

6 Chemicals from human settlements

6.1 Introduction

The world is becoming increasingly urban, particularly in developing countries. The transition of people from rural areas to cities represents a major, and permanent, demographic shift. This movement to cities creates many problems, particularly when housing and infrastructure are unable to keep pace with population growth. However, problems associated with human settlements do not only arise in large cities — even small settlements can carry risks for drinking-water if insufficient care is taken and drinking-water sources are sited close to human habitation. The chemical risks to drinking-water associated with human settlements described in this section are on-site sanitation and sewerage systems, waste disposal, urban runoff, fuel storage, handling and disposal of chlorinated solvents, and pesticide application for public health and vector control.

Risk management strategies for the chemical quality of water used for drinking in urban areas should take into account chemicals that may be possibly derived from human settlements and may affect drinking-water quality. Strategies should also consider potential sources of such chemicals and the assumed mechanisms by which they may contaminate source water. Often, drinking-water will be abstracted from sources within a city, town or village; usually from groundwater. Thus, the activities within that area of human habitation have the potential to pollute the water supply. However, it is also important to consider pollution of surface waters by human habitation upstream from other settlements, which means that the concept of catchment management should be borne in mind when considering this situation.

Sources of potential pollution fall into three broad categories as indicated in Table 6.1. These categories are:

- **point sources**, where there is a defined and usually identifiable source of pollutant or pollutants;
- **nonpoint or diffuse sources**, which are widely spread and difficult to clearly identify;
- **diffuse point sources**, which consist of many small point sources.

The approach to considering each pollution source is slightly different, although there will, of course, be circumstances where there is overlap between the categories. In general, diffuse sources of pollution are more difficult to control than point sources, particularly where systems such as pit latrines and septic tanks are established.

Spills of many chemicals found in urban areas (including petroleum and fuel oils) are also a source of contamination of both groundwaters and surface waters. The volatile components of petroleum oils may penetrate some types of plastic water pipes if these chemicals contaminate the ground surrounding the pipe. Choice of materials for water distribution should take into account such risks and should consider whether pipes are to be laid through contaminated ground.

Table 5.1 Chemicals derived from human settlements

Source category	Activity or hydrological event	Source description	Target water body	Chemicals of concern	Remarks
Point source	On-site sanitation and sewerage	Sanitation facilities, including sewage treatment plants	Surface waters and groundwaters	Nitrate, ammonia	Pit latrines of individual houses should also be taken into account as diffuse point sources
	Waste disposal (land reclamation)	Waste disposal sites	Mainly groundwater	Nitrate, ammonia, other chemicals contained in the waste (in case of industrial waste disposal site)	Past waste disposal sites are also important sources of chemicals. Industrial waste is a more important source of chemicals than domestic waste. Controlled waste disposal may also contaminate surface waters and groundwaters.
Diffuse point source	Fuel storage	Fuel stands, small industries, etc.	Mainly groundwater	Petroleum hydrocarbons, benzene, ethylbenzene, toluene and xylene	Attention to both current and historical sites is necessary
	Chlorinated solvent use	Small industries, cleaning shops, etc	Mainly groundwater	Trichloroethylene, tetrachloroethylene, trichloroethane	Attention to both current and historical sites is necessary
	Pesticide application	Roadside greens, drinking-water storage tanks, etc	Groundwater and drinking-water	Pesticides	Pesticide application to a drinking-water storage tank leads directly to contamination of drinking-water
	Any other urban activities	Small industries, public facilities and individual houses	Surface waters and groundwaters	Unspecified	This type of chemical contamination is very important where there are no adequate sewerage systems
Nonpoint source	Urban runoff	Roads, roofs, open spaces and other sources relating to the activities as written above	Surface waters and groundwaters	Nitrate, ammonia, heavy metals, pesticides, other organic chemicals	Deposits during a dry-weather period (e.g. atmospheric fallout of suspended particulate matter) will be flushed out, together with rainwater runoff

6.2 Data sources

In addition to the general types of data sources discussed in other chapters, it may be useful to make enquires with:

- water supply and wastewater agencies;
- local government and municipal authorities;
- environmental agencies.

6.3 Sewage systems and on-site sanitation

In many cities and towns, a reticulated sewage system collects sewage from domestic premises, public buildings and industrial premises. The sewage is carried to a central treatment works, where it undergoes a number of possible treatments that vary in their ability to break down or remove contaminants. The treated effluent is then discharged, often to a river. In most cases, the point of discharge will be below the city or town, but the impact of such effluent on drinking-water abstracted downstream will depend on the efficiency of the treatment and the quality of the effluent. Indirect reuse of wastewater discharged to rivers or lakes, where it may undergo dilution and further natural purification, has been practised widely for many years. A range of contaminants may be present in wastewater, depending on the nature of the raw sewage and the efficiency of treatment, but these are likely to include nutrients such as nitrogen and phosphorus (unless there is specific treatment to remove nutrients). Many cities and towns on the coast discharge effluent to the sea — a process that does not impact on drinking-water. Less frequently, treated effluent may be used for groundwater recharge.

