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**Qn.1 Explain six major non-domestic use of water.**

**Irrigation**

About 70% of water used globally is in irrigation. In Ethiopia, the total area under irrigation is increasing and irrigation channels like Spray irrigation, where pressurized water is sprayed over plants to feed them, is often used on large farms but greater efficiency of water use can be achieved by drip-feed irrigation systems. In drip-feed irrigation, water is fed to the roots of plants through narrow pipes dripping water onto the soil surface near the base of the plant. This takes the water directly to the growing crops and reduces losses by evaporation.

**Industrial use**

In many industries water is essential. Some industries use piped water supplied from water treatment plants while others draw the water themselves from underground sources and treat it on site for use. The water may be used either as part of the production process or as an ingredient, where water is one of the components of the product, for example in a soft-drink plant. In the production process, it can be used for cooling, washing, diluting, boiling or cooking, transportation of raw materials (for example, moving potatoes in a food factory), and as a cleaning agent.

**Mining use**

Mining activities use huge amounts of water in processing ore to extract minerals. In Ethiopia, mining for gold and other valuable metals is an increasingly important part of the national economy and would not be possible without the use of water.

**Use in power generation**

The rivers of Ethiopia have enormous potential for generating hydroelectric power (HEP). HEP uses the energy from moving water and converts this to electrical energy. The development of HEP has transformed energy supply in recent years and more schemes are under construction or planned. However, it is important to realise that in HEP the water is not ‘used’ in the sense of being consumed, because after passing through the HEP plant the water continues on its path in a river channel.

Another process under development in the Rift Valley area of Ethiopia is the use of geothermal energy, in which energy is derived from the heat of the Earth. This process involves drilling down into hot layers of underground rock and using this heat to convert water into steam, which is then used to drive generators to produce electricity.

**Aqua cultural use**

Water can also be used in aquaculture, which is the farming of aquatic organisms such as fish, crustaceans and molluscs for food. Fish farming obviously needs water for the fish to live in! In this case, water is used to hatch fish eggs under controlled conditions, and the fish are grown to maturity in tanks or ponds, before being sold for food. Although not currently practiced in Ethiopia, the business potential for aquaculture has been recognized and it may be introduced in the future **(Rothuis et al., 2012).**

**Recreational uses**

Water plays an important role in recreational activities and here again it is not consumed in the process of its use. Boat trips are popular on many of Ethiopia’s lakes and several resorts have been built on their shores. .

How water gets to people living in towns

We obtain the water we use from three basic sources: groundwater, surface water and rainwater. Groundwater includes all water that is found underground within the rocks. Surface water means water in rivers, lakes, pools and ponds. Rainwater replenishes both groundwater and surface water, and can also be collected directly.

**Qn.2Briefly describes the important roles that water plays in the human body.**

This substance makes up a majority of your body weight and is involved in many important functions, including:

* **flushing out waste from your body**
* **regulating body temperature**
* **helping your brain function**

You get most of your water from drinking beverages, but food also contributes a small amount to your daily water intake.

**1. It helps create saliva**

Water is a main component of saliva. Saliva also includes small amounts of electrolytes, mucus, and enzymes. It’s essential for breaking down solid food and keeping your mouth healthy. Your body generally produces enough saliva with regular fluid intake. However, your saliva production may decrease as a result of age or certain medications or therapies. If your mouth is drier than usual and increasing your water intake isn’t helping, see your doctor.

**2. It regulates your body temperature**

Staying hydrated is crucial to maintaining your body temperature. Your body loses water through sweat during physical activity and in hot environments. Your sweat keeps your body cool, but your body temperature will rise if you don’t replenish the water you lose. That’s because your body loses electrolytes and plasma when it’s dehydrated. If you’re sweating more than usual, make sure you drink plenty of water to avoid dehydration.

**3. It protects your tissues, spinal cord, and joints**

Water consumption helps lubricate and cushion your joints, spinal cord, and tissues. This will help you enjoy physical activity and lessen discomfort caused by conditions like arthritis.

**4. It helps excrete waste through perspiration, urination, and defecation**

Your body uses water to sweat, urinate, and have bowel movements. Sweat regulates body temperature when you’re exercising or in warm temperatures. You need water to replenish the lost fluid from sweat. You also need enough water in your system to have healthy stool and avoid constipation. Your kidneys are also important for filtering out waste through urination. Adequate water intake helps your kidneys work more efficiently and helps to prevent kidney stones.

**5. It helps maximize physical performance**

Drinking plenty of water during physical activity is essential. Athletes may perspire up to 6 to 10 percent Trusted Source of body weight during physical activity. Hydration also affects your strength, power, and endurance. You may be more susceptible to the effects of dehydration if you’re participating in endurance training or high-intensity sports such as basketball. Negative effects of exercise in the heat without enough water can include serious medical conditions, like decreased blood pressure and hyperthermia. Extreme dehydration can cause seizures and even death.

**6. It helps prevent constipation**

Eating fiber isn’t the only way to prevent constipation. It’s also important to maintain your water intake so your bowel movements contain enough water. If you don’t consume enough water, magnesium, and fiber, you may be more likely to experience constipation. If you’re already constipated, you may find that drinking carbonated water Trusted Source as well as plain water can help ease your symptoms.

**7. It aids in digestion**

Contrary to what some believe, experts confirm drinking water before, during, and after a meal will help your body break down the food you eat more easily. This will help you digest food more effectively and get the most out of your meals. Research shows Trusted Source the body adapts to changes in the consistency of food and stomach contents, whether more solid or more liquid.

**8. It helps with nutrient absorption**

In addition to helping with food breakdown, water also helps dissolve vitamins, minerals, and other nutrients from your food. It then delivers these vitamin components to the rest of your body for use.

**9. It helps you lose weight**

Studies have linked body fat and weight loss with drinking water in both overweight girls Trusted Source and women. Drinking more water while dieting and exercising may just help you lose extra pounds.

**10. It improves blood oxygen circulation**

Water carries helpful nutrients and oxygen to your entire body. Reaching your daily water intake will improve your circulation and have a positive impact on your overall health.

**11. It helps fight off illness**

Drinking enough water can help prevent certain medical conditions Trusted Source. These include:

* constipation
* kidney stones
* exercise-induced asthma
* urinary tract infection
* hypertension

Water also helps you absorb important vitamins, minerals, and nutrients from your food, which will increase your chances of staying healthy.

**12. It helps boost energy**

Drinking water may activate your metabolism. A boost in metabolism has been associated with a positive impact on energy level.

One study found that drinking 500 milliliters of water boosted the metabolic rate by 30 percent in both men and women. These effects appeared to last over an hour.

**13. It aids in cognitive function**

Proper hydration is key to staying in tip-top cognitive shape. Research Trusted Source indicates that not drinking enough water can negatively impact your focus, alertness, and short-term memory.

