

# Condensate A Public Health Engineer's Perspective

David S. Haynes I.Eng, F.CIPHE, F.SopHE, MIET  
Public Health Associate, Hoare Lea.

## Executive Summary – Condensate: The Hidden Risk in Modern Building Services

Condensate is one of the most overlooked by-products of modern building services, yet it is increasingly becoming one of the most persistent and consequential.

As buildings evolve toward higher levels of airtightness, greater energy efficiency, and continuous mechanical operation, condensate generation is no longer occasional or negligible. It is predictable, sustained, and, when aggregated across multiple systems, significant. Despite this, it is still too often treated as a minor coordination issue rather than a fundamental design consideration.

From a public health engineering perspective, condensate sits at the intersection of drainage design, system hygiene, and building performance. Poorly designed or inadequately considered condensate systems can lead to standing water, microbial growth, corrosion, odour transmission, and long-term damage to both plant and building fabric. These failures are rarely complex, but they are consistently avoidable.

This article provides a structured and practical engineering perspective on:

- How condensate is generated across HVAC systems, boilers, and low-carbon technologies
- Why condensate discharge should be calculated and not assumed
- The hydraulic and hygienic implications of treating condensate as a foul discharge
- Common failure modes observed in real projects
- Design principles required to ensure robust, compliant, and maintainable systems

As the industry transitions toward low-carbon solutions such as heat pumps and extended cooling operation, condensate volumes are expected to increase, not decrease. This reinforces the need for a more rigorous and integrated approach to its management.

## Condensate A Public Health Engineer's Perspective

David S. Haynes I.Eng, F.CIPHE, F.SoPHE, MIET  
Public Health Associate, Hoare Lea.

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Condensate is an unavoidable consequence of modern HVAC and heating systems, yet it continues to receive disproportionately little design attention. As buildings become more airtight, more intensively occupied, and increasingly reliant on mechanical cooling and high-efficiency heating, the volume and persistence of condensate generation have increased markedly. From a public health engineering perspective, failures associated with condensate are rarely complex, but they are often consequential. This article explores how condensate is generated, how its discharge should be assessed, and why its mismanagement presents avoidable risks to hygiene, indoor air quality, building fabric, regulatory compliance, and long-term system resilience.

Condensate: an underestimated consequence of modern building design  
In many projects, condensate is still treated as a minor by-product rather than a predictable hydraulic discharge requiring deliberate engineering. It is frequently addressed late in the design process, often during coordination or construction, when options for robust drainage design are already constrained. This approach is increasingly misaligned with the realities of modern building operation.

Higher airtightness standards, improved thermal envelopes, elevated internal moisture loads, extended cooling seasons, and near-continuous plant duty all contribute to sustained condensate production. In offices, healthcare facilities, laboratories, hotels, and educational buildings, condensate generation is no longer intermittent. It is predictable, persistent, and, when aggregated across multiple systems, material in volume.

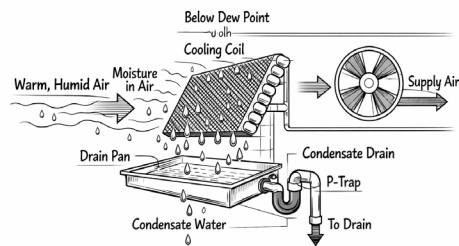
From a public health engineering standpoint, the issue is not simply one of water disposal. Condensate forms in direct contact with internal plant surfaces, cooling coils, drain pans, and combustion products. It therefore sits at the intersection of drainage design, hygiene control, indoor air quality, and asset protection.

### How condensate is generated in practice

The principal sources of condensate within buildings are air handling units (AHUs), fan coil units (FCUs), and modern condensing boilers.

Within AHUs and FCUs, condensate is produced whenever warm, moisture-laden air passes over cooling coils operating below the air dew point. As air is cooled, its ability to retain moisture decreases, and excess water vapour condenses on coil surfaces before draining into collection trays. In buildings with high internal gains or dense occupancy, this process can occur continuously for extended periods, particularly during summer operation.

