Central to all agricultural operations, water is one of the most key inputs. With water making up more than 90% of the mass of fresh cannabis weight, it becomes clear that delivering it effectively and efficiently is crucial to any savvy cultivator. Beyond the plant itself, farmers have a more intimate understanding than most of how important water is as a resource in a shared ecosystem. The water that is used to irrigate indoor cannabis crops is the same water that comes out of your faucet at home. After being used in the cities, it is allowed to flow east into the watershed shared by the eastern part of Colorado, as well as neighboring states, such as Nebraska and Kansas, where it will be used to water their crops and supply their homes. Effectively and efficiently using water becomes even more critical when consideration is taken for all of the other needs society has for this precious resource. In this section, the topics of water both as an input and an output in cannabis cultivation will be discussed, as well as the topic of how to manage the water inside of the cultivation area.

As a raw material, water used for irrigation must first be checked for its suitability to use on crops. Luckily, water delivered in the Front Range is of uniquely high quality due to the purification process of nature’s water cycle, as it comes primarily from Rocky Mountain snowmelt. All water, though, should be checked for impurities. Impurities come in many shapes and sizes, but are largely thought of in a few categories: elemental (e.g., salts and heavy metals); microbial (e.g., E. coli) and manmade (e.g., pesticides and industrial chemicals). Growers should take routine water samples at least twice a year and send them to labs to monitor water quality. If quality is found to be out of spec, a grower should use technologies that filter and sanitize the water (e.g., carbon filtration, reverse osmosis, ultraviolet light treatment) before applying it to their crops.

Once the water is deemed suitable, the next big challenge is delivering it to the plants efficiently. There are several approaches to irrigation, and each one has technology that can aid the grower. From low-tech hand-mixing nutrients and hand watering plants, to high-tech automated fertilizer dosing and delivery, a grower will have to make choices that strike a balance between capital and operating costs as well as plant performance and sustainability goals. Often, the most efficient systems are both best for the plants and have the lowest operating costs. Increased yields and decreased bottom lines are great ways to pay back the investment needed to use these sometimes more initially expensive solutions.

After the water is delivered to the plant, it usually shows up again in two main streams: leachate, or water that has flowed past the plant and not been taken up; or condensate, water that has transpired through the plant or evaporated into the farm and condensed inside of the dehumidification equipment. Both streams tend
to flow to the drain that ultimately leads away from the facility and off to a local wastewater treatment plant. At this point, a farmer can either choose to utilize technology to reclaim and recycle that water so that it can be used again for irrigation, or to make sure that it is of a suitable quality to be sent on to the wastewater treatment site, where it will be processed to be used again for another application.

**WATER USAGE & QUALITY**

**WATER OVERVIEW**

Indoor cannabis cultivation within Denver and surrounding municipalities is currently reliant on the municipal water distribution system for irrigation and operational effluent discharge. As such, there are specific process points of environmental impact, including net consumptive use (= influent - effluent), filtration and treatment, and effluent discharge water quality.

In general, the environmental impacts of municipal consumptive water use include state-specific issues, such as increased urban demand resulting in reduced water availability for rural agricultural production and associated watershed impacts; water-energy nexus concerns; and indirect carbon emissions associated with municipal water treatment systems. In addition, for indoor cultivation operations, influent filtration and treatment requirements result in solid-waste generation, energy consumption and efficiency challenges, while effluent water quality is impacted as a result of the agricultural inputs required for cultivation. The flow of water through a typical indoor cannabis cultivation is presented below.

While consumptive water use and water quality have been preliminarily identified as significant aspects for indoor cannabis cultivation, it is important to note that these concerns are not unique to the cannabis sector. Neither a sector-specific water-use baseline nor production unit theoretical minimum is currently available. However, the implementation of proactive operational efficiency and monitoring practices can readily address the potential water use and quality environmental impacts, while setting the stage for leadership in process integration of progressive technologies for use and cost optimization.

