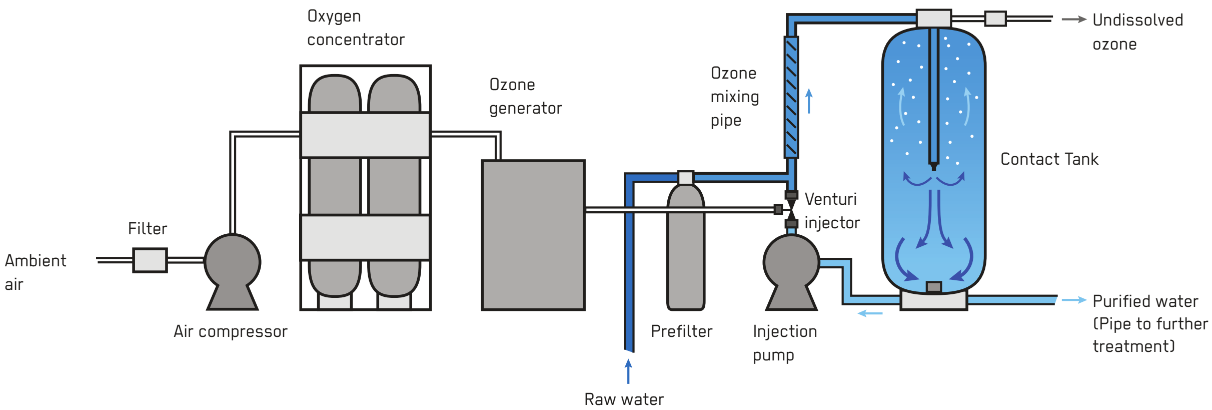
# Ozonation

| Response Phase | Application Level | Management Level | Objectives / Key Features |
|---|---|---|---|
| Acute Response<br>* Stabilisation<br>** Recovery | Household<br>Neighbourhood<br>** City | Household<br>Shared<br>** Public | Removal of organic contaminants |
| **Local Availability** | **Technical Complexity** | **Maturity Level** | |
| * Low | *** High | ** Medium | |




Ozonation is a water treatment process that destroys microorganisms and degrades organic pollutants through the infusion of ozone, a gas produced by subjecting oxygen molecules to a high electrical voltage. During emergencies, the technology is mainly applicable in the stabilisation and recovery phases in urban contexts, where the experience in using such systems already exists.

Ozonation (also referred to as ozonisation) is a chemical water treatment based on the infusion of ozone into water. Ozone is a gas composed of three oxygen atoms ($O_3$) and is one of the most powerful oxidants. In this advanced oxidation process, oxygen ($O_2$) is subjected to either a high electrical voltage or UV radiation to produce a very reactive species ($O_3$) that attacks a wide range of organic compounds and all microorganisms. Ozonation has a wide range of applications, as it is efficient for both disinfection and the degradation of organic and inorganic pollutants. The required amounts of ozone can be produced at the point of use, but the production requires a lot of energy and is therefore costly.

**Design Considerations:** The most common generators produce ozone ($O_3$) by subjecting oxygen ($O_2$) or air to a high electrical voltage ('Corona discharge-type generators') or to UV radiation (UV-type generators). Corona discharge-type generators are used for large-scale systems, producing ozone concentrations of 1–4.5 % by weight. UV-type generators achieve ozone concentrations of 0.1–0.001 % by weight and are used to treat smaller quantities of water. Ozone gas is transferred to the raw water via fine bubble diffusion or side-stream injection. In the contact tank, ozone reacts with the contaminants in the water, requiring only a short contact time (approximately 10–30 minutes). An off-gas system destroys any undissolved ozone.
The ozone gas molecule is highly unstable and therefore reactive toward a wide variety of water contaminants, such as inorganic (e.g. iron, manganese) and organic compounds (e.g. micropollutants) as well as microorganisms. Ozone attacks contaminants either directly or indirectly through its decomposition in water to form hydroxyl radicals (OH-), which react rapidly with many drinking water