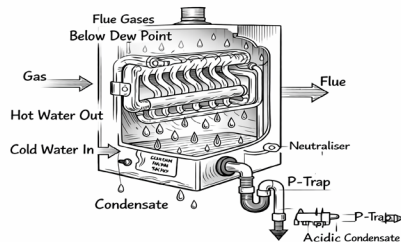
### AHU / FCU Condensate Formation



The resulting condensate is not simply clean water. It has been in contact with coil surfaces, accumulated dust, airborne particulates, and biofilms that inevitably develop within air handling equipment over time. Its management therefore has direct implications for hygiene and indoor air quality.

Condensing boilers introduce a second, chemically distinct source of condensate. As flue gases are cooled below their dew point, water vapor within the products of combustion condenses within the heat exchanger and flue system. This condensate contains dissolved combustion gases and is inherently acidic, introducing a different set of risks and design considerations.

### Condensing Boiler Condensate Formation



### Why condensate discharge should be calculated

A persistent misconception within building services design is that condensate flow rates are too small to warrant calculation. While individual discharges may appear modest, their cumulative and coincident effect is often either underestimated or in some instances overestimated.

In simple terms, condensate discharge is calculated by identifying the source of moisture, determining the rate at which that moisture is converted into liquid water, and adopting a conservative design flow that reflects sustained peak operation rather than short-term

averages. For HVAC systems, this equates to moisture removal at the cooling coil. For boiler plant, it is directly linked to fuel input and combustion efficiency.

The objective is not theoretical precision, but predictability. From a public health engineering perspective, calculated condensate discharge underpins stable drainage behaviour, reliable trap performance, and the avoidance of standing water.

### Methodology for calculating condensate discharge

For air handling units (AHUs) and fan coil units (FCUs), condensate production is governed by psychrometric behaviour. Moisture removal is determined by the difference in humidity ratio between entering and leaving air, multiplied by the air mass flow rate. In many standard applications, manufacturer data implicitly captures this relationship and is adequate for design purposes.

For drainage design purposes, the calculation of condensate discharge is based on the rate at which moisture is removed from the air stream as it passes over the cooling coil. This is determined by comparing the moisture content of the air entering and leaving the coil and relating that difference to the volume of air being handled. In effect, the calculation converts latent moisture removal within the HVAC system into an equivalent hydraulic discharge that can be assessed, sized, and managed as part of the building's foul drainage system.

In accordance with CIBSE Guide A – Environmental Design, condensate production at cooling coils is determined from the moisture balance across the air-handling process and is directly related to the latent load removed from the airstream. In addition to manual calculation using psychrometric charts, a range of dedicated condensate calculation tools available and online free calculators are also available to assist designers in estimating condensate discharge rates, including psychrometric and moisture-balance tools provided by engineering reference websites such as Engineering ToolBox and Adicot. Such tools can be useful for preliminary assessment and sense-checking, provided the underlying assumptions and design conditions are understood and appropriate to the application.

The rate of condensate production is calculated from the difference in humidity ratio between entering and leaving air at the cooling coil:

$$\dot{m}_c = \dot{m}_a \times (\omega_1 - \omega_2)$$

Where:

$\dot{m}_c$  = condensate mass flow rate (kg/s)

$\dot{m}_a$  = dry air mass flow rate (kg/s)

$\omega_1$  = humidity ratio of air entering the coil (kg/kg dry air)

$\omega_2$  = humidity ratio of air leaving the coil (kg/kg dry air)

Dry air mass flow rate is obtained from volumetric airflow using standard air density values consistent with CIBSE Guide A:

$$\dot{m}_a = \rho_a \times \dot{V}$$

Where:

$\rho_a$  = density of air (typically 1.2 kg/m<sup>3</sup> at standard design conditions)

$\dot{V}$  = air volume flow rate (m<sup>3</sup>/s)

$\dot{V}$  (m<sup>3</sup>/s) is the volumetric airflow and you obtain it either from design/specified airflow, by measurement, or by calculation from other known quantities (duct size × velocity, ACH (Air Changes per Hour), or mass flow)

For practical purposes, the condensate mass flow rate may be treated as numerically equivalent to volumetric flow rate, as the density of water is approximately 1000 kg/m<sup>3</sup>. Calculations should be based on sustained summer design conditions rather than short-duration peak events, as it is persistence of discharge rather than instantaneous flow that governs condensate drainage performance.

