14 Potable Water Use from Aquifers Connected to Irrigation of Residual Water

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14.1 Introduction[1]

Four important challenges arise when seeking to use an aquifer for potable water that is recharged with wastewater through farmland infiltration: a) to precisely determine organic compound concentrations, primarily non-regulated and emerging; b) to identify pathogenic and opportunistic micro-organisms of different taxa; c) to establish an efficient and economic water treatment system for purification, and d) to estimate and prevent possible impacts on public health and the environment from purification residues.

This chapter provides a methodological approach to the problem of water quality and emerging contaminants in an aquifer, with the focus on sanitary risk; in other words, probability-prevention of adverse effects on public and environmental health. Initially, it was essential to establish groups of contaminants in accordance with their physico-chemical characteristics, size and molecular structure, for the purpose of providing compound indicators for the treatability tests in the laboratory and on-site. Once the contaminants that can serve as indicators of the presence of emerging contaminants in a contaminated aquifer have been established, the next step is to determine the most appropriate type of treatment for their removal and disposal, taking into account that the water is required for human consumption.

14.2 Background

Water is the main component of living organisms and is therefore a primary necessity for human and economic development in Mexico. Invariably, low quality of water is associated with a low standard of living and the presence of diseases caused by enteric pathogens or chemical contaminants, which affect the social and economic environment of the inhabitants who do not have access to it. Consequently, its availability must be viewed on the basis of quantity and quality (Elimelech, 2006), which are defined through a series of parameters that must be controlled by those responsible for providing water services to the population.

In addition to access to potable water being affected by problems that arise in the contamination control of supply sources from emissions and discharges associated with economic activities, domestic discharge represents one of the main sources of contamination, due to the indiscriminate use of detergents, whiteners, suntan lotions, softeners, fragrances, shampoos, and other personal care items, as well as pharmaceuticals, plasticizers, and fire propellants and retardants, which have recently emerged as contaminants that impact on public health, wildlife and the environment in general (Lopez/Barceló, 2008).

As a result of today's urban lifestyle, a large volume of wastewater and solid residues of variable composition is spilled into the environment, where a broad range of pathogenic micro-organisms and polluting chemicals can potentially affect public health and the environment. Of particular sanitary importance are the emerging and re-emerging pathogens, as well as non-regulated and emerging chemical contaminants that can also enter environmental compartments through different routes and mechanisms (figure 14.1).

The contamination of water resources can occur directly when spilling raw or treated wastewater discharge into receiving surface water bodies, or indirectly when disposing of wastewater, excreta, or solid waste into the ground, where, after adsorption, transformation, leaching, and infiltration processes (Papadopoulou et al., 2007), there is a possibility that the microbiological and chemical quality of the groundwater will be altered.

1 Keywords: Emerging contaminants, contaminated aquifers, potable water, potabilization, membrane processes.

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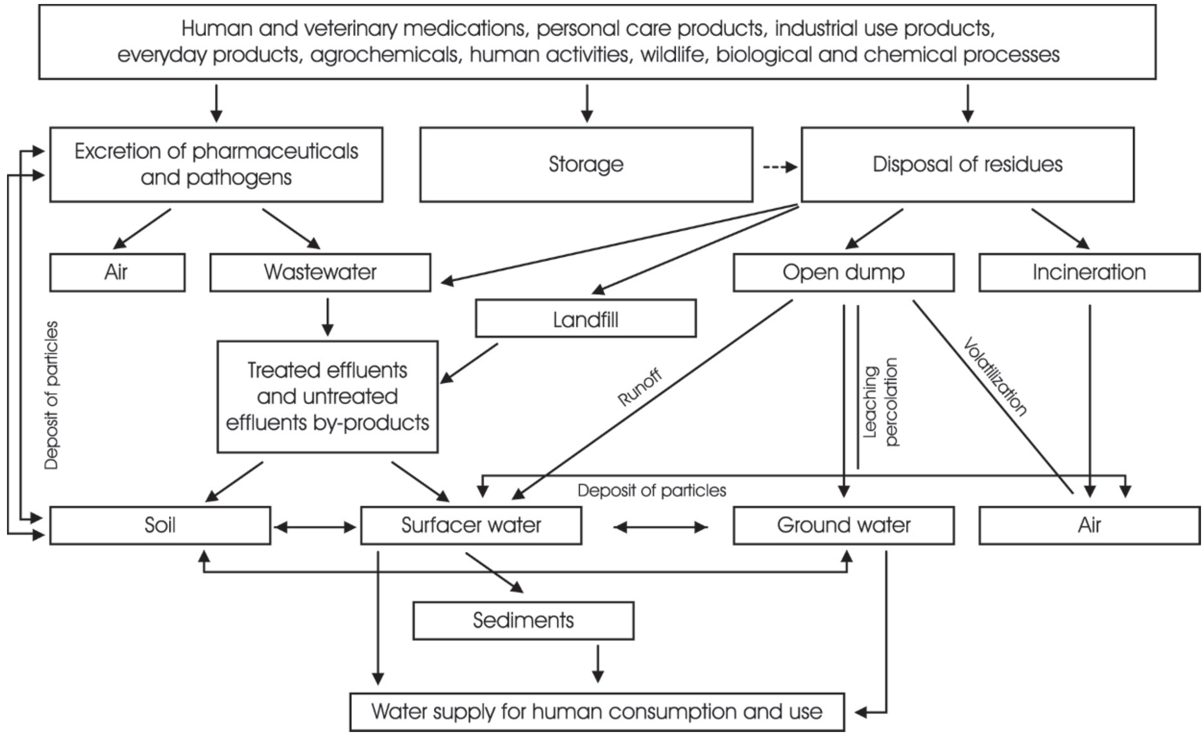
Figure 14.1: Routes of entry of emerging contaminants into the environment and potable water. S**ource:** Adapted from Blasco and Dell Valls (2008).



