

Cutting fluids and lubrication in manufacturing



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Importance Of Cutting Fluids And Lubrication In Manufacturing Processes

1. Introduction:-

Cutting Fluids:-

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Cutting fluids have been used extensively in metal cutting operations for the last 200 years. In the beginning, cutting fluids consisted of simple oils applied with brushes to lubricate and cool the machine tool. Occasionally, lard, animal fat or whale oil was added to improve the oil's lubricity.

As cutting operations became more severe, cutting fluid formulations became

more complex. Today's cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the metalworking industry.

There are now several types of cutting fluids on the market, the most common of which can be broadly categorized as cutting oils or water-miscible fluids. Water-miscible fluids, including soluble oils, synthetics and semisynthetics, are now used in approximately 80 to 90 percent of all applications. Although straight cutting oils are less popular than they were in the past, they are still the fluid of choice for certain metalworking applications.

Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and quality of work. With time and use, fluids degrade in quality and eventually require disposal once their efficiency is lost. Waste

management and disposal have become increasingly more complex and expensive.

Environmental liability is also a major concern with waste disposal. Many companies are now paying for environmental cleanups or have been fined by regulatory agencies as the result of poor waste disposal practices.

Fortunately, cutting fluid life may be extended significantly by implementing an effective fluid management program. The primary objective of fluid management is to maintain fluid quality and performance through administration, monitoring, maintenance and recycling practices. This allows machine shops to make the most cost-effective use of their fluid. It is also the best pollution prevention technology available. Overall, fluid management provides a means to:

Operate in a more environmentally sound manner;

- Improve productivity and reduce costs;
- Increase competitiveness;
- Maintain environmental compliance and reduce environmental liability;
- Consistently manufacture quality products; and
- Provide a healthier and safer work environment for employees.

Proper management of cutting and grinding fluids may also prevent them from being declared a hazardous waste at the end of their useful life.

With increasing environmental regulation, a reduction in cutting fluid waste is an economical, practical and achievable goal.

Cutting Fluids: (Lubricants + Coolants)

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- Used in machining as well as abrasive machining processes
- Reduces friction wear
- Reduce forces and energy consumption
- Cools the cutting zone
- Wash away the chips
- Protect Machined surfaces from environmental corrosion
- The term “ cutting fluids” is used to denote the coolants and lubricants that are used in metal machining and their allied operations like lapping, honing etc.
- Thin-wall milling of aluminum using a water-based cutting fluid on the milling cutter.
- Cutting fluids are various fluids that are used in machining to cool and lubricate the cutting tool.
- There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, and mists.
- They may be made from petroleum distillates, animal fats, plant oils, or other raw ingredients.
- Depending on context and on which type of cutting fluid is being considered, it may be referred to as cutting fluid, cutting oil, cutting compound, coolant, or lubricant.
- Every kind of machining (e. g., turning, boring, drilling, milling, broaching, grinding, sawing, shaping, planing, reaming, tapping) can potentially benefit from one kind of cutting fluid or another, depending on work piece material.

- (Cast iron and brass are usually machined dry. Interrupted cuts such as milling with carbide cutters are usually recommended to be used dry due to damage to the cutters caused by thermo shock).

2. Cutting Fluid Characteristics

Functions Of Cutting Fluid

The primary function of cutting fluid is temperature control through cooling and lubrication. Application of cutting fluid also improves the quality of the workpiece by continually removing metal fines and cuttings from the tool and cutting zone.

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Temperature Control

- Laboratory tests have shown that heat produced during machining has a definite bearing on tool wear.
- Reducing cutting-tool temperature is important since a small reduction in temperature will greatly extend cutting tool life.
- As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/workpiece interface . This cooling effect prevents tools from exceeding their critical temperature range beyond which the tool softens and wears rapidly .
- Fluids also lubricate the cutting tool or work piece interface, minimizing the amount of heat generated by friction. A fluid's cooling and

- Lubrication properties are critical in decreasing tool wear and extending tool life. Cooling and lubrication
- are also important in achieving the desired size, finish and shape of the work piece.
- No one particular fluid has cooling and lubrication properties suitable for every metalworking application.
- Straight oils provide the best lubrication but poor cooling capacities. Water, on the other hand, is an
- effective cooling agent, removing heat 2.5 times more rapidly than oil. Alone, water is a very poor
- lubricant and causes rusting. Soluble oils or chemicals that improve lubrication, prevent corrosion and provide
- Other essential qualities must be added in order to transform water into a good metalworking fluid.