The sustainability impacts of water use and quality include:

- **Economic Competitiveness** - The introduction of water-use efficiency measures can lower operational costs by reducing direct resource purchase (i.e., lower volume equals lower cost). In addition, water-use efficiency may also result in

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**Figure 3: Water Flow for Cannabis Cultivation Facilities**
lower levels of consumables use due to a reduction in influent treatment volume and less wear and tear on process equipment.

- **Community Relations** - As discussed above, concerns about municipal consumptive water use in Colorado include increased urban demand resulting in reduced water availability for rural agricultural production and associated watershed impacts; increased energy usage for operational influent treatment; and indirect carbon emissions associated with municipal water treatment systems. By proactively integrating water-use efficiency techniques and effluent water-quality monitoring, a cannabis cultivation operation can demonstrate the commitment to integrated resource management and community partnering that is required to cultivate strategic relationships with municipal leadership and neighborhood residents – all while anticipating regulatory changes.

- **Environmental Impact** - There is a direct link between water and energy. Water and wastewater utilities account for approximately 5 percent of overall U.S. electricity use, resulting in significant greenhouse gas (GHG) emissions. In addition to energy impacts, there are regional water resource concerns from the cannabis industry – such as loss of agriculture in rural areas, and biodiversity and watershed impacts of piping water outside of its native watershed. Proper water management within a cultivation facility can result in reductions in GHG emissions and negative watershed impacts.

The following topic-specific sections will provide guidance and recommendations for water filtration and purification, irrigation methods and automation, wastewater recycling and improving wastewater quality for an indoor cultivation facility.

**BEST PRACTICES**

Industry best practices for water use span from tap to drain and can substantially reduce water needs while improving water quality. Many practices can be instituted regardless of specific growing or watering procedures.

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WATER FILTRATION & PURIFICATION

To meet the demands of rapid maturation and high yields for indoor cannabis production, the applied water must meet strict specifications. A cultivation facility’s incoming water – regardless of whether it is tap water or well water – should be tested by a trusted analytical lab, such as the Colorado State University soil and water testing lab, to understand if additional filtering is necessary prior to plant application. Similarly, excess process water captured via flood trays or through HVAC condensate will exhibit different characteristics, requiring the need for analysis and purification before subsequent applications. There are multiple ways to improve the quality of incoming water including carbon filtering, reverse osmosis and UV sterilization.

PROCESS DESCRIPTION

According to the Colorado State University Cooperative Extension, irrigation water should be evaluated for four basic criteria:

1. Total soluble salt content (salinity hazard)
2. Relative proportion of sodium cations (Na+) to other cations (sodium hazard)
3. Excessive concentration of elements that causes toxicity or ionic imbalance in plants
4. Bicarbonate anion (HCO3-)
5. Concentration as related to calcium (Ca++) plus magnesium (Mg++) cations

When it comes to a facility’s incoming water supply, salinity hazards and sodium hazards are of particular concern. It is important to test water quality prior to watering crops. In some cases, incoming water may not meet the strict specifications for optimal plant growth; therefore, some level of purification is needed. Water to be applied to plants should be purified and nutrified on demand or purified and held in storage tanks until nutrients can be added prior to application to the crop. Water can be purified using several different methods including carbon filtration, reverse osmosis and UV sterilization. However, it is worth noting that reverse osmosis results in about 40-60% water loss in the treatment process, so it is not recommended for efficient water use.
BEST PRACTICES

When considering environmental inputs, water treatment using carbon filtration has emerged as the most efficient method to reduce contaminants – such as chlorine, chloramine, sodium and bicarbonate levels – in a facility’s incoming water. Carbon filters are very effective at achieving the desired nutrient load for cannabis plants when filtering is performed according to manufacturer’s specifications.

Additionally, filtering leads to very low levels of waste. Only water used to periodically clean filters is disposed of, whereas sterilizing water through reverse osmosis generates substantial water losses in the brine byproduct.