Emerging contaminants are previously unknown or unrecognized contaminants that may have been present in the environment, but that have recently generated concern over their possible short- and longer-term impacts (Lopez/Barceló, 2008). These may include chemical substances of anthropogenic origin that are frequently incorporated into the atmosphere and that may be dangerous even if they are not persistent.

The following list includes a broad range of everyday waste products (table 14.1), some of which have recently been included in the list of high-priority substances in water, others that are candidates for regulation, and others that are considered a research priority (Jacangelo et al., 2006).

Despite the fact that analytical techniques have evolved sufficiently since the 1990s to detect some organic compounds in concentrations as low as parts per trillion and allowed the identification of a broad range of pharmaceuticals, personal care products, pesticides and veterinary products in surface water (Kolpin et al., 2002; Tixier et al., 2003) and groundwater (Sacher et al., 2001), relatively little is known about the presence of these types of contaminants and their transformations and impact on different environmental compartments or the risks to public health, water and land organisms and wildlife (Blasco/DelValls, 2008). This is why they have not yet been fully regulated and why the availability of methods for their analysis in the laboratory remains limited (Richardson, 2003; Gross et al., 2008).

Some conventional purification water treatment processes have shown a substantial yet incomplete degradation of, or the removal of, organic compounds (Stackelberg et al., 2007), so in reality the effectiveness and efficiency of the treatment processes for the removal, transformation or inactivity of this type of contaminants is unknown, as are the effects of disinfectants on emerging and re-emerging pathogens. Furthermore, the negative effects are not necessarily associated with a high persistence. In this case, high production and consumption of these contaminants is relevant, as is their continuous introduction into the environment.

Even though some pesticides are now subject to legislation in Mexico, they recently sparked renewed interest because degradation or transformation products are sometimes as toxic as, or more toxic than the original molecule (Escher et al., 2008). Awareness of the risk of agents such as perfluorinated detergents or pharmaceuticals in the environment is relatively recent and so there is still not enough information to carry

Table 14.1: Some emerging chemical pollutant groups. **Source:** Results from the research team,

Personal care products	Frequent use products	Human and veterinary pharmaceuticals	Miscellaneous
Fragrances Hair care Dental care Skin care Suntan and blocks Surfactants Bath additives	Flavourings Condiments Dyes Food preservatives Goods preservatives Surfactants Some stimulants Cleaning products	Hormones Antidepressants Analgesics and anti-inflammatories (non-steroidals) Antipyretics Antibiotics Anti-epileptics Lipid and glucose regulators Antitussives Antihistamines Bronchodilators Blood pressure regulators Anticoagulants Histamines Drugs of abuse Metabolites and breakdown products Others	PCBs Polyaromatic hydrocarbons Petroleum hydrocarbons Veterinary products Pesticides Domestic insecticides Deodorizers Synthetic dyes Fire retardants Organotins Plasticizers (phthalates) and anti-corrosives Solvents Non-essential metals and metalloids Perfluorinated compounds Disinfection by-products

out a proper valuation of their impact. Furthermore, many of them, including bromate fire retardants, alkylphenol ethoxylate detergents, and some pharmaceuticals, are endocrine disruptors with a potential to alter growth, development, reproduction and neurobehavioural performance in animal and human models. One of the better documented evidences is the feminization of superior water organisms (Fent et al., 2006).

As concerns pathogens, of the 1,407 species of micro-organisms that are known as disease producers in human beings, 177 (13 per cent) of these species are considered emerging or re-emerging and 77 (37 per cent) of these are viruses or prions; 54 (10 per cent) are bacteria; 22 (7 per cent) are fungi; 14 (25 per cent) are protozoa and 10 (3 per cent) are helminths. These pathogens are not associated with specific animal hosts and can persist in different animal reservoirs – mammalian or not – and possess a biological flexibility that allows them to take advantage of the epidemiological opportunities that arise (Woolhouse/Sonya, 2005).