Boiler condensate follows a different logic. Modern gas-fired condensing boilers typically produce in the order of 0.8 to 1.0 litres of condensate per cubic metre of natural gas consumed, depending on appliance design and operating regime. Importantly, boiler condensate production is often continuous during heating demand, and where multiple boilers discharge to a common system, coincident operation should generally be assumed.

The chemistry of boiler condensate and the need for treatment

The acidity of boiler condensate arises from dissolved products of combustion formed as flue gases cool below their dew point. In gas-fired condensing boilers, the predominant acid present is carbonic acid, formed when carbon dioxide dissolves in condensate water.

In addition to carbonic acid, trace quantities of nitric acid may be present as a result of nitrogen oxides formed during combustion dissolving into the condensate. Where fuels contain sulphur compounds, or where combustion conditions promote sulphur oxide formation, sulphuric acid may also be present, albeit typically at low concentrations in modern natural-gas-fired plant.

As a result of this acid composition, boiler condensate commonly exhibits pH values in the range of approximately 3 to 5. While carbonic acid is relatively weak, the combined effect of these acids is sufficient to accelerate corrosion of susceptible materials and to attack cementitious and metallic drainage components.

The increasing adoption of air source heat pumps (ASHPs) and externally mounted air-conditioning condensing units represents a further and often overlooked extension of condensate generation within modern buildings. These systems do not introduce a new

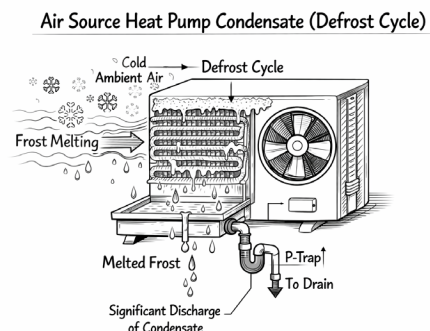
mechanism of condensate formation; rather, they reinforce the principles already discussed, namely that any process which cools air below its dew point will inevitably produce liquid water that must be managed.

Where ASHPs operate in heating mode, the external coil functions as an evaporator and is therefore colder than the ambient air. Moisture contained within the air condenses on the coil surfaces and drains to the base of the unit. In cold and humid conditions, frost accumulation is common, and periodic defrost cycles melt this frost, producing intermittent but often significant discharges of condensate. In UK climatic conditions, these defrost events frequently dominate the total volume of condensate generated.

External air-conditioning plant, including VRF and VRV systems, behaves in a similar manner when operating in reverse-cycle or heat-pump mode. Although such systems are often assumed to be 'dry' at roof level, this assumption does not hold during heating or defrost operation. Condensate generation in these cases is therefore not exceptional but entirely consistent with the mechanisms already described elsewhere in this paper.

The relevance of these systems to condensate drainage design lies not in the chemistry of the condensate, which is typically neutral and derived from atmospheric moisture, but in the location and timing of its discharge. Rooftop condensate is most heavily produced during cold weather conditions, precisely when the risk of freezing, icing, and blocked drainage is greatest. This reinforces the earlier discussion that condensate should be assessed on the basis of impact, nuisance, and safety risk, rather than appearance or perceived cleanliness.

Accordingly, condensate from rooftop ASHPs and external air-conditioning plant should be treated as an integral part of the overall condensate management strategy, subject to the same principles of positive drainage, protection against freezing, and coordination with rainwater and building drainage systems as other condensate sources discussed in this paper.