Resources:
- Colorado State University - Soil and Water Testing Laboratory
- Denver Water Quality Reports
- Example of water testing report

IRRIGATION METHODS & AUTOMATION

Accurate irrigation is essential to the growth of healthy plants and the overall performance of a cultivation facility. Inefficient water use not only wastes this precious resource, but also can harm the plant; cause facility damage by encouraging fungal growth; and create worker safety hazards and add extra load to the HVAC system, wasting energy. A variety of irrigation methods are used in today’s cannabis industry. Selecting both the right method for a given facility and following good operational practices for that method are equally important for achieving optimal efficiency and plant growth.

Figure 4: Irrigation & Fertigation System Diagram. Source: Netafim
PROCESS DESCRIPTION

Seven different methods are commonly used in indoor cultivation facilities: flood tables, aeroponic systems, wick systems, nutrient film technique (NFT), water culture systems, drip irrigation and hand watering.

Flood Tables
Flood tables are very popular in agriculture and horticulture greenhouses. Generally used with seed trays, plug trays or small pots, flood tables (also known as ebb and flow tables) work by periodically flooding the entire tray with nutrients while pots wick up the water through the drainage holes. This method can be more difficult with large pots. Most often with the flood method, tray water not absorbed by the plants is run through a pipe to a holding tank to be reused. Typically, the recycled water will be treated to kill any water-borne plant pathogens (e.g., Pythium, Phytophthora, Fusarium), which can be done chemically or through UV light exposure. Flood tables use a lot of water per irrigation cycle, so this method is best used when the majority of the water will be absorbed or when the cultivator is prepared to sanitize, re-nutrify and reuse the water. Flood tables are often used with rock wool mediums, and the runoff is captured in a tank directly below the tray to be sanitized and re-nutrified in place.

Aeroponics
Many cultivators use aeroponic systems, such as an EZ-Clone machine, for propagation. Aeroponic systems utilize spray nozzles to mist the stem or roots with a nutrient solution. Cultivators using large-scale aeroponic systems are more likely to use a channel system in which the roots of many plants are enclosed within a channel and spray misters line the inside of the channel. Another method is the bucket system, in which nutrified water and air are maintained in buckets, into which the roots grow.

Deep Water Culture Systems
In water culture systems, the plant is held in a basket just above the nutrient solution and the roots hang down into the nutrient solution. The roots do not suffocate because the reservoir is continuously aerated. This allows the plant to receive an ideal amount of nutrients, as well as oxygen.

Wick Systems
Using a wick, the plants pull nutrient solution up from a reservoir through capillary action. This system is better suited for smaller plants. Heavy feeders like cannabis can lose weight and yield if the wicking process is too slow.

NFT Systems
The Nutrient Film Technique (NFT) consists of a very shallow nutrient solution that cascades downward in a tube or tray toward the reservoir, where it is reused. It is most commonly used on smaller plants with a short crop cycle, and cannabis plants are very sensitive to interruptions in electricity and the water cycle. This system allows only a relatively small space for cannabis roots to thrive, which can impact crop performance.

Hand Watering
Watering by hand using hoses or watering cans is a common watering method used at cannabis cultivations. Many growers prefer the hands-on aspect of hand mixing and hand feeding each plant. However, this method allows for the largest margin of error and is the most labor intensive. Nutrient mixing by hand can easily vary by day or by employee, leading to inconsistent final solutions. The total volume of water being applied to each plant can vary greatly, especially if staff are inattentive. Nevertheless, most cultivation operations use the hand-watering method at some stage of plant growth. Cultivators must have good standard operating procedures and employee training for hand watering to minimize mistakes.

Drip Watering
Drip irrigation is widely considered the most water efficient way of irrigating a crop. Nutrified water is pumped through irrigation tubes and drip emitters to each plant. Many options exist for flow volumes and types of emitters. Cultivators should consult with an irrigation specialist to help determine the correct emitter based on water pressure, length of irrigation runs, container sizes, number of plants to be irrigated at once, etc. Drip irrigation allows the cultivator to
fine tune how much water is given to each plant. High-quality drip emitters are pressure compensated, so each plant gets the same amount of water regardless of position on the irrigation line. Many cultivators using drip irrigation systems water several times per day (pulse irrigation), delivering the total desired volume of water over a longer period. This allows the cultivator to carefully manage the amount of water runoff. To maximize water conservation, cultivators should measure moisture levels within the media as well as electrical conductivity to determine irrigation timing and quantity. Drip irrigation is usually accompanied by a fertigation system that automatically injects nutrients into the water line according to specifications and can be run on programmed time schedules.

