (HRS) of these sites. A HRS of 28.5 is needed to be included on the NPL.

2.9 Answer

The USEPA has identified 36,000 potential superfund sites, and as of 1993, 1,200 sites were on the NPL with about 100 sites added each year. Cleanups, averaging 11 years and $25 million per site, have been completed at 183 NPL sites and are in progress at over 1000 others. Superfund was reauthorized in 1986, but expired in 1994. It has not yet been reauthorized, except for special activities. There are still several unresolved issues, such as risk assessment, cleanup standards, innovative technologies, and the "Polluter pays" system.

2.10 Answer

Cradle to grave in RCRA under Subtitle C provide criteria for defining hazardous waste, generators responsibilities, transporter's requirements, manifest systems and treatment storage and disposal facility requirement. It aims to control and document all stages from the point of generation/identification to the final storage and disposal. For example, spent solvent at an industrial facility requires a detailed characterization first and then documentation of its storage, transport and disposal/treatment.

2.11 Answer

Following the SARA site assessment procedure, a Phase I investigation should be performed. If the site is though to be contaminated, the investigation should proceed to Phase II. Phase II involves detailed characterization of the type and extent of contamination. Phase III involves actual remedial measures of a designated contaminated site.

2.12 Answer

The regulations related to leaking underground storage tanks (LUSTs) are promulgated under RCRA and HSWA. Specifically, the regulations can be found in the Subtitle I part of RCRA (40 CFR 264.190). These regulations are listed in a new amended section named Superfund Amendments and Reauthorization Act (SARA). Additional state and local regulations may be applicable depending on the site location.

2.13 Answer

Much like the federal government, state and local governments are obligated to set policies regarding environmental protection. State and local governments are expected, at a minimum, to follow the laws enacted by the federal government. In many cases, the laws and regulations passed by state and local governments surpass those of the federal government. It is unlawful, however, for these smaller governments to adopt policies which undermine or contradict those laws passed by the federal government.

Federal laws may not entirely support the needs of every region. State and local governments are more in tune with the environmental needs of their jurisdictions, which enables them to develop environmental laws specific to their needs. In these instances, state and local governments have the ability to supplement federal legislation by introducing laws or stricter policies to accommodate local environmental needs. For example, RCRA, a federal law enacted to regulate the management of hazardous and non-hazardous solid waste, authorizes states to develop and enforce their own hazardous waste programs in place of the program administered by the federal Environmental Protection Agency.

2.14 Answer

The similarities between RCRA and CERCLA are as follows:

- Both RCRA and CERCLA address issues related to the management of hazardous waste.
- Both laws were enacted as a result of abuses regarding the uncontrolled disposal of waste materials and the negative environmental impacts related this issue.

The differences between RCRA and CERCLA are as follows:

- RCRA addresses the management of newly generated hazardous and non- hazardous waste in addition to placing emphasis on recycling over waste disposal. RCRA does not address abandoned or historical sites.
- CERCLA, on the other hand, was enacted to manage existing, abandoned and uncontrolled hazardous waste sites. CERCLA focuses on the assessment and investigation of existing waste sites and prioritizing the implementation of remedial activities.

2.15 Answer

Subtitle I (40 CFR264.300 through 264.317) and Subtitle C (40 CFR 264).

2.16 Answer

Example of small quantity generators of waste are:

- Dry cleaners
- Demolition/construction site
- Laboratory at educational institutions
- Photo processing lab
- Vehicle maintenance business

2.17 Answer

Phase I includes a visual inspection of property and a review of such information as prior ownership and use, agency records and known contamination sites, aerial photographs, and

interviews with neighbors and/or past employees. This phase determines whether or not the purchaser has reason to believe that contamination could exist at the site. If problems are detected in Phase I, Phase II is performed, with the purpose of determining the extent of the problem. Phase II involves performing detailed site characterization to determine the type and extent of soil and groundwater contamination. Phase III involves remediation effort.

2.18 Answer

This is one of the complex cases since the former owner Saichek Plating Works went out of business 20 years ago. According to the CERCLA, potentially responsible parties (PRPs) that include present and past owners of the site are financially responsible for the cleanup. If the former owner does not exist, the current owner is responsible for the entire cleanup. An environmental site assessment should have been performed before the land was purchased.

2.19 Answer

Three possible topics that would be applicable are:

- Impacts of streams, groundwater, floodplains, and wetlands and on water uses and quality
- Impacts on aquatic and terrestrial plants and animals
- Socioeconomic impacts on affected communities related to long term water supply and management.