contaminants. Ozone rapidly decomposes in water, making its lifespan very short (less than one hour) and rendering it unsuitable as a residual disinfectant, i.e. protecting the drinking water distribution system from regrowth/recontamination. Ozonation and Chlorination **(T.6, T.7)** can be used in tandem to inactivate a wide range of microorganisms at the treatment plant and to protect water during distribution/storage. Ozonation of water containing organic matter will produce assimilable organic carbon that allows biological regrowth in subsequent processes and the network. Therefore, Ozonation should be followed by a treatment process allowing biological degradation, such as Slow Sand Filtration **(T.9)** or GAC **(T.13)**.

**Materials:** Materials include oxygen, oxygen concentrator, ozone generator, pre-filter, injection pump, venture injector, contact tank and a reliable power supply **(see S.9–S.12)**. Local availability of materials will be limited.

**Applicability:** Ozone can be added at several points in drinking water treatment: as a pre-treatment (pre-Ozonation), after sedimentation and before filtration (intermediate Ozonation) or as a final disinfection step. As a pre-treatment, it reacts with micropollutants, iron, manganese and sulphur as well as compounds affecting the colour, odour and taste. The subsequent removal of degraded compounds is improved in subsequent treatment steps, e.g. sedimentation or filtration processes including Sand Filters **(T.2, T.9)** and GAC Filters **(T.13)**. In low turbidity water, ozone forms colloids ('micellisation process') that can be transformed to micro flocs by adding a small amount of coagulant, and these micro flocs are easily retained by sand filters.
To target organic compounds, the required amount of ozone and subsequent ozone decomposition is highly dependent on the quantity and types of contaminants. As a rule of thumb, the initial ozone demand is 2.5 mg ozone/mg of Chemical Oxygen Demand (COD). As a disinfectant to inactivate microbial pathogens in water, required ozone concentrations and contact times ('CT values') can be found in the WHO guideline for drinking-water quality. In general, it is more effective against many bacteria and viruses than chlorine and UV. For inactivating Cryptosporidium, however, WHO states that there are currently no accepted CT values (ozone concentration multiplied by contact time), as the results vary widely between studies and even between replicate trials for different temperatures and levels of inactivation.

**Operation and Maintenance:** The design, construction and O & M needs well-trained operators. The high-tech equipment is costly and has a high-power demand. Systems occasionally develop ozone leaks, requiring an ambient ozone monitor and regular checks of the generator and contact tank. O & M also includes maintaining the required flow of generator coolant; regular inspection and cleaning of the ozone generator, feed gas supply and electrical assemblies; and monitoring the ozone gas-feed and distribution system to ensure that the necessary volume of ozone comes into sufficient contact with raw water.

**Health and Safety:** The Ozonation of bromide-containing waters can form bromate, a known carcinogen, though usually at concentrations well below the health concern threshold. Techniques to control bromate formation involve Ozonation at slightly acidic pH values, multi-stage Ozonation and the use of ammonia or chlorine. Once bromate is formed, GAC filters and UV irradiation can remove it to a limited degree. Ozone gas is possibly toxic and extremely irritating to the human body, so leaks must be controlled to prevent worker exposure.

**Costs:** The costs for Ozonation equipment, operations and energy are high.

**Social and Environmental Considerations:** Local capacities for managing such a sophisticated treatment process will be limited. Acceptance of the treated water is good, as the process does not include any chemical components, which could affect the taste. Ozonation has a high energy consumption. In areas where fossil fuels are used for power, it has a high $CO_2$ footprint.

**Strengths and Weaknesses:**

- (+) Eliminates inorganic (iron, manganese, sulphur) and organic contaminants (micropollutants)
- (+) Deactivates bacteria, viruses and protozoa effectively and rapidly
- (+) Has stronger germicidal properties than chlorination and no chemicals are added to water

- (−) Has high equipment, operation and energy costs
- (−) Provides no residual protection in the distribution system
- (−) Potential fire hazard and toxicity associated with ozone generation

→ **References and further reading material for this technology can be found on page 219**