**14. It helps improve mood**

Not getting enough water can also affect your mood. Dehydration may result in fatigue and confusion as well as anxiety.

**15. It helps keep skin bright**

Adequate water intake will help keep your skin hydrated and may promote collagen production. However, water intake alone isn’t enough to reduce the effects of aging. This process is also connected to your genes and overall sun protection.

**16. It prevents overall dehydration**

Dehydration is the result of your body not having enough water. And because water is imperative to so many bodily functions, dehydration can be very dangerous. Severe dehydration can result in a number of severe complications, including:

* swelling in your brain
* kidney failure
* seizures

Make sure you drink enough water to make up for what’s lost through sweat, urination, and bowel movements to avoid dehydration.

**The bottom line**

Water is important to nearly every part of your body. Not only will hitting your daily recommended intake help you maintain your current state of being, it may even improve your overall health.

**Qn.3 List the types of people who are most vulnerable to waterborne diseases. Explain your answers why and how to overcome the diseases**

Water is important to human life and health, the most common and widespread health risk associated with drinking water is contamination, either directly or indirectly, by human or animal waste. Waterborne diseases account for an estimated cases 4.1% of the global burden of diseases, and cause about 1.8 million human deaths annually and 88% is attributed to unsafe water supply, sanitation and poor personal hygiene. According to the World Health Organization 884 million people lack access to even basic drinking water service, including 159 million people who are dependent on surface water such rivers and lakes. Also 423 million people taking water from unprotected springs and wells.

Globally, at least 2.1 billion people use a drinking water sources contaminated with faces. Contaminated water and poor sanitation are linked to transmission of diseases such as diarrhoea, cholera, dysentery, typhoid and polio. Diarrhoeal death cases reported was estimated to be 502 000 each year. Some 842 000 people are estimated to die each year from diarrhoea as a result of unsafe drinking-water, sanitation and hand hygiene. Diarrhoea is the most widely known disease linked to contaminated food and water but there are other hazards. Almost 240 million people are affected by schistosomiasis – an acute and chronic disease caused by parasitic worms contracted through exposure to infested water.

According to UN Environment Programme (UNEP), 300 million people in Africa still do not have reasonable access to safe drinking water and nearly 230 million people defecate in the open. Waterborne diseases are caused by several pathogenic microorganisms that include bacteria, viruses, protozoan and helminthes. This is usually occurred as a result of poorly treated drinking water and waste water or natural disaster like flooding and environmental pollution. In developing countries, accessibility of safe drinking water is still a problem and people are forced to use available unimproved water sources. These water sources are often microbiologically unsafe and as a result, the most well-known waterborne diseases such as cholera, amoebic dysentery and typhoid are reported from almost all African countries especially in tropical areas of the region.

Much cases of diarrhoea were recorded by researchers and the government and children of five years found out that Top most common contributors of waterborne which stated that the effects arising from contact of waterborne pathogens vary depending on the volume of water ingested by an individual and the individual immune status with the children and elderly being the most susceptible. Children also have less body mass than adults. This means that waterborne pathogens may be dangerous for a child at a concentration that is relatively harmless for an adult. Diarrhoea is the most prevalent waterborne diseases in the study site followed by skin infections during the period of study. World health organization has predicted that there will be about 5 million deaths in children below age of five by 2025 of which 97% will be in developing countries and mostly caused by infectious disease within which diarrhoea will continue to play a prominent role

**Symptoms of waterborne diseases**

**How to relief from several allergies**

* Illness
* Diarrhea
* Vomiting’s
* Skin, ear, respiratory or some eye problems

Waterborne disease are easily transmitted through contaminated water or material that enters into their mouth. Thus, the following reasons are transmitted to get infected like dirty hands, cooking vessels, dirty clothes, mugs, uncovered foods and drinking water.

**How to prevent waterborne diseases?**

**Stop drinking untreated water**

One should carry their own water bottle while travelling. You should keep yourself clean and be hygienic. Drink from an open water source is never advisable. You should range and even protects some potentially harmful health problems. Always, you should keep yourself hydrated by drinking plenty of water. You should use an ultraviolet light water purification system. This helps to remove viruses and can be transmitted through water.

**Keeping hygiene**

The best to reduce waterborne ailments are by using water purification system. Always make sure to wash your hands. Keep yourself clean and is by using a cutting board. The cutlery is properly cleaned before and after cleaning.

**Stop eating raw foods**

Foods that include vegetables, raw meat, shellfish and raw fruits, they should be exposed to contaminated water. Thus, keep a water bottle that you need to carry while travelling.

* You must drink only filtered water
* Clean your hands properly before eating
* Cleanse the containers daily
* Eat warm foods and homemade cooked foods
* Avoid eats roadside foods
* You should keep yourself clean and clean fingernails
* Wash toilets
* Wash vegetables before cooking and cook at high temperature to kill harmful bacteria
* Avoid flies due to organic waste
* Keep your food closed
* Avoid swimming in rivers and creek

The categories are defined by the types of intervention that can control morbidity and mortality, rather than by the biological taxonomy of the organisms that cause them. As such, this model has helped engineers and public health professionals to work together on practical control strategies **(Kolsky, 1993).** A similar classification exists for excreta-related diseases **(Feachem et al, 1983a )**but has been less widely used. There are four categories in the Bradley-Feachem classification of water-related disease:

* *Faecal-oral* (waterborne *and* waterwashed). These include infections that are transmitted by swallowing faecally contaminated matter (food and water) containing pathogens. They can be caused by lack of sufficient water to maintain personal and domestic hygiene *as well as* by drinking contaminated water. Diseases in this group include, among others, diarrhoeal diseases, typhoid, cholera and hepatitis A and E.
* *Strictly water-washed* (skin and eye infections). These are conditions that are exacerbated by lack of water for washing and hygiene, but are *not* faecal-oral. These diseases are largely related to skin and eyes, such as scabies, trachoma and conjunctivitis.
* *Water-based aquatic intermediate host*. Aquatic organisms such as snails act as hosts to parasites, which then infect humans either by being swallowed or through contact in water (e.g. by piercing the skin of those wading in the water). Diseases in this group include guinea worm and schistosomiasis.
* *Water-related insect vector*. These diseases depend on insect vectors, such as mosquitoes and flies, which breed in or near water. They transmit disease to humans, for example, through bites. The diseases involved include malaria, filariasis, yellow fever, dengue and onchocerciasis (river blindness).

From the four categories in the Bradley-Feachem classification it becomes clear that interventions focused on water quantity have broader impact than those focused on water quality. Water quality only affects faecal-oral diseases, whereas quantity affects both faecal-oral and water washed diseases.