Poorly maintained or damaged sewers that leak may also contaminate water resources. Where sewers run close to drinking-water mains there is a danger that more direct contamination through ingress into the water mains may occur. System failures may also lead to the discharge of untreated sewage into water bodies.

Sewage treatment produces biosolids (sewage sludge). These may be used as a soil conditioner in agriculture or for other purposes, such as land reclamation. Biosolids that are not used for these purposes are disposed of in various ways, including by landfill. In some circumstances, the disposal of biosolids may give rise to leaching, particularly of nitrates. Where biosolids are heavily contaminated with industrial waste, such as heavy metals, these contaminants may also need to be considered.

In settlements where there is little or no reticulated sewerage, human excrement is generally disposed of on-site through pit latrines, septic tanks or leach fields. When pit latrines and septic tanks are badly sited, constructed or maintained, they can contaminate local water supplies, particularly with nitrate. Nitrate concentrations in shallow groundwater commonly exceed drinking-water guidelines in areas with on-site sanitation (BGS, 2001). In some urban settings, other chemicals (including petroleum hydrocarbons, household chemicals and even solvents) may be disposed of through latrines, leading to localized water contamination problems from these chemicals.

Box 6.1 summarizes the main risk factors associated with on-site sanitation and sewage systems.

Box 6.1 Risk factors — on-site sanitation and sewers

Site suitability

On-site sanitation systems are:

- used in the vicinity of a potable water supply
- located in the vicinity of a waterway
- located in an area where there is little soil cover and bedrock is exposed
- located near open wells, sinkholes or other features that allow direct access to the water table
- located where the water table is close to the surface (e.g. it can be readily exposed by a hole dug with a shovel at the end of the wet season).

Sewer lines are installed below the water table.

Composition of the waste

The on-site sanitation system receives wastes from an industrial facility.

Discharges to the sewerage system are unlicensed and unregulated.

Operation and maintenance

Treatment plants and pumping stations are operated without emergency storage facilities to cope with system breakdowns.

Treatment plants are operated without ongoing monitoring of the quality of wastewater entering the plant.

Sewer pipelines are operated without an ongoing regime of inspection and testing.

6.4 Waste disposal

Household and general waste in some urban areas may be disposed of through uncontrolled dumping in vacant areas. In low-lying swampy areas, this form of disposal may be seen as a form of land reclamation. If this disposal is on land associated with surface water collection or groundwater recharge, the potential exists for various chemicals present in the waste to contaminate the water resource. The decay of putrescible organic material within the waste generates considerable amounts of leachate, which can easily percolate into groundwater, especially in low-lying areas where the water table is shallow.

In cities where urban waste is deposited in municipal landfills, there may be limited control over the type of waste deposited at a particular site. Where landfill sites are unlined or unconfined, leachate can potentially pollute groundwater and surface water. The leachate may contain a range of chemical contaminants, including high levels of phenols (which can give rise to significant taste and odour problems in drinking-water following chlorination), ammonia, nitrate and heavy metals. Depending on local hydrogeological conditions, a groundwater contamination plume from a waste disposal site may extend a considerable

distance in the direction of groundwater flow from the site, and may affect the quality of groundwater over a large area.

Box 6.2 summarizes the main risk factors associated with waste deposition.

Box 6.2 Risk factors — waste deposition

Site suitability

Waste is deposited:

- near a source of potable water
- near a waterway that links to a source of potable water
- near open wells, sinkholes, or other features that allow leachate direct access to the water table
- in an area where there is little soil cover and/or bedrock is exposed
- where the water table is close to the surface (e.g. it can be readily exposed by a hole dug with a shovel at the end of the wet season).

Composition of the waste

The waste site receives wastes from one or more industrial facilities.

Sewage or the contents of latrines is deposited at the site.

Operation and maintenance

Wastes have been deposited in an unregulated way with no form of containment or lining to the site.

The site receives significant rainfall.

6.5 Urban runoff

6.5.1 General considerations

Urban runoff will contain both chemical and microbiological contaminants, the range and concentrations of which can vary considerably over short periods of time. As the area of impermeable surfaces increases, the problem of stormwater collection and disposal becomes more significant. The major sources of contamination of stormwater include:

- substances deposited on impermeable surfaces from:
 - motor vehicles (leakage of fuel, lead from exhaust, metals from brake and rubber and other substances from wear of tyres);
 - atmospheric fallout of suspended particulate matter;
 - salts used for deicing;
- accidental and deliberate spills of industrial effluent into stormwater systems.