The emerging, re-emerging and non-regulated hydro-transmissible pathogens (table 14.2), include organisms that use a faecal-oral route as the primary transmission route. These may include *Cryptosporidium*, *Escherichia coli* O157, rotavirus, hepatitis virus and norovirus (or Norwalk virus), and other bacteria like *Legionella* that use different routes of transmission. Thus, the importance of water in the transmission of organisms recognized as emerging pathogens is continuously being evaluated with the new technological epidemiologist tools available. *Helicobacter pylorus* is a pathogen example that emerged as a potentially hydro-transmissible bacterium (Shahamat et al., 1993).

There have been few projects in Mexico related to the presence of emerging contaminants in wastewater and natural and potable water and these have all been developed in the Mezquital Valley where Irrigation Districts 03 and 100 are located. These areas use raw sewage water from Mexico City to irrigate farm crops. This water then recharges the Tula aquifer that supplies potable water to the inhabitants of the area.

It is clear that knowledge about these contaminants and their sanitary and environmental impacts is a problem that must be approached holistically with a focus on risk, mainly because four important challenges arise when the intention is to use an aquifer recharged with farmland wastewater from natural infiltration for potable purposes. We must:

a.) precisely determine organic compound concentrations, primarily non-regulated and emerging;
b.) identify pathogenic and opportunistic micro-organisms of different taxa;
c.) establish an efficient and economic water treatment system for purification, and
d.) estimate and prevent possible impacts from purification residues on public health and the environment.

Table 14.2: Potentially hydro-transmissible emerging, re-emerging and non-regulated pathogens. **Source:** Results from the research team.

Bacteria	Viruses	Protozoa
Aeromonas hydrophila	Bacteriophage	Free life ameoba (*Acanthamoeba*)
Escherichia coli (pathogen strains)	Adenovirus	Entamoeba histolytica
Helicobacter pilori	Calicivirus	Cyclospora cayetanensis
Mycobacterium avium	Coxsackievirus	Giardia lamblia
Salmonella spp	Echovirus	Naegleria fowlery
Shigella spp	Norovirus	Microsporidia
Vibrio spp	Rotavirus	Toxoplasma gondii
Yersinia spp	Poliovirus	
	Hepatitus virus	

14.3 Objective

To provide a methodology to respond to the presence of emerging contaminants in raw and treated wastewater used in farm irrigation and its impact on the water quality of an aquifer used for potable water supply, with a focus on public and environmental health.

14.3.1 Application in an Area of Interest and Current Situation

The Valle del Mezquital, located in the state of Hidalgo (figure 14.2), is a clear example of an aquifer recharge with raw and partially treated wastewaters based on its reuse in farming irrigation of approximately 90,000 hectares in Irrigation Districts 03 Tula (dependent on the Requena dam) and 100 Alfajayucan (dependent on the Endhó dam).

The aquifer of Valle del Mezquital is a source of potable water that helps to support the needs of Mexico City. Various water quality studies of groundwater have been carried out to evaluate water treatment technologies for the purification of water. These include the determination of some emerging organic contaminants, as well as some pathogens.

The study carried out by Downs et al. (1999) in Tezontepec and the Colorado Cerro spring concluded that nitrates are a water quality problem, and detected eight semivolatile non-regulated contaminants, seven polychlorinated biphenyls, and 11 trace metals.

Later, the same authors (2000) integrated chemical and microbiological tracers into a ‘general panorama’ to compare the effectiveness of two natural treatment processes in accordance with the site, water type, sampling day and indicator: a) an irrigation channel and a stabilization-storage dam – comparing on-site surface water samples before and after storage, and b) ground infiltration – groundwater flow – comparing surface water samples with groundwater samples (groundwaters adjacent to and near the site). The study concluded that semivolatile organic compound removal is efficient using a process that combines volatilization, photolysis, biodegradation, sorbing, precipitation and sedimentation. The ground appears to operate like a slow sand filter. Most likely removal during the groundwater flow is the dominant process. The study suggests that the environmental conditions (high temperature, large amounts of substrate for the micro-organisms, high level of insulation and retention times in dams and channels) appear to encourage natural degradation processes. However, the study considers that since the system was not completely evaluated, important potential risks to public health may exist.

Jiménez et al. (2004), analysing the wastewater of the Mexico City and Tula aquifers, concluded that the supply sources show low concentrations of emerging contaminants; however, there are exact sources showing the presence of carbamazepine, nonylphenols and salicylic acid and they do not comply with the maximum permissible limit for total dissolved solids, aluminium nitrates and fluorides (Jiménez and Chávez, 2004). They also detected bacteria, bacteriophages and protozoa in some wells, springs, and watermills.