Diarrhoeal diseases, which are faecal-oral, are responsible for the greatest number of episodes of illness (morbidity) and deaths (mortality) worldwide, compared to any other single classification of water and sanitation-related disease. Based on data presented for World Health Organization (WHO) member states, It has been estimated that diarrhoeal disease represents 90 per cent of the health impact associated with water supply and sanitation (White et al, 1972). Diarrhoeal diseases are estimated to kill around 1.8 million people every year worldwide **(WHO, 2004 )**of which the overwhelming majority is children.

This toll is equivalent to 12 jumbo jet crashes every day or almost twice (1.9) the number of people who ‘died in the World Trade Center on the 11th of September 2001’ per day. There is some reason to believe that the number of deaths has fallen since the 1980s, possibly due to water and sanitation programmes and increased use of oral rehydration therapy **(Bern et al, 1992)**. However, it appears that the number of episodes of diarrhoeal disease has remained constant.

**Health Impacts of Water- and Sanitation-Related Diseases;**

Approximately 90 per cent of diarrhoeal disease cases are estimated to be attributable to environmental factors (Murray and Lopez, 1996). Apart from water supply, sanitation and hygiene, diarrhoeal disease is also associated with a number of other risk factors including age, malnutrition, lack of breastfeeding, and seasonality.

**The F-Diagram**

The F-diagram, depicted by (**Wagner and Lanoi**)  which has been widely used as a model of faecal-oral disease transmission. Unless faeces are isolated from potential contact with humans, animals and insects, pathogens may be carried on unwashed hands, in contaminated water or food, or via flies and other insects on to further human hosts. The first way to stop or reduce transmission is to ensure the safe disposal of faeces, through sanitation. Safe excreta disposal and washing hands following defecation is referred to as ‘the first barrier’ and considered the most important health intervention, as it keeps faecal pathogens out of the living environment. Children’s faces in particular are known to contain a high load of pathogenic organisms, such as Ascaris and Trichuris, but are also least likely to be safely disposed of **(Cairncross, 1989; Kolsky, 1993**). The secondary barriers to faecal-oral disease transmission protect people from whatever faecal contamination of the environment is present. These are based on hygienic practices, such as washing hands before handling food, fly control, safe food storage and the use of footwear.

F-diagram. SOURCE: After **(Wagner and Lanoix 1958)**; with permission from the World Health Organization.

The F-diagram graphically presents multiple routes of transmission. A single type of pathogen may be transmitted by several of these routes, and the population at risk may be vulnerable to many different pathogens, which may favour different routes. Numerous commentators have advocated integrated measures to control diarrhoeal disease by combating multiple routes of transmission **(Lewin et al, 1996; Curtis et al, 2000a).** The greater the range of interventions, the greater the chance in successfully reducing diarrhoeal disease transmission; The F-diagram also shows that while water quality only affects one route, the quantity of water available for personal and domestic hygiene affects almost all routes.

Following the discovery in the 19th century of the undeniable role that water quality played in the epidemics of cholera and typhoid, there was a natural focus on the improvement of drinking water quality. This focus produced dramatic results in the reduction of waterborne epidemics. The F-diagram clearly shows that this would be the case where water contamination is the main route of transmission.

Where routes other than water consumption are more important for disease transmission, however, improving water quality will have far less effect. While waterborne epidemics are dramatic and alarming surprises, the sad truth is that the everyday endemic (non-epidemic) toll of faecal-oral disease is far, far higher, and most of the latter seems to be transmitted through routes other than water. While improving water quality does not necessarily affect endemic transmission, increasing the quantities of water available to improve personal and domestic hygiene *can* have a greater effect on this unacceptable toll (**Cairncross, 1995)**. Most health benefits will be obtained from large amounts of water of a good quality.

But if resources are scarce, public health professionals generally recognize the greater importance of access to water in quantity for hygiene, compared with the quality of that water (**Esrey et al, 1985, 1991)**. Unfortunately, in practice, the main efforts in ‘water and sanitation for low-income areas’ are often still directed towards the improvement of the water quality of the public water supply, rather than improving access by poor households, and thus the quantity of water that those households can use. The beneficiaries of such efforts are more likely to be people who already have access to water than people with no access. Sanitation and hygiene promotion are even lower priorities in practice, although the principles of the F-diagram suggest that they should have equal or higher priority **(Curtis et al, 2000b**).

**Recent and Forthcoming Research**

Most studies of the impact of water quality have been based upon water quality measurements at the source or collection point. It is known however, that the degree of faecal contamination of water increases during transport to the household **(Clasen and Bastable, 2003**). There is also increasing evidence that improving water quality at the point of use has a positive health impact **(Conroy et al, 2001; Iijima et al, 2001; Fewtrell et al, 2005; Clasen, 2006)**. This is regarded by some as an exception to the dominant paradigm **(Clasen and Cairncross, 2004)**. While data support health benefits for people that have at least 15 litres of water per capita per day there are reasons to believe that benefits are reduced when access levels to water are lower (**Clasen, 2006**). However, at this time not enough data are available to substantiate this **(Clasen, 2006)**. Systematic reviews and meta-analyses, such as those of the Cochrane Library infectious diseases group **(Clasen et al, 2004 )**and field research will be needed to clarify these new findings and examine if these are in conflict with the current paradigm.

**Qn.4 Suppose that inhabitants of a village obtain water from a spring. What advice would you give to the users about the prevention of contaminants entering the spring?**

The source of drinking water can be either surface water based (lakes, rivers and streams) or groundwater based (aquifers). Water is always found in combination with compounds such as minerals or chemicals of one kind or another, that can be present naturally or as a result of human activity. In both cases, there could be presence of some contaminants (metals, radioactive compounds, microorganisms, among others) that have the potential to be hazardous to humans. The Water Source Protection means protecting from contamination and overuse (at the source), both water quality and quantity we drink and use, thus reducing risks to public health from exposures to contaminated water (**EPA n.y; SDWF 2017**).

Water source protection involves the protection of surface water sources (e.g. lakes, rivers, man made reservoirs) and groundwater sources (e.g. spring protection, dug well protection, and drilled well protection) to avoid water pollution (see also pathogens and contaminants).

While surface water sources and springs are directly exposed to human activities, groundwater sources are often protected through overlaying soil layers. However, accessing groundwater sources through dug or drilled wells allows contaminants to enter aquifers, polluting the well itself and the water in nearby lakes, rivers, or neighboring wells, which consequently threatens both public health and the environment (MANCE n.y.).

In the past, the need for water source protection has often been neglected. As a consequence, many drinking water sources have become contaminated making water purification measures indispensible. The very slow flow of groundwater makes rehabilitation of contaminated aquifers both costly and time-intensive. While removal of pathogenic contamination through disinfection is more likely to be successful, some metals and chemical substances will permanently remain in the soil.