6.5.2 Pathways of contamination by urban runoff

Groundwater contamination is most likely where stormwater is discharged into soakaways (e.g. pits filled with rubble to speed transfer to groundwater) or infiltration areas, and where the aquifer is vulnerable. However, in many cases, stormwater is collected in the drainage system, which may discharge into sewers. Stormwater or (when sewer capacity is exceeded) a combination of stormwater and diluted raw sewage, may be discharged into surface waters.

Box 6.3 summarizes the main risk factors associated with urban runoff.

Box 6.3 Risk factors — disposal of urban runoff

Site suitability

Stormwater/urban runoff is discharged to ground close to a well used for potable water supply.

Stormwater is discharged:

- to a surface water close to a potable water supply point
- into sinkholes or other features typical of limestone that link to groundwater used for drinking-water
- to a soakwell or infiltration basin where the water table is close to the surface.

pH

The pH of the stormwater is less than 4.5.

6.6 Fuel storage sites

The leakage of fuels from large storage tanks is a significant source of groundwater contamination in some regions, particularly where the storage and handling of fuels is poor. Many oils can pool on the surface of aquifers, causing long-term contamination. The more volatile fuels (e.g. gasoline) contain compounds that will dissolve in water, in particular, the BTEX compounds — benzene, toluene, ethylbenzene, and xylenes. Unleaded gasoline may also contain oxygenate compounds that improve combustion. The most common of these is methyl tert-butyl ether (MTBE), which has caused significant contamination of groundwater in some countries, particularly the United States of America (USA), because of its high solubility in water and its slow degradation. MTBE is of concern for drinking-water because it has a very low taste and odour threshold. Other fuels (e.g. diesel) also contain water-soluble components, such as the trimethylbenzenes, which have a very low taste and odour threshold. Drinking-water contaminated with these fuels can be unacceptable to consumers.

Many countries have introduced regulations for the construction of underground and overground fuel storage tanks and pipelines that will significantly reduce the risks associated with fuel. Relatively small leaks of a few litres per day may not be easily noticed but, over an extended period of time, can give rise to significant problems. Such leaks can also saturate soil, creating the potential for long-term contamination of groundwater.

Box 6.4 summarizes the main risk factors associated with fuel leakages.

Box 6.4 Risk factors — fuel storage

Fuels are stored in tanks, above or below ground, that are not of an appropriate standard to prevent leakage.

Storage tanks are not checked for leaks and are not monitored to detect leaks.

Water supply wells, including tubewells, are located close to fuel storage tanks or a site previously used for bulk fuel storage.

Petrol or diesel-like odours have been reported by water consumers.

6.7 Chlorinated solvents

A number of small chlorinated organic molecules, such as tri- and tetrachloroethylene, are used as solvents for metal degreasing and drycleaning. These chemical compounds are only sparingly soluble in water but are miscible with water. When discharged or spilled onto the ground they rapidly soak through the soil and, where the aquifer is vulnerable to surface contamination, they percolate through the ground to the aquifer. The rate of degradation of these chemicals is extremely slow and they have caused significant pollution of groundwater used for drinking-water. In the past, waste solvents were disposed of into shallow pits, in the expectation that they would evaporate. Although this practice is no longer common, it has resulted in significant areas of historical pollution of groundwater dating back many decades. In some cases, the subsequent development of the aquifer as a drinking-water source has resulted in these chemicals being drawn to the groundwater abstraction point after an extended period of pumping.

Box 6.5 summarizes the main risk factors associated with chlorinated solvents.

Box 6.5 Risk factors — chlorinated solvents

Groundwater is used for water supply in an urban area where chlorinated solvents are, or have been, stored, used or disposed of.

6.8 Public health and vector control

Where public health agencies use pesticides for public health and vector control, it is most appropriate to refer to the agency responsible for vector control, to determine which chemicals are used and the management practices employed. Where the chemicals are applied in circumstances that affect drinking-water either directly or indirectly, the likely impact needs to be considered. However, there is a balance to be struck between the potential toxicity of the pesticides and the risks from insectborne diseases.

Herbicides are sometimes also used in urban areas for control of weeds on railway lines and roadside verges, and around areas of hard standing. Some of the herbicides used are sufficiently persistent to be able to be washed into drains or soil, and possibly percolate into groundwater. One of the most common of these herbicides is atrazine, which has been found in the groundwater of many countries. Awareness of the potential for contaminating

groundwater and careful selection of herbicides, where they are required, has significantly decreased contamination in many of the areas where it was common.

6.9 Reference

BGS (British Geological Survey) (2001). Assessing risk to groundwater from on-site sanitation, available online at <http://bgs.uk/hydrogeology/argoss>