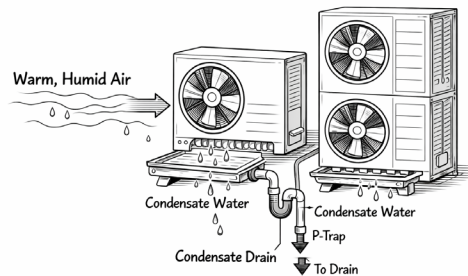


In addition to air source heat pumps, external air-conditioning condensing units associated with split, multi-split, and VRF/VRV systems must also be recognised as potential sources of condensate under certain operating conditions. While it is commonly assumed that external

condensing units remain dry during normal cooling operation, this assumption does not hold where such systems are configured for reverse-cycle or heat-pump operation.

During heating operation, the external coil of an air-conditioning condensing unit functions as an evaporator in a manner analogous to an air source heat pump. Under these conditions, atmospheric moisture will condense on the coil surfaces whenever air is cooled below its dew point. In cold and humid weather, frost formation may occur, requiring periodic defrost cycles that melt accumulated ice and discharge intermittent but potentially significant volumes of condensate.

External AC & VRF Condenser Condensate Production



The relevance of external air-conditioning condensate lies not in its chemical composition, which is typically benign and derived from atmospheric moisture, but in its discharge location. Where external condensing units are installed at roof level, condensate is released directly into an exposed environment and often during periods of low ambient temperature, thereby increasing the risk of freezing, icing, blocked drainage points, and slip or falling ice hazards.

Accordingly, condensate arising from external air-conditioning condensing units should be treated as part of the same overall condensate management strategy as other mechanical plant discussed in this paper. Such condensate should be positively drained, protected against freezing, and coordinated with the building's rainwater and drainage systems, rather than being allowed to discharge freely onto roof surfaces or building fabric.

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This acidity has direct implications for pipework durability, trap longevity, and downstream drainage infrastructure. In higher-duty installations, neutralisation using limestone or magnesium-based media is frequently provided to raise pH toward neutral and mitigate long-term degradation. Where neutralisation is not installed, material selection becomes the primary protective measure, with plastic pipework systems offering significantly greater resistance to acidic effluent than copper, cast iron, or concrete-based materials.

### **Condensate as a drainage and public health issue**

In practice, condensate from HVAC and boiler systems is routed to the foul drainage system. From a public health engineering and regulatory perspective, condensate should be treated as a foul discharge, not a surface water flow.

Condensate is considered a foul discharge because it is not simply rainwater or uncontaminated surface runoff. It is generated within building services plant and forms in direct contact with internal components such as cooling coils, drain trays, heat exchangers, and flue systems. During this process, condensate can entrain particulate matter, biofilm residues, corrosion products, and microbial contamination from within the plant. In the case of boiler condensate, it also contains dissolved acidic combustion by-products. As a result, condensate has characteristics more closely aligned with foul effluent than surface water, and its discharge is therefore regulated accordingly.

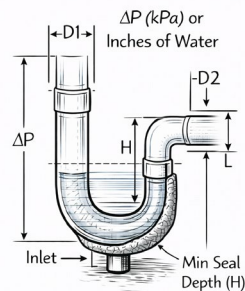
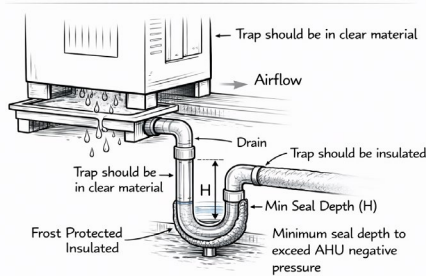
From a regulatory and public health standpoint, this distinction is critical. Surface water systems are intended to convey rainfall and uncontaminated runoff only, whereas foul systems are designed to receive effluent arising from internal building processes. Condensate clearly falls within the latter category, as its quality and origin cannot be guaranteed to remain uncontaminated throughout the life of the system. Treating condensate as a foul discharge therefore reflects both its physical origin and its potential to impact drainage infrastructure, the environment, and public health if misrouted.