Recently, establishing adequate water source protection has been recognised as the most suitable and cost-effective method to keep contaminants out of drinking water and making costly water purification measures and construction of new wells unnecessary **(GCC 2011; CONSERVATION ONTARIO 2009).** This holds both for industrialised and developing countries.

Implementing water source protection requires a legal framework. This usually involves a protection plan, which formulates responsibilities, specific protection measures and basic rules that apply to all community members and water source users.

**Surface Water Source Protection Measures**

As many surface water sources are used for drinking water purposes, protection is vital. Generally, three basic strategies exist for protection **(UNEP 2010)**.

* **Prevention**: No discharge of waste, pollutants or untreated water from domestic, industrial or agricultural use; optimised water use and practices in agriculture in order to stop nutrients from entering aquatic systems (e.g. establishing buffer zones).
* **Treatment**: treatment of polluted water prior to discharge; storm water management: ensuring that run-off cannot transport pollutants into water bodies.
* **Restore ecosystems**: Enable or support natural rehabilitation processes.

**Groundwater Source Protection Measures**

Numerous simple preventative measures can be applied to protect springs, wells and aquifers from contamination. They are presented in the following five steps.

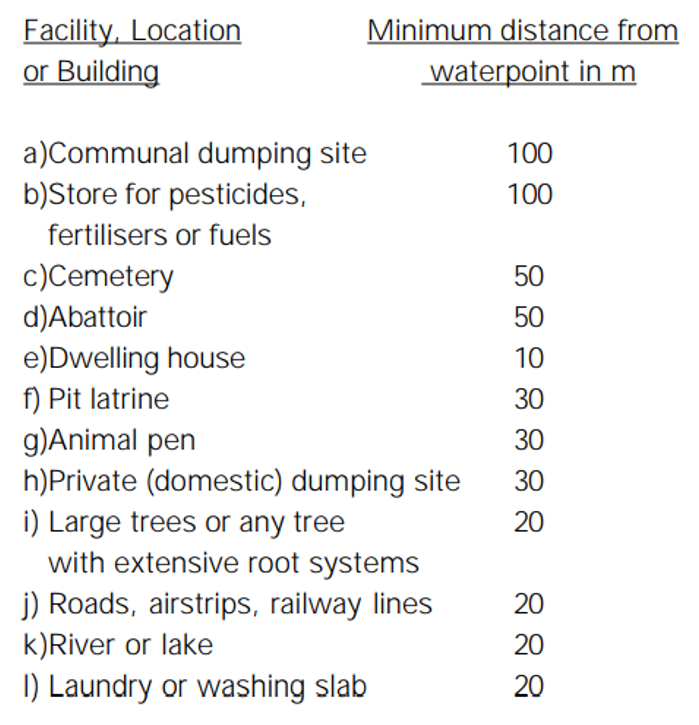
**Step 1: Location / Site Selection of the Water Source - Never Close to Pollutant Sources**

Before the drilling of a well or construction of a spring tapping starts, an appropriate site has to be found. Villagers or landowners are a good source of information and mostly point out a suitable location for them as users. However, several other important aspects have to be kept in mind when selecting the optimal site for a water source **(WAL 2010)**.

A water point of any kind or source should be:

* Situated above the (seasonal) flood level of any nearby river or lake;
* In a location, which guarantees easy access for all water users all year round; this refers to physical access but also to legal access.
* In proximity to the actual point of water use;
* In an area allowing the rapid dispersal of spilt water;
* In a sunny area without shade to guarantee that the immediate well surroundings remain dry, so as to prevent bacteria, algae, etc. to evolve.
* In a location where the level of the water table is at a depth of at least two metres all year round (for wells);
* In distance from agricultural activities of any kind; particularly if pesticides or fertilisers are applied.
* In an area not susceptible to erosion;
* In safe distance to saltwater and any source of pollution such as a pit latrine, abattoir, dumping site, fertiliser or pesticide store, etc. **(COLLINS 2000; WAL 2010**).

The minimum distances to sources of pollution are given on the following table:

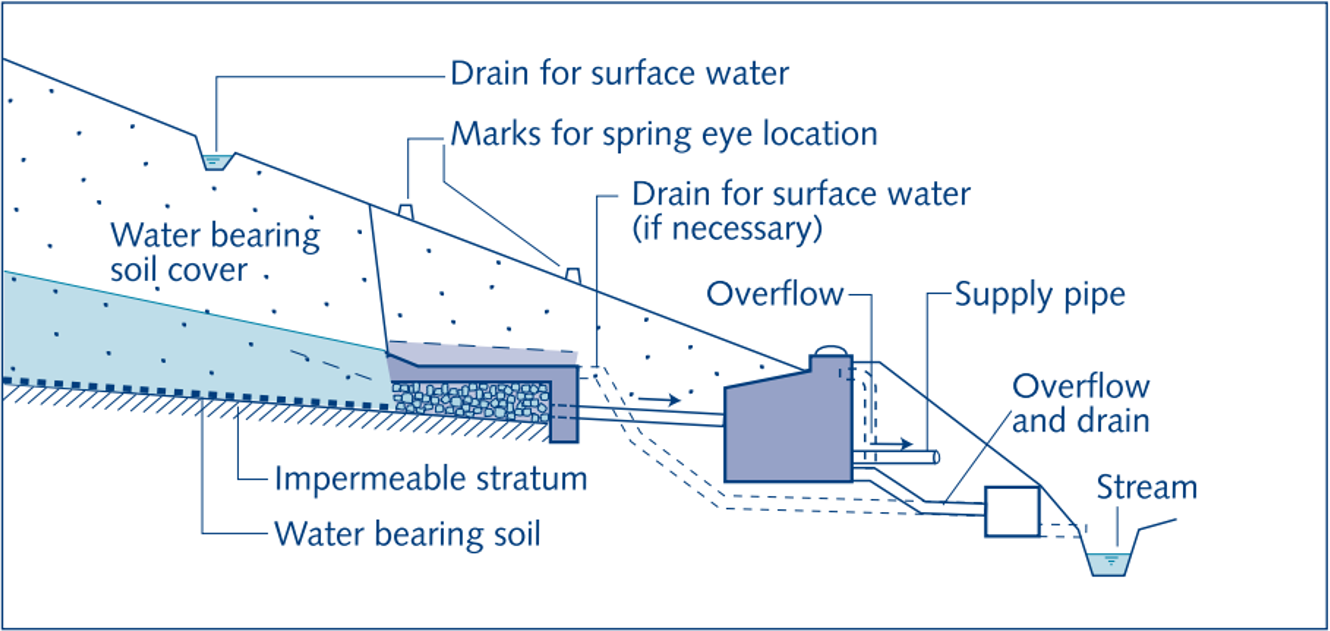


*Minimum distances to potential sources of contamination. Source:* **(COLLINS 2000)**

**Step 2: Construction of Spring- and Well Protection**

In order to protect contaminants from entering the spring, well and the aquifer through the water point itself, several specific measures can be applied:

Springs can be protected by installation of a spring tapping, a spring box and an adequate drainage system. Additionally, a surface water drainage ditch, dug above and around the spring area, diverts surface water run off from polluting the source. If the area around a spring intake is unstable or exposed to erosion, gabions or dry stone masonry can be used to stabilise the area (**OXFAM 2008**).