Removal Of Cuttings And Particulates

- A secondary function of metalworking fluid is to remove chips and metal fines from the tool/workpiece
- interface. To prevent a finished surface from becoming marred, cutting chips generated during machining
- operations must be continually flushed away from the cutting zone.
- Application of cutting fluid also reduces the occurrence of built-up edge (BUE). BUE refers to metal particulates
- which adhere to the edge of a tool during machining of some metals. BUE formation causes
- increased friction and alters the geometry of the machine tool. This, in turn, affects workpiece quality,

- often resulting in a poor surface finish and inconsistencies in work piece size. Metalworking fluids
- decrease the occurrence of BUE by providing a chemical interface between the machine tool and work piece.

Cutting Fluid Properties

In addition to providing a good machining environment, a cutting fluid should also function safely and effectively during machining operations.

Corrosion Protection

- Cutting fluids must offer some degree of corrosion protection. Freshly cut ferrous metals tend to rust
- Rapidly since any protective coatings have been removed by the machining operation. A good
- Metalworking fluid will inhibit rust formation to avoid damage to machine parts and the work piece.
- It will also impart a protective film on cutting chips to prevent their corrosion and the formation of
- Difficult-to-manage chunks or clinkers.
- To inhibit corrosion, a fluid must prevent metal, moisture and oxygen from coming together. Chemical metalworking fluids now contain additives which prevent corrosion through formation of invisible, nonporous films.
- Compounds (such as amines and fatty acids) which form a protective coating on a metal's surface, blocking chemical reactions. Passivating films are formed by inorganic compounds containing oxygen (such as

borates, phosphates and silicates). These compounds react with the metal surface, producing a coating that inhibits corrosion.

Management for Small 3 Cutting Fluid

Stability/Rancidity Control

- In the early days of the industrial revolution, lard oil was used as a cutting fluid. After a few days, lard oil
- would start to spoil and give off an offensive odor. This rancidity was caused by bacteria and other microscopic
- organisms that grew and multiplied within the oil. Modern metalworking fluids are susceptible to
- the same problem.
- No matter how good the engineering qualities of a coolant, if it develops an offensive odour, it can cause problems for management.
- The toxicity of a fluid may also increase dramatically if it becomes rancid due to chemical decomposition, possibly causing the fluid to become a hazardous waste.
- Fluid rancidity shortens fluid life and may lead to increased costs and regulatory burdens associated with fluid disposal.
- A good cutting fluid resists decomposition during its storage and use. Most cutting fluids are now formulated
- with bactericides and other additives to control microbial growth, enhance fluid performance and
- improve fluid stability.

Transparency And Viscosity

- In some operations, fluid transparency or clarity may be a desired characteristic for a cutting fluid.
- Transparent fluids allow operators to see the workpiece more clearly during machining operations.
- Viscosity is an important property with respect to fluid performance and maintenance.
- Lower viscosity fluids allow grit and dirt to settle out of suspension.
- Removal of these contaminants improves the quality of the fluid recirculating through the machining system. This can impact product quality, fluid life and machine shop productivity.

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3. Fluid Selection

Oil-Based Fluids – including straight oils, soluble oils and ag-based oils

Chemical Fluids – including synthetics and semisynthetics

Fluids vary in suitability for metalworking operations.

Petroleum-based cutting oils are frequently used for drilling and tapping operations due to their excellent lubricity while water-miscible fluids provide the cooling properties required for most turning and grinding operations.

A. Oil-Based Cutting Fluids

Straight Oils (100% Petroleum Oil)

Straight oils, so called because they do not contain water, are basically petroleum, mineral, or age-based oils. They may have additives designed to

improve specific properties. Generally additives are not required for the easiest tasks such as light-duty machining of ferrous and nonferrous metals.

For more severe applications, straight oils may contain wetting agents (typically up to 20% fatty oils)

These additives improve the oil's wettability; that is, the ability of the oil to coat the cutting tool, workpiece and metal fines.

They also enhance lubrication, improve the oil's ability to handle large amounts of metal fines, and help guard against microscopic welding in heavy duty machining. For extreme conditions, additives (primarily with chlorine and sulfurized fatty oils) may exceed 20%. These additives strongly enhance the Antiwelding properties of the product.