Although condensate may appear visually clean, it is formed in contact with internal plant surfaces, cooling coils, drain trays, and combustion products, and cannot be assumed to be

uncontaminated. Discharge to surface water drainage systems should not be permitted as a default position.

In the UK, discharge of condensate to surface water systems requires explicit written agreement from the sewerage undertaker or relevant authority. In the absence of such written permission, condensate should be discharged to the foul drainage system.

AHU Condensate Trap – Typical Arrangement  
(Negative Pressure)



Where gravity drainage is not possible, condensate may be pumped. Pumped condensate systems are an acceptable design solution, but they introduce additional resilience considerations, including reliance on power supply, controls, and level sensors.

### What happens when condensate systems fail

When condensate systems fail, the consequences are rarely immediate but are often persistent. Failures commonly result in standing water, corrosion of plant, degradation of finishes, microbial growth, odour transmission, indoor air quality complaints, and damage to building fabric.

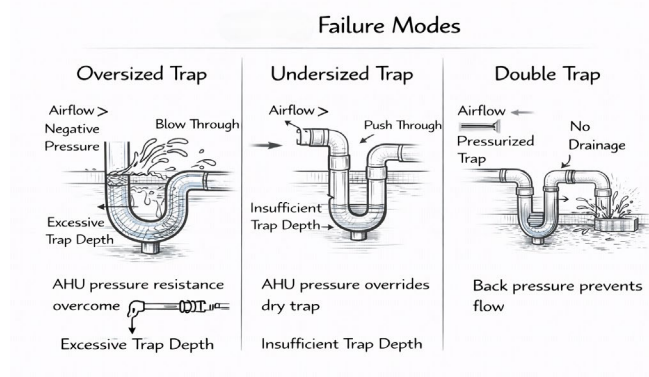
In AHUs, ineffective drainage may allow contaminated moisture to be aerosolised and re-entrained into the supply air stream. Loss of trap seal can allow foul air from drainage systems to be drawn into ventilation systems operating under negative pressure.

In pumped systems, failure of pumps or controls can result in rapid overflow, often outside normal working hours, increasing the extent of damage.

Why AHU condensate traps must be engineered, protected, and visible

AHUs operate within pressurised airflow environments, meaning condensate trap seal depth must be calculated to overcome casing pressure. Protection against freezing, mechanical damage, and evaporation is essential.

The widespread use of transparent traps reflects the need for visibility, allowing operators to confirm seal depth and flow without dismantling systems.



### Commissioning, handover, and Soft Landings

Many condensate failures originate during commissioning and handover. Systems are often tested at partial duty only, with traps and pumps appearing to function correctly under conditions that do not reflect real operation.

A Soft Landings approach requires condensate systems to be verified under realistic operating conditions, with performance revisited during early occupation.

### Condensate in a low-carbon future

As buildings decarbonize, condensate volumes are likely to increase rather than decrease. Electrification of heating extended cooling seasons, and higher humidity events all contribute to increased condensation.

#### Design of condensate drainage systems

Condensate drainage should be deliberately engineered rather than treated as an incidental connection. Pipework routes should minimise dead legs, unnecessary changes in direction, and extended horizontal runs that encourage standing water. Where gravity drainage is used, consistent falls should be provided to promote positive drainage under all operating conditions.

Design must also consider the interaction between airflow pressure and drainage performance, particularly for air handling units operating under negative pressure. Trap seal depth must be calculated to overcome maximum casing pressure, and traps should be protected against evaporation, freezing, and mechanical damage. Where condensate is pumped, designers should consider failure modes, alarms, and secondary containment to prevent uncontrolled discharge.

From a public health engineering perspective, access for inspection and maintenance is fundamental. Condensate pipework and traps concealed within ceiling voids or risers without access provision represent a long-term risk. Transparent traps, visible discharge points, and clear identification on drawings and as-built documentation support ongoing hygiene management throughout the building lifecycle.