**BEST PRACTICES**

The selection of watering methods is highly influenced by an individual cultivator’s personal preferences, as the benefits and drawbacks of each method are varied. It is generally recommended to select the most efficient method(s) that fit within the budget and expertise of facility staff. However, any facility exceeding 2,500 square feet in size should seriously consider an automated watering system. Clear standard operating procedures and frequent training of staff with irrigation responsibilities are essential to ensuring that the chosen system operates optimally.

Table 6 below highlights some of the benefits and drawbacks of the three most commonly used irrigation methods:

<table>
<thead>
<tr>
<th>Irrigation Method</th>
<th>Efficiency</th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
</table>
| Hand Watering     | Low        | • Eyes on all plants during watering  
                  |            | • Gives grower “hands on” feel  
                  |            | • No high-tech equipment required  |
|                   |            |          | • Inconsistency of volume per pot  
                  |            | • Inconsistency between employees responsible for task  
                  |            | • Labor-intensive  |
| Drip              | High       | • Automated  
                  |            | • Precise volume of water  
                  |            | • Allows cultivator to water a large number of plants at once  |
|                   |            |          | • Potential clogging of dripper  
                  |            | • Manual inserting/removal of dripper when moving plants  
                  |            | • High cost to install and maintain  
                  |            | • More technical, with high learning curve  |
| Flood Tables      | Medium     | • Automated  
                  |            | • Less chance of under-watering plants  
                  |            | • Easy and inexpensive to build  |
|                   |            |          | • Large amounts of water used at once  
                  |            | • Increased humidity if reservoirs do not have lids  
                  |            | • Manual labor to clean and refill reservoirs  |
**Table 7: Grow Media Comparison**

<table>
<thead>
<tr>
<th>Grow Media</th>
<th>Description</th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral Soil</td>
<td>Often thought of as “dirt,” soil can vary greatly depending on its composition.</td>
<td>• Natural&lt;br&gt;• Contains nutrients&lt;br&gt;• Easily amended</td>
<td>• Not sterilized and may contain pests&lt;br&gt;• Very heavy (worker safety)&lt;br&gt;• Low steerability&lt;br&gt;• Loose media requires more work to keep facility clean.&lt;br&gt;• Not all soil is the same, selecting the right kind with the right amendments can be challenging</td>
</tr>
<tr>
<td>Rockwool</td>
<td>Made by melting rocks and spinning the molten material into fibers.</td>
<td>• Lightweight&lt;br&gt;• Inert, so grower can control nutrients&lt;br&gt;• Manufacturing process ensures material is clean&lt;br&gt;• High steerability</td>
<td>• Natural high pH, requires conditioning before use.&lt;br&gt;• One time use&lt;br&gt;• Fast drainage leaves plants prone to wilting if not managed properly.</td>
</tr>
<tr>
<td>Coco Fiber</td>
<td>A fibrous media made from the husks of coconuts.</td>
<td>• Natural&lt;br&gt;• Easily amended&lt;br&gt;• Medium steerability (depends on thickness of fibers)</td>
<td>• Not sterilized and may contain pests&lt;br&gt;• Very heavy (worker safety)&lt;br&gt;• Loose media requires more work to keep facility clean.</td>
</tr>
</tbody>
</table>

**AUTOMATION**

Automated watering systems are highly recommended to help control accuracy and efficiency and to increase data collection, as well as for the ease of mining that data. Cultivators mining the most data for anomalies, efficiencies and tracking will continue to stay on the cutting edge of the industry. Automated data collection ensures that real-time data is collected daily. Several major manufacturers currently offer environmental and fertigation packages that tie into one software program, allowing for a streamlined data collection process and easy, intuitive data mining. Production is all about repeatability, and data collection helps ensure repeatability. Data collection also helps improve procedures by targeting issues and concerns.