2.20 Answer

Major practical limitations are: limited funding, difficulty in identifying potentially responsible parties (PRPs), and stringent clean up regulations.

2.21 Answer

RCRA-no significant changes since 2000
CERCLA-Brownfields Amendment (January 2002)-reduces liabilities to small businesses based on their waste output and in some cases what they can realistically afford. Also, makes some protection for “innocent” land owners.
Clean Water Act-last significant changes in 1987.
Clean Air Act-last significant changes in 1990.

2.22 Answer

Answer varies depending on the state you live in.

Illinois laws and regulations relating to environment are:

Year	Title
1974	Fedral Safe Drinking Water Act
1976	Illinois Uniform Hazardous Substances act
1977	Environmental Training Resource Centre
1980	Underground Injection Control Program Draft
1981	Legislation to ban landfilling of liquid hazardous wastes
1984	Illinois Toxic Pollution Prevention Act
1984	National Municipal Policy Act
1985	Illinois Pesticide Act
1986	Solid Waste Management Act
1987	Underground Storage Tank (UST) fund
1987	Illinois Groundwater Protection Act
1988	Illinois Responsible Property Transfer Act.

2.23 Answer

Answer varies depending on the country you selected.

Insert

2.24 Answer

Refer to Problem 1.6 for various tasks involved. The site has to comply with the regulatory requirements set forth in CWA, SDWA, TSCA, RCRA, HSWA, CERCLA and SARA. Applicable state and local regulations should also be complied with.

2.25 Answer

Brownfields are real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of hazardous substance, pollutant or contaminant. In addition to the protection of public health and the environment, brownfield redevelopment can utilize existing infrastructure, tax incentives, labor concentration, and progressive legislation, providing smart growth and architectural beauty. The main difference between brownfields and CERCLA sites is that SBLR&BRA relieves liability to small business owners who sent small amount of waste, protecting them while insuring that the polluted site continues to be cleaned up.

CHAPTER 3: CHEMICAL BACKGROUND

3.1 Answer

(a) The oxidation state of Al in the neutral compound $Al_2(SO_4)_3$ is calculated as follows:
0(neutral compound) = 2X+3(-2)
0= 2X-6
X= +6/2
Al oxidation state =+3

The oxidation state of sulfur in the sulfate ion, SO_4^{2-}, is calculated as follows: -2(ionic charge) = X + 4(-2)
X= +6
So the oxidation state of S= +6.

Similarly the oxidation state of oxygen in the sulfate ion SO_4^{2-}, is calculated as follows: -2(ionic charge) = 6 + 4 X
X= -2

(b) The oxidation state of C in the neutral compound $C_6H_{12}O_6$ is calculated as follows:
0(neutral compound) = 6X+12(+1)+6(-2)
C= 0
For H, 0 = 6 (0) + 12 (X) + 6(-2) = +1
For O, 0 = 6(0) + 12 (+1) + 6 (X) = -2

(c) The oxidation state of nitrogen in the nitrate ion, NO_3^-, is calculated as follows:
-1 (ionic charge) =X+ 3(-2)
X= +5
Oxidation state of O can be calculated by putting +5 value in equation for N –1 = +5 + 3(X) = -2

3.2 Answer

Formula weight of NaCl = 22.990 + 35.453 = 58.443
Formula weight of H_3AsO_4 = 3(1.0079) + 74.922 + 4(15.999) = 141.9417

3.3 Answer

(a) NaCl

Number of moles = weight of compound / molecular weight of compound
Molecular weight of NaCl = 22.990 + 35.453 = 58.443
Thus number of moles = 100/58.443 = 1.711

(b) $KMnO_4$

Number of moles = weight of compound / molecular weight of compound
Molecular weight of $KMnO_4$ = 39.098 + 54.938 + 4(15.999) = 158.032
Thus number of moles = 100/158.032 = 0.632

(c) $PbCrO_4$

Number of moles = weight of compound / molecular weight of compound
Molecular weight of $PbCrO_4$ = 207.2 + 51.996 + 4(15.999) = 323.192
Thus number of moles = 100/323.192 = 0.309

(d) $C_6H_{12}O_6$

Number of moles = weight of compound / molecular weight of compound
Molecular weight of $C_6H_{12}O_6$ = 6(12.011) + 12(1.0079) + 6(15.999) = 180.1548
Thus number of moles = 100/180.1548 = 0.555