## Further technical considerations in condensate drainage design

From a public health engineering perspective, condensate drainage must be approached as a low-flow, high-consequence system. Unlike sanitary drainage, condensate pipework rarely benefits from self-cleansing velocities and is therefore inherently vulnerable to partial blockage, biofilm development, and progressive performance degradation. This places greater emphasis on layout, detailing, and long-term maintainability than might otherwise be assumed.

### Hydraulic behaviour under low-flow conditions

Condensate systems typically operate at very low Reynolds numbers, often within laminar or transitional flow regimes. Under such conditions, particulate matter, corrosion products, and biological residues are more likely to adhere to pipe walls rather than be transported downstream. This reinforces the need to avoid small-bore pipework where practicable, minimise changes in direction, and limit extended horizontal runs that promote deposition.

Where multiple condensate sources connect to a common branch, designers should consider cumulative discharge and ensure that downstream pipework is sized to maintain reliable drainage even when individual upstream flows are intermittent. The absence of surge flow means that reliance on occasional flush-through effects is misplaced.

### Air pressure interaction and trap performance

In air handling systems, condensate drainage is directly influenced by casing pressure. Negative pressure at the drain connection can inhibit discharge, draw air through traps, or strip water seals entirely if trap depth is insufficient. Conversely, positive pressure can force air into the drainage system, disrupting downstream trap seals.

Trap seal depth must therefore be calculated against maximum expected casing pressure, including allowances for dirty filters, variable-speed fan operation, and abnormal operating conditions. From a public health standpoint, loss of seal is not merely a nuisance; it presents a direct pathway for foul air ingress into ventilation systems and occupied spaces.

### Common header arrangements and cross-interference

Where condensate from multiple AHUs or FCUs is combined into a common header, pressure interactions between units can occur. A unit operating under negative pressure may induce backflow or air ingress from adjacent branches if traps are inadequately designed or poorly located. Segregation of condensate drainage by system or pressure regime should be considered where practicable, particularly in complex plantrooms or multi-storey installations.

### Access, rodding, and inspection provision

Given the low-flow nature of condensate systems, access for inspection and maintenance is not optional. Cleanouts, removable trap components, and accessible pipework routes allow early identification of blockages, biological growth, or material degradation. Concealed condensate drainage without access provision represents a long-term operational and public health risk.

Transparent traps and visible discharge points provide immediate confirmation of system performance and should be regarded as a design feature rather than a maintenance convenience.

### **Interface with pumped condensate systems**

Where pumped condensate systems are used, hydraulic simplicity should still be prioritised upstream of the pump. Short gravity runs to collection tanks reduce reliance on pumps and limit the volume of stored condensate. Pump selection should consider not only flow rate but also solids tolerance, resistance to biofouling, and the consequences of failure.

From a public health engineering perspective, pumped systems serving critical plant should incorporate high-level alarms and fault indication to building management systems. Secondary containment or overflow routes may be appropriate where uncontrolled discharge could affect occupied or sensitive areas.

### **Integration with building drainage strategy**

Condensate drainage should be clearly identified within the overall drainage strategy rather than treated as an incidental connection. Coordination with foul drainage layouts, invert levels, and venting arrangements reduces the risk of misconnection, inappropriate termination, or accidental discharge to surface water systems.

Clear labelling, specification notes, and as-built documentation support correct operation and future modification, particularly where condensate systems intersect with wider drainage infrastructure.

In addition to understanding how condensate is generated, treated, and classified, it is essential to consider both the materials used for condensate drainage and the principles governing the design of condensate drainage systems. These aspects are central to long-term durability, hygiene control, and regulatory compliance, and are frequently overlooked during design coordination.

### **Condensate drainage materials**

Selection of materials for condensate drainage is a critical public health and durability consideration. Unlike surface water systems, condensate pipework is exposed to prolonged low-flow conditions, periodic stagnation, and, in the case of boiler condensate, acidic effluent. Materials must therefore be resistant to corrosion, chemical attack, and long-term degradation.