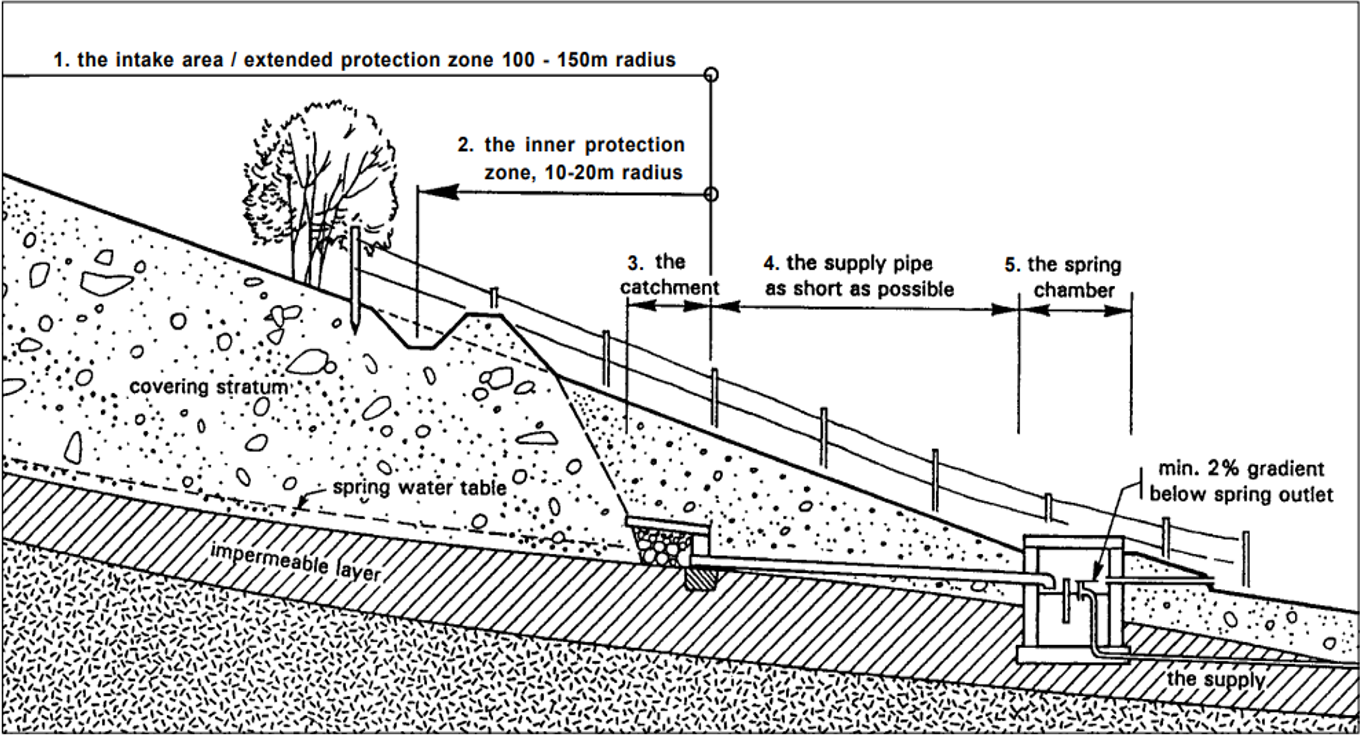


**Lay-out of a spring water collection area (gravity spring).** *Source:* **(SMET & WIJK 2002 )**

Drilled and dug wells need a proper sealing. First, an apron guarantees that no contaminants enter the well from the access point area. Second, an impermeable lining (for dug wells) or casing (for drilled wells) makes sure, that no close-to-surface-water laterally enters the well. As for springs, adequate drainage installations keep the immediate surroundings dry. After the completion of the well, a final disinfection with chlorine kills most pathogens that entered during construction.

The most decent construction of a spring taping, well lining, casing and apron is without effect, if pollutants are entering the aquifer in the mediate surroundings of the water point. In a fenced, inner protection zone (with a radius of 10 – 20 m), all activities posing a risk of contamination are restricted (e.g. farming, grazing, firing, application of pesticides and fertilisers, construction of latrines, use of chemicals, etc.). It should only be planted with grass - all trees and bushes should be uprooted. Roots can damage the catchment by cracking the structures or by blocking the pipes. **(MEULI & WEHRLE 2001)**.

Additionally, an extended protection zone (at least 100m in radius) should be put up. Its size depends on the depth and the type of the covering soil. The required radius thus increases if the spring catchment is close to the surface and if the soil is highly permeable (**MEULI & WEHRLE 2001)**. E.g. if the soil mainly consists of rough sand and gravel, its permeability is rather high. The radius of the extended protection zone should then be extended to more than 150m. The area in this zone should be planted with mixed trees and bushes to prevent erosion and heavy run-off. The planting of trees that absorb large amounts of water (such as eucalyptus) is not recommended for the protection zone. Examples of more useful trees include cypress and pine. However, local varieties, which do not absorb large quantities of water, should be given priority.(**MEULI & WEHRLE 2001**).

Protection zone for a spring*. Source:* (**MEULI & WEHRLE 2001**)

**Step 3: Fencing**

Fences build around the water source precisely mark the inner protection zone and prevent animals from entering, defecating or destroying installations. Fencing is mainly applied for springs, as they are more susceptible to superficial contamination. However, shallow wells may also need protection zones. It is advisable to fence the inner protection zone with barbed wire and preferably to support the wire by planting a solid hedge of solid bushes around the fence **(MEULI & WEHRLE 2001).**

In many countries, groundwater protection zones are regulated institutionally. Specific rules define what kinds of activities are allowed in each of the protection zone levels (they may include more than two protection levels!). They can range up to several kilometres in diameter and allow everything between no activities and nearly all activities. In Switzerland, for example, the government has defined three levels of protection zones (**WPO 1998):**

* "**S1 Wellhead protection zone**: The zone S1 comprises the area immediately surrounding a groundwater well or artificial recharge facility (at least 10 m around the well and around the collection system). In this zone, only construction work and activities connected with drinking water supply are permitted. The aim is to prevent damage to the facilities or direct contamination of the water abstracted. The zone S1 should therefore be purchased and fenced in by the drinking water supplier.
* **S2 Inner protection zone**: The inner protection zone S2 is primarily designed to prevent contamination of drinking water with pathogenic microorganisms and to ensure that groundwater flows are not adversely affected or obstructed as they approach the well. In this zone, the spreading of liquid manure is therefore prohibited, as are the infiltration of wastewater and the construction of buildings and installations.
* **S3 Outer protection zone**: The outer protection zone is designed to ensure that, in the event of an accident, sufficient time and space are available to ward off any hazards to drinking water. Thus, facilities that pose a hazard to groundwater (e.g. petrol stations) are not allowed to be located in zone S3. Wastewater seepage and gravel extraction are likewise prohibited in this area.”