3.4 Answer

Balanced reaction is:

$$MnO_2 + 2NaCl + 2H_2SO_4 \rightarrow MnSO_4 + 2H_2O + Cl_2 + Na_2SO_4$$

3.5 Answer

pH=5.0
pH + pOH = 14.0
So pOH =14.0- pH
pOH = 14.0-5.0
pOH = 9.0

Hydrogen ion concentration $[H^+] = 10^{-pH}$
$[H^+] = 10^{-5}$ mol L^{-1}

Similarly, hydroxyl ion concentration $[OH^-] = 10^{-pOH}$
$[OH^-] = 10^{-9}$ mol L^{-1}

3.6 Answer

Write a balanced reaction summary (from Table 3.3)

$PbCl_2$ (s)	$\Leftrightarrow$	Pb^{2+} (aq)	+	$2Cl^-$ (aq)
-x M		+x M		+x M

where x is the molar solubility

From Table 3, pKsp = $-\log_{10}(Ksp)$ =4.8
Ksp= $10^{-4.8} = 1.58 \times 10^{-5}$
Thus, Ksp = $[Pb^{2+}]\,[Cl^-]^2 = (x)\,(2x)^2 = 1.58 \times 10^{-5}$
$4x^3 = 1.58 \times 10^{-5}$
$x = (1.58 \times 10^{-5})^{1/3} = 1.6 \times 10^{-2}$ M (molar solubility)

3.7 Answer

A molecule or atom that binds to another molecule is known as a ligand. Ligands are also molecules or atoms that donate or accept a pair of electrons to form a coordinate covalent bond with the central metal atom of a coordination complex.

3.8 Answer

The oxidation of NH_4^+ to N_2 takes place in the following two set of half-reaction:

Set 1
$1/6\ NH_4^+ + 1/3\ H_2O = 1/6\ NO_2^- + 4/3\ H^+ + e^-$
$1/3\ NO_2^- + 4/3\ H^+ + e^- = 1/6\ N_2\ (g) + 2/3\ H_2O$

Set 2
$1/8\ NH_4^+ + 3/8\ H_2O = 1/8\ NO_3^- + 5/4\ H^+ + e^-$
$1/5\ NO_3^- + 6/5\ H^+ + e^- = 1/10\ N_2\ (g) + 2/5\ H_2O$

3.9 Answer

Henry's law describes the solubility of gas in a liquid. It states that the amount of a gas that dissolves in a liquid is proportional to the partial pressure of the gas over the liquid, provided no chemical reaction takes place between the liquid and the gas. It is used to determine the volatilization of dissolved gases during the remedial operations.

3.10 Answer

Often organic compounds are classified based upon their functional groups because molecules with the same functional groups have similar chemical properties. The major functional groups are –H (hydrocarbon), -OH (Alcohols), -CO-H (Aldehydes), -COOH (carboxylic acid), -CO- (Ketones), -O- (Ethers), $-NH_2$ (Amines), -SH (Thiols), $-NO_2$ (Nitro compounds). The functional groups result in a wide range of organic compounds with different properties and toxicity.

3.11 Answer

The general formula of alcohol is R-OH where R can be alkyl or aryl group like CH_3- or C_6H_5-

The general formula of ketone is R-CO-R' where R and R' can be alkyl or aryl group like CH_3- or C_6H_5-. If R and R' are same (alkyl or aryl group), then it is called simple ketone; otherwise it is known as mixed ketone.

3.12 Answer

The properties of organic compounds that are important from a geoenvironmental engineering point of view are: aqueous solubility, vapor pressure, Henry's Law constant, octanol/water partition coefficient, and rate of biodegradation. These properties for benzene, trichloroethylene and phenanthrene at 25^o C are summarized in the following table:

Organic compound	**Aqueous solubility**	**Vapor pressure**	**Henry's Law constant**	**Octanol/water partition coefficient**	**Rate of biodegradation**
Benzene	1.64 mol L^{-1}	0.90 atm.	0.75 L atm mol^{-1}	2.13	0.059 mg/day
Trichloroethylene	4.65(mg/L)	7.68 torr	2.27 m^3 atm mol^{-1}	.672	.0016 l/day
Phenanthrene	5.2 mol L^{-1}	6.79 atm.	1.45 L atm mol^{-1}	4.57	.236 l/mg/hr