Plastic pipework systems, including polypropylene and PVC-based materials, are commonly specified for condensate drainage due to their resistance to acidic conditions and low susceptibility to corrosion. Conversely, copper, cast iron, carbon steel, and cementitious materials are vulnerable to accelerated attack when exposed to acidic condensate and should be avoided unless adequately protected. Material selection should also consider joint integrity, accessibility for inspection, and compatibility with neutralisation systems where provided.

### **Condensate interaction with water hygiene risk management**

Although condensate systems are not potable water systems, their presence within HVAC plant means they can influence water hygiene risk indirectly. Poorly drained condensate trays, traps, and pipework can create persistently wet environments that support biofilm formation. Where such conditions exist within air handling units, there is potential for microbial amplification within plant that may undermine broader water safety management objectives. From a public health engineering perspective, condensate systems should therefore be considered when developing and reviewing water hygiene risk assessments, particularly in healthcare, residential, and high-occupancy buildings.

### **Interface with humidification and heat recovery systems**

Modern air handling units frequently incorporate humidification, dehumidification, and heat recovery functions. These systems can significantly influence condensate generation rates and drainage behaviour. Heat recovery devices that lower coil surface temperatures may increase the frequency and duration of condensation, while humidification systems can elevate moisture loads upstream of cooling coils. Designers should consider these interactions explicitly, ensuring that condensate drainage systems are sized, routed, and protected to accommodate combined operational effects rather than nominal cooling-only scenarios.

### **High-rise and basement plant considerations**

In tall buildings and developments with extensive basement plant, condensate drainage presents additional challenges. Long vertical drops, pressure differentials, and reliance on pumped systems increase both hydraulic and operational complexity. In such cases, designers should consider zoning of condensate drainage, provision of intermediate collection points, and segregation of critical plant discharges to limit the extent of failure should blockages or pump faults occur. Alarmed pump sets and remote monitoring may be appropriate where failure consequences are high.

### **Freezing risk and external condensate pipework**

Where condensate pipework is routed externally, freezing risk becomes a significant design consideration. Frozen condensate lines are a common cause of plant shutdown and internal flooding when thaw occurs. Protection measures may include routing pipework internally wherever practicable, insulation and trace heating, or termination within frost-protected

drainage systems. External condensate discharge should never rely on assumed ambient conditions and must be assessed against local climate exposure.

### **Verification, inspection, and lifecycle management**

Condensate systems require ongoing verification beyond initial commissioning. Periodic inspection of traps, pipework, and pumps is necessary to confirm that drainage paths remain clear and that trap seals are maintained. Lifecycle considerations should include access provision, replacement of neutralisation media, and review of condensate performance following changes to building use or HVAC operation. From a public health engineering standpoint, condensate systems should be treated as active components requiring management throughout the building lifecycle rather than static installations.

### **Condensate Collection for Greywater Recycling and Reuse**

When designed, installed, and maintained correctly, condensate reuse systems offer a practical and low-energy means of reducing potable water consumption. Their successful implementation depends on recognising condensate as a recoverable resource, while maintaining robust public health safeguards and ensuring seamless integration with the building's overall water and drainage strategy.

From a drainage design standpoint, it is essential that condensate reuse systems do not compromise the primary function of safe and reliable discharge. Fail-safe arrangements must ensure that any blockage, isolation, or system failure cannot result in condensate backing up within plant or causing internal overflow. Gravity discharge to foul drainage should always remain available as a resilient fallback condition.

Nevertheless, condensate generation remains inherently variable and seasonal, influenced by occupancy patterns, internal gains, and external climatic conditions. Peak production is generally associated with summer cooling operation, while volumes may reduce significantly or cease during colder periods. To ensure resilience, reuse systems should incorporate buffer storage, automatic top-up from potable or alternative supplies, and compliant overflow arrangements to foul drainage.

One of the key advantages of condensate reuse is its alignment with peak building demand. Condensate production typically coincides with periods of high cooling load, which often correlate with increased water usage for irrigation or cooling systems. This natural alignment can improve the efficiency and utilisation of reuse systems when compared with other intermittent water sources. Where integrated effectively, condensate can therefore form a reliable supplementary supply within a wider water management strategy.