These studies generally conclude that the ground treatment capacity in Valle del Mezquital produces an aquifer of ‘acceptable quality’, yet they recommend advanced treatment for potable use, changes in the regulations and research into the transportation and removal of contaminants. There is still no evidence to be found in available information on the determination of persistent contaminants such as some sulfa or synthetic type antibiotics, polychlorinated biphenyl, or aromatic hydrocarbons and dyes, among others. Also, the contaminants that are generated inside Valle del Mezquital as a result of the different economic ac-

Figure 14.2: Localization of the Mezquital Valley. **Source:** Google Earth.

tivities (for example: dental clinics, agro-chemical clinics and hospitals, doctors' surgeries, residues generated by cattle, veterinary products, or hydrocarbons from the refinery at Tula) were not identified either.

It is also important to consider that in the case of emerging pathogens, veterinary antibiotic use to promote animal growth encourages resistance to drugs that were used initially or were eventually developed for use by humans. The emergence of this resistance to bacteria possibly occurs with exposure to concentrations lower than the detection limits of current methods used in the monitoring systems (Smith et al., 2002).

The situation inside the Tula Valley allows us to assume that the water issue is complex, particularly if we also consider that there are 128 deep wells, 61 springs and 18 diverse sources (watermills, galleries, conduction lines, rivers). It is important to take into account that the different uses of the ground: residential, agricultural, cattle and industrial, with their variants (petrochemical, textile, cement, limekiln, metallurgical, electrical energy, veterinary products, foods, manufacturing, chemical, and agrochemical), can affect public and environmental health.

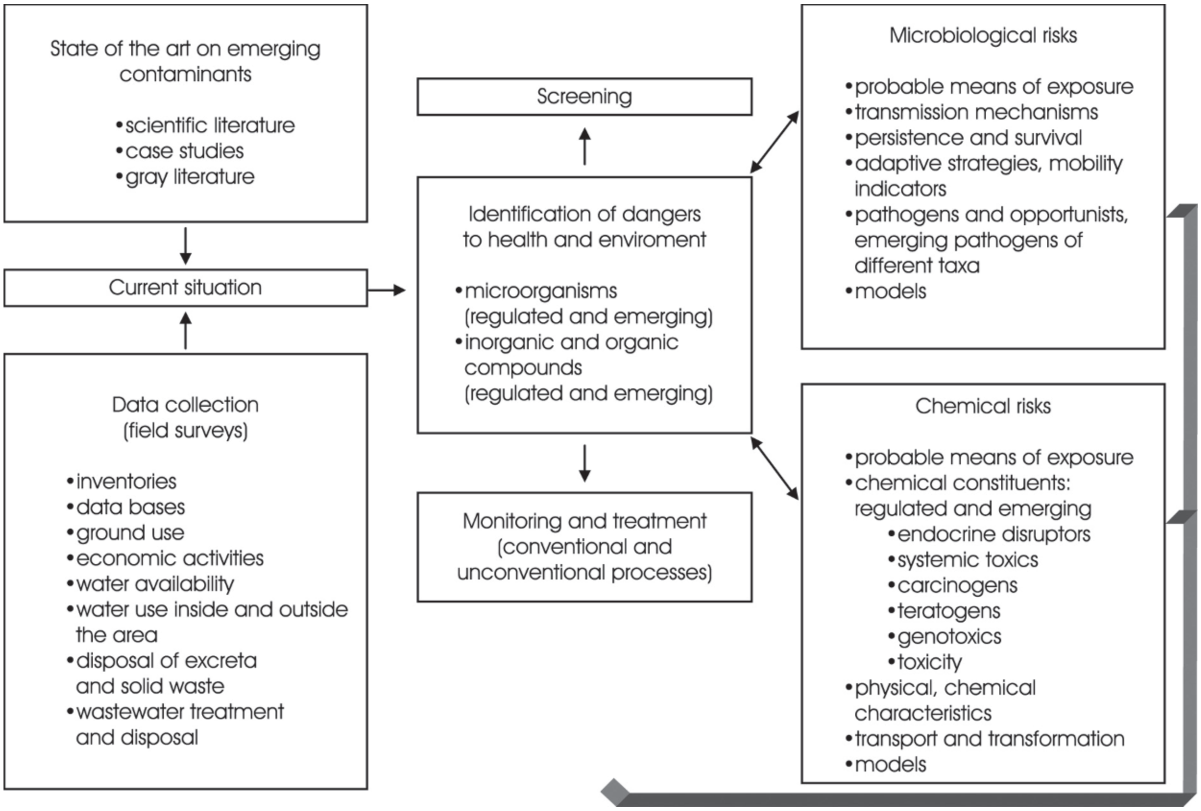
It is not known whether the wastewater treatment systems operate efficiently in the five municipalities that have them or what type of control exists for the disposal of solid waste that can alter the quality of groundwater through leaching.