**Step 4: Set up Rules for all Community Members**

Any protection plan rises and falls with the behavior of the community members, their attitude towards the plan and their knowledge. Besides the installation of constructional measures, simple rules should be set up and communicated by a local caretaker.

Such rules can include:

* Don’t defecate close to the well,
* Don’t let your animals graze close to the well,
* Don’t throw any garbage into the well, etc.

**Step 5: Management of Operation and Maintenance**

Only adequate operation by the water users and frequent maintenance by a local caretaker can ensure a safe long-term usability of the water point. Operation and maintenance activities are best organised through a local management plan.

The remit of a caretaker involves the:

* Inspection, cleaning and repair of spring installations and well (e.g. cracks in the apron, leaking parts, etc.)
* Monitoring activities in the surrounding area
* Up keeping the protection zone/ repair of the fence
* Checking for appropriate operation by users and providing health education **(OXFAM 2008).**
* Checking whether the basic rules are respected by the users

**Step 6: Abandoned and Unused Wells**

 Abandoned wells are wells that are no longer in use. Over the years, many wells around homes and farms have been abandoned without being properly sealed and decommissioned. Abandoned wells or improperly decommissioned wells can pose a serious threat to groundwater quality and can also be a safety hazard. Therefore, all abandoned wells should be properly plugged to prevent contamination and to eliminate any safety hazards. When a new water well has to be drilled, the old well should be plugged (MANCE n.y)..

**Abandoned wells:**

* Can allow surface run off to directly enter an aquifer, contaminating the aquifer and potentially contaminating nearby wells;
* Can permit cross-contamination of different aquifers encountered by the well bore;
* Can be a physical safety threat, as they are often not marked or covered, and can pose a hazard to people or animals that might fall into them;
* Can be a liability problem if the well contaminates neighboring wells, or if the abandoned well still exists at the time of property resale (MANCE n.y.).

**Cost Considerations**

Increasingly, water planners and communities are looking to source water protection as a key to improve water quality and lowering water purification costs. Focusing on the protection of the drinking water sources in order to reduce or eliminate the need for purification is a more sustainable approach than cleaning the water once it is polluted.

Protection measures are simple and can be constructed with locally available material by local people; consequently, costs are relatively low. Basic rules for community members can quickly be set up and communicated. The tricky part is keeping the water sources well maintained and making sure that people respect the basic rules that come with the measures. Also, healthy, resilient ecosystems help to purify water, regulate the water cycle, and thereby degrade many contaminants before they enter and pollute water sources **(UNEP 2010).**

All in all, water source protection keeps contaminants out of drinking water and is often more cost-effective than removing contaminants after the water source has been polluted(**GCC 2011**).

**Qn.5 The following are pollution sources. Give two specific pollutants for each source**.

1. **A residential area**:

**Biomass fuels**

About 50% of the world’s population (about 3 billion people) have little or no access to modern forms of energy, and use biomass fuels for cooking, heating and lighting. These are frequently burned within the households in open fires or inefficient stoves. In the rural areas of Latin America, 30–75% of households use biomass fuels for cooking, which have a dramatically high production of PM and carbon monoxide (CO). Solid fuels are still the dominant source of energy in households in rural China. In China, indoor air pollution from biomass fuels is responsible for approximately 1 000 000 premature deaths annually, compared with the 1 200 000 estimated to be caused in the country each year by outdoor PM pollution. A recent quantification of the disease burden caused by different risk factors globally indicates that in 2010, over 3.5 million deaths were attributable to household air pollution from solid fuels, representing more than 50% of the total deaths attributable to air pollution from particulate matter and ozone.

There is strong evidence of increased risk of acute lower respiratory infections in childhood (at least 2 million deaths annually in children under 5 years of age). There is also evidence of an association with the risk of developing chronic obstructive pulmonary disease (COPD), mostly for women, and with the risk of tuberculosis and asthma.

The International Agency for Research on Cancer has classified emissions from the indoor combustion of coal as a Group 1 carcinogen, i.e. a known carcinogen for humans. Indeed, there is strong evidence that women exposed to smoke from coal fires in the home have an elevated risk of lung cancer (the evidence is moderate for men). Meta-analyses in low-income countries have estimated increased risks from solid fuel combustion averaging 3.5-fold for acute respiratory infections in children, 2.5-fold for chronic bronchitis in women, and 2.8-fold and 2.3-fold for COPD and chronic bronchitis in all adults, respectively.

**Dampness/Mould**

Dampness is present in 10–50% of houses. Moulds are a source of allergens, mVOCs and mycotoxins. Meta-analyses show associations of dampness/mould with increases of approximately 30–50% in respiratory and asthma-related health outcomes, including current asthma, ever-diagnosed asthma, upper respiratory tract symptoms, cough, wheezing and the development of asthma. According to the World Health Organization (WHO), dampness-related factors are also associated with dyspnoea, respiratory infections, bronchitis and allergic rhinitis. Positive associations, although not always statistically significant, have been found in children/infants or young adults between fungal concentration (expressed by culture colony counts) and risk of allergic sensitisation and asthma. Significant associations have also been found between exposure to moulds and respiratory symptoms or doctor-diagnosed asthma, regardless of atopy.

Some studies have found increased risks of wheezing and allergic sensitisation in relation to high exposure to ergosterol (a mould marker), whereas others found no such association. Other epidemiological studies have evaluated mould exposure based on β-glucans (components of the bacterial cell wall) or mycotoxins (fungal products). Exposure to β-glucans did not affect respiratory/allergic disorders, whereas there is insufficient evidence to implicate mycotoxins in mould-related respiratory effects. Recently, a new method has been developed to measure fungal DNA as a mould marker in dust/air. The main advantage of using DNA is the possibility of also identifying dead or dormant organisms. Significant positive associations have been reported between the quantity of DNA of certain fungi and wheezing, nocturnal dry cough, persistent cough, daytime breathlessness or a diagnosis of asthma.