**MEASUREMENT**

The water applied to plants should be measured during each phase of growth. This is most easily achieved when using an automated watering system as described above. Similarly, cultivators should measure runoff to ensure that water is not being wasted, and should set a low runoff target. Ten percent to 15% runoff per watering event is a highly efficient target. Salt levels in the media should be monitored at these low runoff levels to ensure crop quality. Ongoing measurement against this target will help maintain overall water efficiency and identify factors that affect water use, such as employee turnover, schedule changes and equipment changes.

**What measurements should I take when monitoring irrigation?**

- Ascertaining pH is critical for nutrient uptake. Being outside of range can cause nutrient deficiencies.
- Electrical conductivity (EC) measures the amount of fertilizer in your nutrient solution or root zone. Controlling this value determines how much food you are feeding your plants.
- Volumetric water content (VWC) is the amount of water in the media relative to maximum capacity. Use this number to make sure your roots are getting enough water, but aren’t staying too saturated.
- Temperature is critical for root health and function. Too cold and the plant won’t eat; too warm and the roots become susceptible to disease.
ELECTRICAL CONDUCTIVITY

Many growers are feeding plants based on specific electrical conductivity (EC) levels identified by the nutrient line they are using. It is important to frequently monitor the EC levels of both the nutrient water being given to the plants and the EC level of the planting medium with either probes or a handheld device. Cultivators have had success with very high EC levels and very low EC levels.

- Averages for vegetative growth: 1.0-2.5 EC
- Averages for flowering growth: 2.0-4.0 EC

Growers should test runoff frequently to determine if any salts are building up in the medium. Total volumes of water applied to the plant to create runoff may hinge on these numbers. If the plants are able to absorb all of the water and nutrients provided, frequent flushing may not be necessary.

While production goals will often drive the target EC for feeding plants, it is important to remember that fertilizer use is another area where cultivators can look to improve their sustainability impact. Many fertilizers are mined from the ground, and some nutrients, such as phosphorus, are being depleted at a rapid pace. Avoiding overfeeding by keeping ECs on the lower side of a target range; recycling and reusing irrigation runoff; and using environmentally friendly sources of nutrients are a few examples of how growers can minimize their impact when it comes to fertilizers.

Resources:
- Home Hydro Systems: Aeroponic Systems
- How to Grow Marijuana: Aeroponics
- Current Culture H2O: Hydroponic System Info

Drip irrigation resources:
- Irrigation Tutorials: The Basic Parts of a Drip System
- Irrigation Tutorials: Drip Irrigation Design Guidelines

Procedure for flushing plants:
- American Agriculture: Flushing Potted Plants

WATER RECYCLING

Cultivating cannabis in controlled indoor environments provides multiple opportunities for water efficiencies and water recycling. Virtually all excess water runoff and water vapor can be captured and delivered back to the beginning of the watering process.

Figure 5: Irrigation water recapture process

Note: This water reuse practice is not to be confused with Denver’s updated graywater regulations. Graywater – which includes wash water, shower water and sink water – can be applied only to outdoor landscapes, not reused indoors or applied to consumable crops.

Water applied to cannabis plants through hand watering, flood trays or drip methods can be easily captured in two complementary ways.

PROCESS DESCRIPTION

First, applying water onto plants generally produces some amount of excess water that can be captured and piped back to water storage tanks. This excess water should be filtered and sterilized again to avoid contaminants and then stored for the next round of watering.

The second water recycling method involves capturing HVAC condensate. Healthy cannabis plants naturally transpire a majority of the applied water after each watering cycle through
transpiration. This water vapor passes through the cultivation room’s HVAC equipment and condenses back to relatively clean liquid water that can be directed to a facility’s water storage area to begin the water process anew.