14.4 Methodology

A study of this nature requires a holistic approach with a focus on sanitary risk (figure 14.3); in other words, a probability-prevention of adverse effects on public and environmental health with the application of methodologies to evaluate environmental and public health risks, as well as the identification of high-priority emerging contaminants for the recharge process of the aquifer, considering short- and long-term impacts. For example:

a.) micro-organisms (environmental reservoirs, pathogenicity, infective doses, latency, adaptive strategies, persistence and resistance to treatment and disinfection processes);
b.) chemical contaminants (neurotoxicity and other systematic poisonous effects, genotoxicity, estrogenicity, carcinogenicity, among others);
c.) identification and analysis of national, regional, and international regulations concerning natural

Figure 14.3: Sanitary risk focus to respond to the problem of aquifer recharge in an irrigation zone with raw sewage water. **Source:** Results from the research team.



and artificial recharge of aquifers for potable use (opportunities and barriers);

d.) determination of the capacity of existing purification systems for the removal of emerging contaminants.

14.5 Proposed Methodology

The methodology proposed as an alternative solution for this problem has various stages:

14.5.1 Screening

The relevant questions are: What contaminants are present? What concentrations are present in the water? How often are they spilled into the water? What are the possible mechanisms for transformation? In what other environmental compartments could they be present?

14.5.2 Information Review and Analysis

To respond to these questions it is essential to carry out a state-of-the-art study on the physicochemical and microbiological parameters of sanitary and environmental importance in plans to recharge aquifers for potable use, with the objective of establishing the universe of emerging and non-regulated contaminants.

In the case of the Valle del Mezquital aquifer, the recharge is basically through infiltration or percolation of raw sewage (coming from Mexico City) or partially treated sewage (the hydro-agriculture infrastructure eliminates some suspended pathogens, solids and some chemical contaminants) that is used for crops (Downs et al., 2000). Consequently, it will be necessary to review the diffusion processes and the ground-aquifer systems to determine the destination of the contaminants in the recharge site, including particulated matter, dissolved organic components, nutrients (nitrogen, phosphorus) and micro-organisms, always keeping in mind public and environmental health protection.

It will also be necessary to identify precise and non-precise sources of contamination within the Valle del Mezquital, since these impacts on surface water quality, the ground and potentially the leachates that infiltrate the aquifer.

14.5.3 Pre-screening of Contaminants

The identification of danger includes a screening of the possible contaminants that arrive at the aquifer from wastewaters used in irrigation, as well as those produced in the recharge zone as a result of farming practices and other industrial activities in the zone. This can be carried out through surveys that allow data to be obtained on the use of agrochemicals (inventories), wastewater discharge (industrial inventory), availability and uses of groundwater, disposition of excreta and solid waste, and treatment and disposal of wastewaters.

An important challenge is posed by the products used in personal care, different daily activities, products used in industry, pharmaceuticals for human and veterinary consumption (including hormones), and the consumption of illegal drugs. The most important compound groups considered in the specialized international literature are:

- brominated fire retardants;
- disinfection sub-products;
- gasoline additives;
- hormones and other endocrine disruptors;
- organometallic (organotin) compounds;
- perfluorinated compounds;
- pharmaceuticals and personal care products;
- polar pesticides, their degradation and metabolite products;
- surfactants and their metabolites; and
- organophosphate fire retardants and plasticizers.

It is possible to obtain data by consulting the databases of environmental agencies in different countries, specialized databases, case studies, environmental monitoring programme reports, listings of high-priority substances, and basic medicine charts of the Ministry of Health (SSPA), as well as information available in other national institutions. For example, the following are some of the most common pharmaceutical products in Mexico:

- antibiotics: sulfa drugs, penicillin, tetracycline;
- stimulants: caffeine and other prescribed stimulants;
- antiasthmatics and bronchodilators: cimetidine, salbutamol;
- stimulant medications and anti-depressants;
- analgesics and anti-inflammatories: antipirine, codeine, hydrocodone;
- hyperglycaemics: metformin;
- antipyretics: acetaminophen;
- blood pressure control: dialtiazen, nifedipine;
- histamines: ranitidina;
- hormonal therapy: antioestrogenics, ovulation promoters, birth control.

The information is concentrated into a matrix, where lists can be cross-referenced. The frequency with which the agents are spilled into the environment will become a basic selection criterion to monitor a particular polluting agent in the study. Physicochemical and persistence chemicals will also be considered, as will biomagnification and bioaccumulation capacities.

14.5.4 Prioritization of Contaminants

Prioritization is based on the application of risk assessment methodology for public and environmental health. Particular care must be taken with agents from the list of contaminants obtained in the previous phase that appear in the scientific literature with enough evidence to conclude that they have a toxicological effect and that they are frequently detected in industrial and municipal waste products. Viruses and other pathogens in non-cultivable viable state must also be considered, along with nanomaterials.