1. **A metal plating plant**:

**Phytoremediation**

Phytoremediation, the use of plants to remove or degrade contamination from soils and surface waters, has been proposed as a cheap, sustainable, effective, and environmentally friendly alternative to conventional remediation technologies. Plants use solar energy (through photosynthesis) to extract chemicals from the soil and to deposit them in the above-ground part of their bodies, or to convert them to a less toxic form. These plants can then be harvested and treated, removing the pollutants.

An ideal phytoremediator would have: high tolerance to the pollutant; the ability to either degrade or concentrate the contaminant at high levels in the biomass; extensive root systems; the capacity to absorb large amounts of water from the soil; and fast growth rates and high levels of biomass.

Although several species can tolerate and grow in some contaminated sites, these species typically grow very slowly, produce very low levels of biomass, and are adapted to very specific environmental conditions. And trees- which have extensive root systems, high biomass, and low agricultural inputs requirements- tolerate pollutants poorly, and do not accumulate them. Conventional plants therefore fail to meet the requirements for successful phytoremediators.

**Cleaning Up More Efficiently with Green, Biotech “Mops”**

The remedial capacity of plants can be significantly improved by genetic manipulation and plant transformation technologies. The introduction of novel traits for the uptake and accumulation of pollutants into high biomass plants is proving a successful strategy for the development of improved phytoremediators. This Pocket K reviews some of the research efforts in this field, and highlights future challenges.

**Cadmium, Zinc, Lead, and Selenium**

Toxic metals affect crop yields, soil biomass, and fertility, and accumulate in the food chain. Metal-tolerant species protect themselves from the toxicity of metal ions by binding metals ions with specific proteins that render them in a safer form. Three classes of proteins are important for metal detoxification in plants: metallothioneins, phytochelatins, and glutathione. The genes coding for these have been successfully used to improve phytoremediators through genetic engineering.

For example, shrub tobacco (Nicotiana glauca) transformed with the phytochelatin TaPCS1 shows very high levels of accumulation of zinc, lead, cadmium, nickel, and boron, and produces high biomass. In Arabidopsis, Indian mustard, and tobacco plants, improved metal tolerance was achieved through the over-expression of enzymes that induce the formation of phytochelatins.

Plants naturally tolerant to heavy metals have also been used as a source of genes for phytoremediation. Transgenic Arabidopsis plants expressing a selenocysteine methyltransferase (SMTA) gene from the selenium hyperaccumulator Astralagus bisulcatus contain eight times more selenium in their biomass when grown on selenite compared to non-transgenic controls. Comparison of gene expression profiles between Arabidopsis thaliana and the closely related species A. hallerri, which is tolerant to cadmium and hyperaccumulates zinc, is also helping identify major genes required for metal tolerance.

1. **Agricultural activities**:

Agricultural pollution refers to biotic and abiotic byproducts of farming practices that result in contamination or degradation of the environment and surrounding ecosystems, and/or cause injury to humans and their economic interests. The pollution may come from a variety of sources, ranging from point source water pollution (from a single discharge point) to more diffuse, landscape-level causes, also known as non-point source pollution. Management practices play a crucial role in the amount and impact of these pollutants. Management techniques range from animal management and housing to the spread of pesticides and fertilizers in global agricultural practices.

**Abiotic sources**

**Pesticides**

**Cropduster spraying pesticides.**

**Aerial application of pesticide.**

Pesticides and herbicides are applied to agricultural land to control pests that disrupt crop production. Soil contamination can occur when pesticides persist and accumulate in soils, which can alter microbial processes, increase plant uptake of the chemical, and are toxic to soil organisms. The extent to which the pesticides and herbicides persist depends on the compound’s unique chemistry, which affects sorption dynamics and resulting fate and transport in the soil environment. Pesticides can also accumulate in animals that eat contaminated pests and soil organisms. In addition, pesticides can be more harmful to beneficial insects, such as pollinators, and to natural enemies of pests (i.e. insects that prey on or parasitize pests) than they are to the target pests themselves.

**Pesticide leaching**

Pesticide leaching occurs when pesticides mix with water and move through the soil, ultimately contaminating groundwater. The amount of leaching is correlated with particular soil and pesticide characteristics and the degree of rainfall and irrigation. Leaching is most likely to happen if using a water-soluble pesticide, when the soil tends to be sandy in texture; if excessive watering occurs just after pesticide application; if the adsorption ability of the pesticide to the soil is low. Leaching may not only originate from treated fields, but also from pesticide mixing areas, pesticide application machinery washing sites, or disposal areas.

**Fertilizers**

Only a fraction of the nitrogen-based fertilizers is converted to produce and other plant matter. The remainder accumulates in the soil or lost as runoff. High application rates of nitrogen-containing fertilizers combined with the high water-solubility of nitrate leads to increased runoff into surface water as well as leaching into groundwater, thereby causing groundwater pollution. The excessive use of nitrogen-containing fertilizers (be they synthetic or natural) is particularly damaging, as much of the nitrogen that is not taken up by plants is transformed into nitrate which is easily leached. Nitrate levels above 10 mg/L (10 ppm) in groundwater can cause "blue baby syndrome" (acquired methemoglobinemia). The nutrients, especially nitrates, in fertilizers can cause problems for natural habitats and for human health if they are washed off soil into watercourses or leached through soil into groundwater. Moreover, the abuse of fertilizers caused air pollution in the form of ammonia

**Biotic sources**

**Greenhouse gases from fecal waste**

The United Nations Food and Agriculture Organization (FAO) predicted that 18% of anthropogenic greenhouse gases come directly or indirectly from the world’s livestock. This report also suggested that the emissions from livestock were greater than that of the transportation sector. While livestock do currently play a role in producing greenhouse gas emissions, the estimates have been argued to be a misrepresentation. While the FAO used a life cycle assessment of animal agriculture (i.e. all aspects including emissions from growing crops for feed, transportation to slaughter, etc.), they did not apply the same assessment for the transportation sector.

A PNAS model showed that even if animals were completely removed from U.S. agriculture and diets, U.S. GHG emissions would be decreased by 2.6% only (or 28% of agricultural GHG emissions). This is because of the need replace animal manures by fertilizers and to replace also other animal coproducts, and because livestock now use human-inedible food and fiber processing byproducts. Moreover, people would suffer from a greater number of deficiencies in essential nutrients although they would get a greater excess of energy, possibly leading to greater obesity.

**Biopesticides**

Biopesticides are pesticides derived from natural materials (animals, plants, microorganisms, certain minerals). As an alternative to traditional pesticides, biopesticides can reduce overall agricultural pollution because they are safe to handle, usually do not strongly affect beneficial invertebrates or vertebrates, and have a short residual time. Some concerns exist that biopesticides may have negative impacts on populations of nontarget species, however.