**BEST PRACTICES**

Water should not be a single-pass ingredient for cannabis production. Cultivation facilities equipped with water storage can easily incorporate water-recapture methods into existing cultivation practices for reuse. Water can be captured as follows:

- As excess runoff while watering: Best accomplished when all runoff water is contained in drain lines or ditches.
- As HVAC condensate and dehumidification water: Often very clean (almost reverse osmosis quality); however, it should be checked for heavy metals that can leach off the cooling coils.
- Pipe captured water to a holding tank for reuse.

Recaptured water may need to be purified again. There are several options available, but method selection should be based on what the cultivator is trying to remove from the irrigation water. Cultivators should look for technologies that kill waterborne pathogens such as Pythium, Phytophthora, Fusarium and Rhizoctonia.

Options include:

- UV technologies, which are very popular in the greenhouse/nursery industry
- Copper technologies, which are helpful for use against Pythium and Phytophthora
- Electrochemically Activated Water (ECA)
- Water storage located immediately upstream of the water-filtering process
- Chemical treatments, such as ozone and hydrogen peroxide, simultaneously disinfect and raise the oxygen levels within the water

Subsequent rounds of watering should first be pulled from this storage tank before requiring any new “tap” water to be drawn. This recaptured water can make up the vast majority of the next watering cycle’s water.
Resources:

- DDPHE Rules and Regulations Governing Graywater Treatment Works
- Greenhouse Management - 10 Tips for Recycling Irrigation Water
- Greenhouse Product News - Grower 101, Water Disinfection
- Greenhouse Management - Disinfecting Recycled Irrigation Water
- Clean Water 3 - Treatment Technologies

Examples of UV purification products:
- Hortimax Growing Solutions
- Superior Aqua Systems

Examples of copper purification products:
- Aqua-Hort
- Priva Vialux Line Water Disinfection

Examples of ECA products:
- Horti-Daily
- Royal Brinkman

Figure 6: Example of piped drainage from trays

Figure 7: Piped drainage running into floor sink

Figure 8: Example of coarse filter on tray to keep large debris out of recycled water

Figure 9: Sediment Filter

Figure 10: Hortamax Vitalite UV Filter

Figure 11: Brinkman ECA System
IMPROVING WASTEWATER QUALITY

Certain practices in cannabis production can lead to unintended high levels of contaminants in a facility’s wastewater discharges. Such contaminants can add stress to treatment facilities and may be largely unnecessary.

PROCESS DESCRIPTION

Purifying water using reverse osmosis generates significant volumes (at least a 1:1 wastewater to water ratio) of brine which must be discarded to sanitary drains. The concentration of brine (high in salts and minerals) creates difficulties in removal at water treatment plants. It is best to avoid the reverse osmosis process altogether and use other water filtration methods (see Water Filtration and Purification above).

High concentrations of cleaning agents in wastewater are difficult to process as well. When cleaning cultivation rooms and associated equipment, cultivators should use cleaning products according to the manufacturer’s specifications. Concentrated cleaning solvents should be diluted appropriately as described on the label.

A higher concentration of solvent does not necessarily clean better and will lead to poor indoor air quality and difficulties in processing the wastewater.

BEST PRACTICES

Cultivators should:
- Use cleaning products as directed; dilute concentrated products according to the intended cleaning purpose on the label.
- Use environmentally friendly cleaners such as those rated by Green Seal, Eco Logo or Safer Choice.
- Use filtration for water purification to avoid significant water discharges from reverse osmosis.
- Use water nozzles for any cleaning operations to avoid excess water use.
- Avoid over-watering crops as this can lead to unintended high levels of chemicals and suspended solids in sanitary drains.
- Refrain from dumping any liquids into storm drains.

Resources:
- Green Seal
- Eco Logo
- EPA Safer Choice

ADDITIONAL CONSIDERATIONS

Storm drains empty directly into local waterways. There is no treatment to storm drain effluent. In fact, by law, nothing is allowed to be dumped down storm drains – only rainwater and snow melt. Cultivators can help keep local streams clean by not dumping into storm drains, keeping property free of litter and using dry, absorbent cleanup methods for liquid spills outdoors.