Also, the observable effects in environmental exposures (figure 14.4) that appear over the long term or where concentrations in the water are generally small must also be kept in mind. When speaking of dangerous and emerging chemical contaminants, the concentrations are arranged in order of pico-, nano-, and micrograms per litre.

The basic effects to include in a new matrix when considering what is appropriate for potentially exposed organisms are: birth and development defects, development retardation, neurotoxicity, cancer, effects on the endocrine system, gastrointestinal (including hepatotoxicity), hematological, hormonal activity, immune system (including sensitization and allergies), renal system, reproduction and fertility, skin, respiratory system, toxicity of wildlife and environment, persistence, bioaccumulation and biomagnification in water and on land, including humans.

The weight of evidence is an important criterion and for this assessment a scale of values and ranking aspects must be designed for the polluting agent, water organisms, wild flora and fauna, and more vulnerable sub-groups of the population such as developing organisms (tables 14.3 and 14.4).

Figure 14.4: Theoretical framework of the attempts to trace organic compounds and their relative significance for human health risks (prioritization). **Source:** Adapted from Asano and Cotruvo (2004).

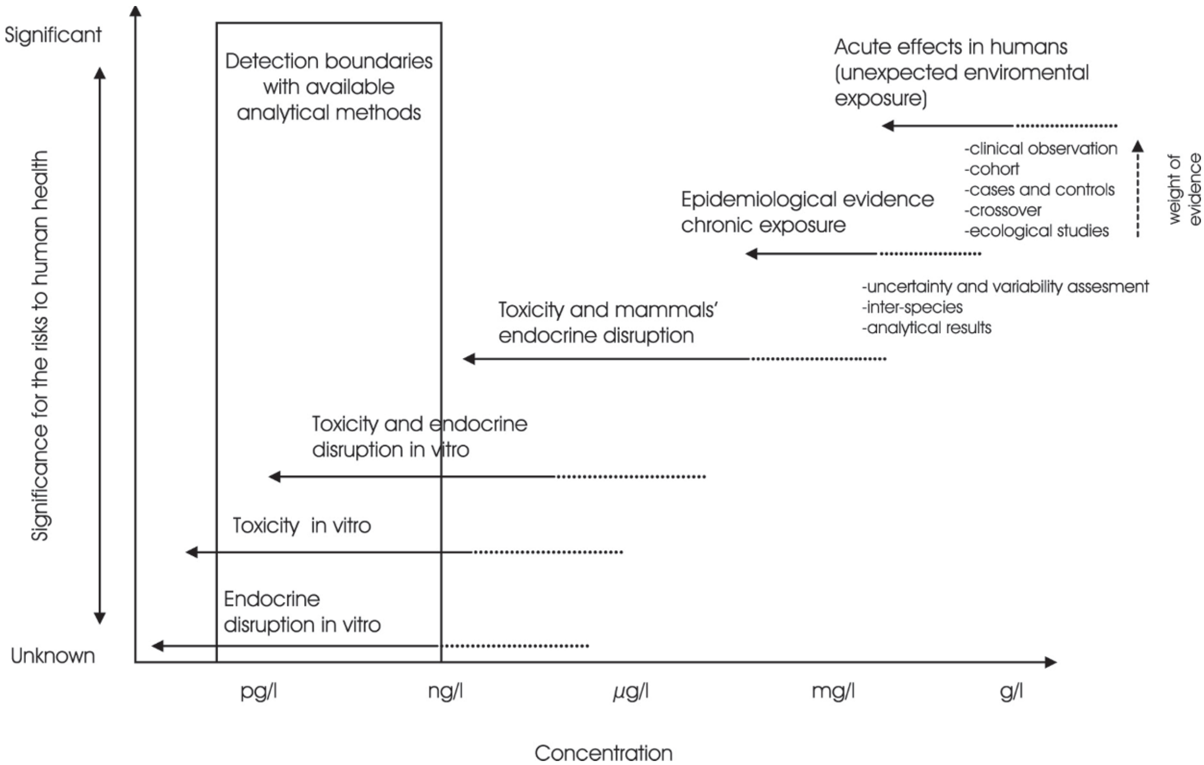


Table 14.3: Prioritization: effects of low dose chemicals. **Source:** Results from research team.

Effect on health	Most vulnerable group	Example of associated chemicals
Cancer	All	PAHs, some plaguicides, metals and solvents, PCBs
Cardiovascular disease	Particularly older adults	Arsenic, lead, cadmium, cobalt, calcium, magnesium
Reproductive: Quality and quantity of sperm, testicular function, fecundity and fertility, abortions, gender proportions, abnormalities in reproductive organs	Adults in reproductive years	PCBs, some pesticides organochlorides, some phthalates Endochrine disruptors
Development	Foetus and children	Lead, mercury, hormonal disruptors
Immune system	Foetus and children	Some endocrine disruptors
Nervous system disorders	Foetus and children	PCBs, heavy metals (mercury, lead, manganese, aluminium), organic solvents, some pesticides, some hormonal disruptors

It is important to mention that human experimentation has ethical limitations in cases concerning exposure to contaminants with unknown effects, so that it is often necessary to resort to the epidemiological evidence of observational studies as well as animal studies and test-tube models where it is not always possible to confirm causality.