In the United States, biopesticides are regulated by EPA. Because biopesticides are less harmful and have fewer environmental effects than other pesticides, the agency does not require as much data to register their use. Many biopesticides are permitted under the National Organic Program, United States Department of Agriculture, standards for organic crop production.

1. **An uncontrolled landfill site:**

Waste deposited in landfills or in refuse dumps immediately becomes part of the prevailing hydrological system. Fluids derived from rainfall, snowmelt and groundwater, together with liquids generated by the waste itself through processes of hydrolysis and solubilization, brought about by a whole series of complex biochemical reactions during degradation of organic wastes, percolate through the deposit and mobilize other components within the waste. The resulting leachate subsequently migrates from the landfill or dump and has the potential to contaminate local groundwater either through direct infiltration on site or by infiltration of leachate-laden runoff off-site. The risk posed to groundwater-fed drinking-water sources by waste disposal in landfills or dumps can be considered in terms of three controls:

**• waste composition and loading**

**• Leachate production**

**• Leachate migration – attenuation and dilution.**

Leachate production most waste deposited in landfills is not inert. Degradation of many components of waste including food, paper and textiles consumes oxygen thereby changing the redox potential of the liquid present and potentially influencing mobility of other constituents. Plastics, glass and metal compounds tend to be less reactive and degrade more slowly. Under some conditions, metals may, however, become rapidly mobilized. Percolating rainwater provides a medium in which waste, particularly organics, can undergo degradation into simpler substances through a range of biochemical reactions involving dissolution, hydrolysis, oxidation and reduction, processes controlled to a large extent within landfills and dumps by microorganisms, primarily bacteria. Mechanisms regulating mass transfer from wastes to leaching water, from which leachate originates can be divided into three groups of processes:

**• Hydrolysis of solid waste and biological degradation;**

**• Solubilization of soluble salts contained in the waste;**

**• Suspension of particulate matter.**

The first two groups of processes, which have the greatest influence on the composition of leachate produced, are associated with the stabilization of waste. Initially, organic matter in the form of proteins, carbohydrates and fats, is decomposed under aerobic conditions (i.e. oxidized), through a series of hydrolysis reactions, to form carbon dioxide and water together with nitrates and sulphates via a number of intermediate products such as amino acids, fatty acids and glycerol. Such oxidation reactions are exothermic, so temperatures in the landfill become elevated.

Carbon dioxide is released as a gas or is dissolved in water to form carbonic acid (H2CO3) which subsequently dissociates to yield the bicarbonate anion (HCO3 - ) at near neutral pH. Aerobic decomposition of organic matter depletes the waste deposit of oxygen (O2) as buried waste in the landfill or refuse dump becomes compacted and circulation of air is inhibited. As oxygen becomes depleted, it is replaced as the oxidizing agent by, in succession, nitrate (NO3 - ), manganese (as MnO2), iron (as Fe(OH)3) and sulphate (SO4 2-). In general, the aerobic stage is short, no substantial volumes of leachate are produced, and aerobic conditions are rapidly replaced by anaerobic conditions. The main stages of anaerobic digestion are

1. acetogenic (acid) fermentation,
2. intermediate anaerobiosis, and
3. methanogenic fermentation,

all three of which can be operating simultaneously in different parts of the landfill. Acetogenic fermentation brings about a decrease in leachate pH, high concentrations of volatile acids and considerable concentrations of inorganic ions (e.g. Cl- , SO4 2-, Ca2+, Mg2+, Na+ ). As the redox potential drops, sulphate is slowly reduced, generating sulphides, which may precipitate iron, manganese and heavy metals that are dissolved by the acid fermentation. Decrease in pH is due to production of volatile fatty acids (VFAs) and to high partial pressures of carbon dioxide (CO2), whilst the increased concentrations 348 Protecting Groundwater for Health.

Leachate migration in unsealed landfills above an aquifer, waters percolating through landfills and refuse dumps often accumulate or mound within or below the landfill. This is due to production of leachate by degradation processes operating within the waste, in addition to the rainwater percolating down through the waste. The increased hydraulic Waste disposal and landfill: Potential hazards and information needs 351 head developed promotes downward and outward flow of leachate from the landfill or dump.

Downward flow from the landfill threatens underlying groundwater resources whereas outward flow can result in leachate springs yielding water of a poor, often dangerous, quality at the periphery of the waste deposit. Observation of leachate springs or poor water quality in adjacent wells/boreholes are indicators that leachate is being produced and is moving. Leachate springs represent a significant risk to public health, so their detection in situation assessment is critical in order to prevent access to such springs. Conceptual diagram of leachate migration from a landfill **(Freeze and Cherry, 1979; reprinted by permission of Pearson Education, Inc., Upper Saddle River),** NJ One method used to reduce the generation of leachate and, hence, hydraulic heads generating flow from a closed landfill is to place a capping of low permeability material (e.g. clay or high density polyethethylene) over the waste deposit in order to reduce infiltration of rainwater.

These should be recorded in situation assessment because if a landfill is capped to impede rainwater ingress, reducing leachate volumes, a more concentrated leachate will be generated. Also, microbial and biochemical reactions will be inhibited thereby prolonging the degradation process and the activity of the waste possibly for decades or even centuries. Groundwater pollution potential from older capped landfills may therefore be higher than from younger, open landfills. Leachate migration is also affected by the manner in which waste is deposited.

**e) Urban surface water run-off**

Urban-use pesticides present a unique risk to non-target organisms in surface aquatic systems because impervious pavement facilitates runoff that may lead to serious contamination and ensuing aquatic toxicity. Fipronil is an insecticide used at high rates in urban environments, especially in regions such as California. This compound and its biologically active degradation products have been detected in urban runoff drainage and downstream surface water bodies at concentrations exceeding toxicity thresholds for sensitive aquatic invertebrates, necessitating a better understanding of the runoff sources and causes of this contamination at sites of application. In this study, we evaluated sorption of fipronil, fipronil desulfinyl, fipronil sulfide, and fipronil sulfone in urban dust, soil, and concrete, matrices commonly associated with the perimeter of a residential home.

Samples were also collected from five single family homes treated with fipronil in Riverside, California, for five months to determine the occurrence of fipronil and its degradates in runoff water, urban dust, soil, and on concrete surfaces. Statistical analysis was performed to determine which urban matrices contributed more significantly to the contaminant levels in runoff water. Freundlich sorption coefficients for fipronil and its degradation products in dust were 3- to 9-fold greater than their values in soil.

Fipronil and its degradates were detected in 100% of runoff samples and their presence was observed in dust, soil, and concrete wipe samples for 153 d after the treatment. Linear regression analysis showed that concrete surfaces were a primary source of all four compounds to runoff, and loose dust on concrete pavement also served as an important contributor.

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