From a public health engineering perspective, however, the reuse of condensate must be approached with the same level of rigour as any other non-potable water system. Despite its clear appearance, condensate is not sterile. It is formed in contact with cooling coils, drain trays, and associated pipework, where biofilms, particulates, and microbial contamination may be present. As such, condensate should be treated as a process water stream requiring

appropriate filtration, disinfection, and storage controls in accordance with the intended end use and relevant guidance.

In buildings with high latent cooling loads, such as offices, data centres, healthcare facilities, and large commercial developments, the volume of condensate available during peak operation can be significant and, in some cases, predictable enough to form part of a broader water reuse strategy.

- Supplementary supply to non-potable water storage systems
- Process water for suitable building systems
- Vehicle washing and external cleaning
- Cooling tower make-up water
- Irrigation and landscape watering
- Toilet and urinal flushing

Condensate generated from air handling units, fan coil units, and similar cooling processes is typically low in dissolved solids and mineral content when compared with conventional greywater sources. This characteristic can make it particularly well suited to a range of non-potable applications within a greywater system. Typical uses include:

The collection and reuse of condensate is increasingly being recognised as a valuable opportunity within sustainable building design. In many modern buildings, particularly those with large air handling systems or extended cooling operation, condensate can represent a consistent and recoverable source of water that would otherwise be discharged to waste. When appropriately managed, this resource can contribute meaningfully to water efficiency strategies and the reduction of potable water demand.

## Conclusion

Condensate generated by building services plant is frequently treated as a minor or incidental by-product of heating and cooling processes. This article has demonstrated that such an approach is increasingly untenable. Condensate is a predictable and persistent discharge arising from the normal operation of air handling units, fan coil units, condensing

boilers, air source heat pumps, and external air-conditioning plant, and its management has direct implications for drainage performance, hygiene, and long-term system reliability.

A key theme emerging from this article is that condensate should be regarded as a designed discharge, not an afterthought. The mechanisms by which condensate is generated are well understood and can be quantified using established psychrometric principles. Where calculation is undertaken, condensate discharge can be translated into an equivalent hydraulic flow and properly integrated into foul drainage design, trap sizing, and discharge arrangements. The increasing availability of condensate calculation tools, including online calculators and psychrometric resources, further reinforces that the technical barriers to quantification are low and should not be relied upon as a justification for omission.

The article has also highlighted that, despite its often clear appearance, condensate cannot be assumed to be benign. Its interaction with internal plant surfaces, drain trays, and pipework means it may carry biofilms, particulates, or acidic residues, particularly in the case of combustion appliances. From a public health engineering perspective, this reinforces the long-established principle that condensate should be treated as a foul discharge and managed accordingly, with appropriate air gaps, drainage connections, and safeguards against cross-connection to surface water systems.

Particular attention has been drawn to systems operating under negative pressure, where inadequately designed condensate traps can lead to air ingress, loss of seal, or persistent operational failure. Similarly, the intermittent but concentrated nature of condensate discharge associated with heat pump defrost cycles and external plant highlights the need to consider freezing risk, visibility of discharge, and maintenance access as integral parts of system design rather than secondary considerations.

The potential collection of condensate for greywater reuse has been considered as part of wider water efficiency strategies. While condensate can contribute to non-potable water supplies under certain conditions, its variability, seasonality, and water quality characteristics mean that reuse systems must be carefully designed and should never compromise the primary function of safe and reliable drainage. Where these constraints cannot be robustly addressed, discharge to foul drainage remains the most defensible solution.

Ultimately, effective condensate management sits at the intersection of mechanical services design and public health engineering. By applying clear calculation methods, acknowledging real-world operating behavior, and designing drainage systems that reflect both hydraulic and hygienic requirements, condensate can be managed as a routine and controlled aspect of building services rather than a recurring source of defects. As building services systems continue to evolve, particularly with the wider adoption of low-carbon technologies, a rigorous and integrated approach to condensate drainage will remain essential to safeguarding building performance and occupant health.