14.5.5 Sampling and Sampling Analysis

Environmental assessment studies must also be included in prioritization studies. For example: destination and transformations in the environment, environmental monitoring, and ecological effects. In the Valle del Mezquital, the treatment 'capacity' of the hydro-

Table 14.4: High priority: hormonal disruptors. **Source:** Results from the research team.

Persistent organic contaminants	Polychlorinated biphenyls Dioxins DDT and metabolites	Alteration of the metabolism/transportation of steroid hormones (EH), interaction with thyroid hormone, neuroendocrine effects
Products used in farming and livestock	Insecticides Organochlorides Triazoles, imidazoles Triazines Diethyldithiocarbamate	Oestrogenic and/or androgenic effects EH biosynthesis inhibition Hypothalamus-hypophysis-gonadal Thyrostatic effects
Frequent use industrial products	Nonyl and octyl phenols Bisphenol A Some phthalates Polybrominated fire retardants Organotins Parabens UV-screen	Estrogenic agonist and receptors Estrogenic agonist receptor Prognana agonist, effects on the biosynthesis of the steroid hormone Interaction with prognana, altering homeostasis of the steroid and thyroid hormones Aromatase inhibitors Oestrogenic agonist and receptors Oestrogenic agonist receptor

Table 14.5: Wastewater and methods of analysis. **Source:** Results from the research team.

Bacteria	**Virus**	**Protozoa**
Aeromonas hydrophila *Escherichia coli* O:157 Helicobacter pylori Mycobacterium avium *Salmonella* spp *Shigella* spp *Vibrio* spp *Yersinia* spp	Bacteriophage. F+ Infect masculine stocks of E. coli (they have pili); specifically of faeces. Groups II and III are specifically of human stocks and I and IV of animal stocks Enterovirus	Free life amoebas *(Acanthamoeba)* *Entamoeba histolytica* *Cyclospora cayetanensis* *Microsporidia* *Cryptosporidium* *Toxoplasma gondii*
Analytical methods		
Enrichment, isolation through selective means, identification through batteries of biochemical tests and serologic confirmation (ELISA)	Polymerase chain reaction (PCR) Bacteriophage plate count	Microscopy, including indicator culture and vital dye ELISA

agriculture infrastructure must be assessed; in other words, the storage effects on the water of the dams and the route of the water through the irrigation channels (table 14.5). To do this, samples of wastewater discharges that reach the areas of interest must be obtained, covering at least three sites considered influence sites for the aquifer in accordance with the following plan:

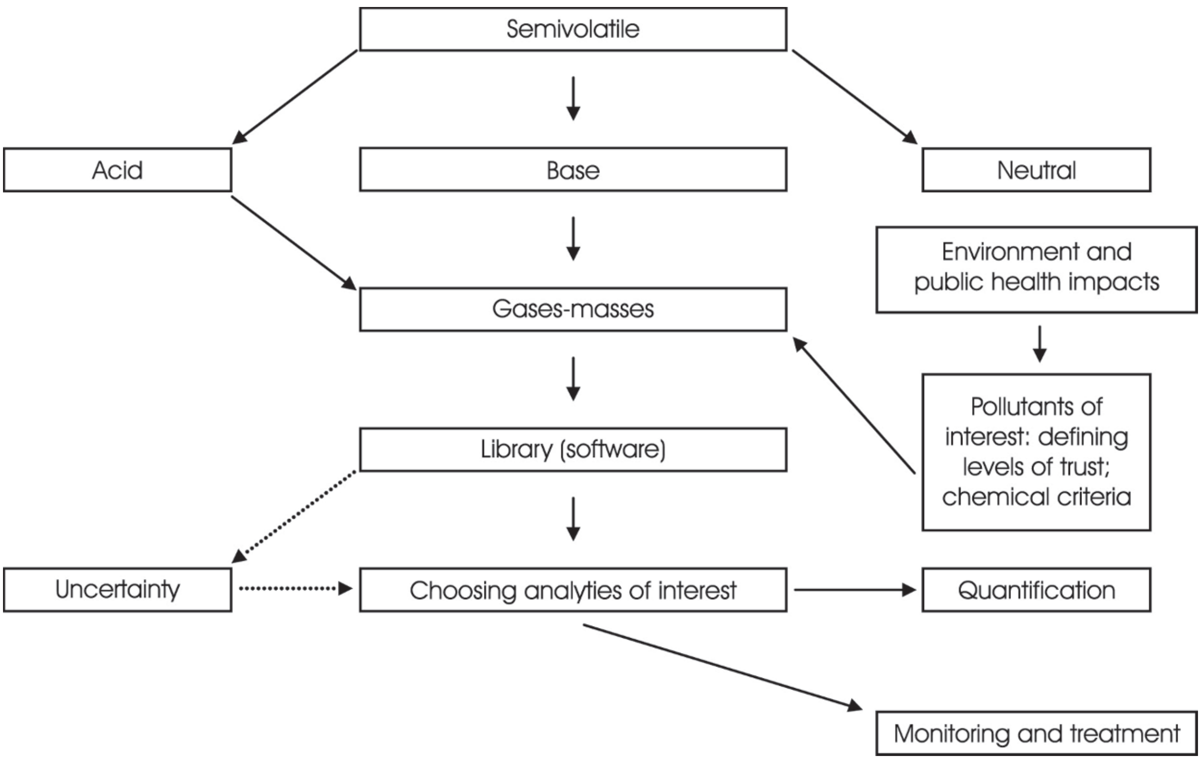
a.) *Bacteriological indicators*. Precise sample at time of greatest flow in accordance with national norms.
b.) *Pathogenic and opportunistic bacteria*. Concentration using Moore 24-hour hyssop, transported and preserved in mineral support until analysis in the laboratory.
c.) *Parasites and viruses*. Concentration in situ by means of filtration, in sample cartridges and specific pore size for each interest group.
d.) Establishment of analytical methods that allow the identification and quantification of microbiological contaminants in the laboratory, which may include any of the following:
e.) *Regulated, non-regulated and emerging organic compounds*. 24-hour composed sample, obtained, transported and preserved until analysis in accordance with national regulations and, if required, with the recommendations of international organizations or scientific publications.

Some studies suggest the use of formaldehyde to 1 per cent to prevent the degradation of some white compounds until the analysis. They also suggest that before the enrichment of the samples, they be filtered

Table 14.6: Methods for analyzing organic compounds. **Source:** Results from the research team.

Parameter	Method
Semivolatile and persistent organic compounds	Acid, base and neutral extraction. Gas chromatography/mass spectrometry
Pharmaceutical compounds	Chromatography of high resolution liquids/ Ionization/mass spectrometry
Antibiotics	Extractions for different groups. Extraction in solid phase, gas chromatography/ mass spectrometry
Hormones	Extraction in solid phase, gas chromatography/mass spectrometry

Figure 14.5: Strategy for the screening of semi-volatile organic compounds. **Source:** Results from the research team.



through fibre glass or cellulose, with a pore size that will depend on the content of organic matter.

Gas chromatography and high-resolution liquid chromatography are techniques par excellence in environmental analysis. They focus more on the analysis of non-polar and volatile compounds, non-volatile compounds such as pharmaceuticals and surfactants, personal care products, oestrogens and others, which can be determined after a derivation step.

It is advisable to obtain a second list of compounds for the different analysis methods from chromatograms and the available library, which should be compared with the theoretical list as well as with environmental and public health risk information systems (table 14.6). This will provide a definitive list of white contaminants or analytes of interest, which must be monitored twice more, to provide quantitative information of low water and rain. An example of the work strategy appears in figure 14.5.

14.6 Samples and Sampling Analysis

First, the relevance and efficiency of the methods of applicable treatment and disinfection must be analysed and then the treatability tests at the laboratory and directly at the site of interest must be carried out.

For the treatability test at the laboratory and on site, it is advisable to establish groups of contaminants in accordance with their physicochemical characteristics, size, and molecular structure, in order to have compound indicators. A first stage may consist of preparing a synthetic solution containing high-priority emerging contaminants, under controlled salinity conditions. In a second stage, it is possible to work directly with wastewater treated and enriched with the contaminants of interest.

Concerning purification, the use of nanofiltration membranes is a viable option for removing emerging organic contaminants because these types of systems consume less energy than inverse osmosis and produce water that requires minor amounts of remineralization. In some studies, nanofiltration membranes of a molecular cut of 200 daltons found on the market were tested and showed retentions of pharmaceuticals and hormones of up to 93 per cent with molecular weights between 194.2 and 318.1 g/mol, in addition to certain minerals (especially polyvalent cations and anions). Based on the quality of the rejections, it is important to analyse treatment alternatives such as oxidation-adsorption or advanced oxidation.

It is also advisable to carry out tests at the laboratory with contaminants of interest, and depending on the results, to test the most efficient method on a pilot scale (1 l/s), directly on the water supply source.

Another important aspect that must be taken into account in any kind of purification system that is found to be appropriate is the treatment and disposal of purification residues. The cost of this stage must be considered in the total cost of the treated water and must comply with regulations and available guidelines and recommendations.

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