Soluble Oils (60-90% Petroleum Oil)

- Soluble oils (also referred to as emulsions, emulsifiable oils or water-soluble oils) are generally
- comprised of 60-90 percent petroleum or mineral oil, emulsifiers and other additives.
- A concentrate is mixed with water to form the metalworking fluid. When mixed, emulsifiers (a soap-like material) cause the oil to disperse in water forming a stable "oil-in-water" emulsion .
- They also cause the oils to cling to the workpiece during machining. Emulsifier particles refract light, giving the fluid a milky,
- Opaque appearance.

ADVANTAGES. Soluble oils offer improved cooling capabilities and good lubrication due to the blending of

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oil and water. They also tend to leave a protective oil film on moving components of machine tools

and resist emulsification of greases and slideway oils.

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Soluble oils are a general purpose product suitable for light and medium duty operations involving a variety of ferrous and nonferrous applications.

Although they do not match the lubricity offered by straight oils, wetting agents and EP additives (such as chlorine, phosphorus or sulfur compounds) can extend their machining application range to include heavy-duty operations. Most cutting operations handled by straight oils (such as broaching, trepanning, and tapping) may be accomplished using heavy-duty soluble oils.

B. Chemical Cutting Fluids

Chemical cutting fluids, called synthetic or semisynthetic fluids, have been widely accepted since they were first introduced in about 1945. They are stable, preformed emulsions which contain very little oil and mix easily with water. Chemical cutting fluids rely on chemical agents for lubrication and friction reduction.

- These additives also improve wettability
- These compounds react with freshly-machined metal to form chemical layers which act as a solid lubricant
- and guard against welding during heavy-duty machining operations.
- Fluids containing EP lubricants significantly

- Reduce the heat generated during cutting and grinding operations.

Synthetics (0% Petroleum Oil)

- Synthetic fluids contain no petroleum or mineral oil. They were introduced in the late 1950's and generally consist of chemical lubricants and rust inhibitors dissolved in water. Like soluble oils, synthetics are provided as a concentrate which is mixed with water to form the metalworking fluid.
- These fluids are designed for high cooling capacity, lubricity, corrosion prevention, and easy maintenance.
- Due to their higher cooling capacity, synthetics tend to be preferred for high-heat, high-velocity turning operations such as surface grinding. They are also desirable when clarity or low foam characteristics are required.
- Heavy-duty synthetics, introduced during the last few years, are now capable of handling most machining operations.
- Synthetic fluids can be further classified as simple, complex or emulsifiable synthetics based on their composition. Simple synthetic concentrates (also referred to as true solutions) are primarily used for light duty grinding operations.
- Complex synthetics contain synthetic lubricants and may be used for moderate to heavy duty machining operations. Machining may also be performed at higher speeds . inning Operations
- Synthetics are easily separated from the workpiece and chips, allowing for easy cleaning and handling of these materials. In addition, since the amount of fluid clinging to the workpiece and chips is reduced

Disadvantages.

Synthetic fluids are easily contaminated by other machine fluids such as lubricating oils and need to be monitored and maintained to be used effectively.

Semisynthetics (2-30% Petroleum Oil)

- As the name implies, semisynthetics (also referred to as semi-chemical fluids) are essentially a hybrid of
- soluble oils and synthetics. They contain small dispersions of mineral oil, typically 2 to 30 percent, in a
- water-dilutable concentrate . The remaining portion of a semi-synthetic concentrate
- Semisynthetics are often referred to as chemical emulsions or preformed chemical emulsions since the
- concentrate already contains water and the emulsification of oil and water occurs during its production.
- Most semisynthetics are also heat sensitive. Oil molecules in semisynthetics tend to gather around the cutting tool and provide more lubricity. As the solution cools, the molecules redisperse.

4. Mechanisms Of Actions**Cooling:-**

- Metal cutting operations involve generation of heat due to friction between the tool and the pieces and due to energy lost deforming the material.
- The surrounding air alone is a rather poor coolant for the cutting tool, because the rate of heat transfer is low.

- Ambient-air cooling is adequate for light cuts with periods of rest in between, such as are typical in maintenance, repair and operations (MRO) work or hobbyist contexts.
- However, for heavy cuts and constant use, such as in production work, more heat is produced per time period than ambient-air cooling can remove.
- It is not acceptable to introduce long idle periods into the cycle time to allow the air-cooling of the tool to “ catch up” when the heat-removal can instead be accomplished with a flood of liquid, which can “ keep up” with the heat generation.

Lubrication At The Tool-Chip Interface:-

- Besides cooling, cutting fluids also aid the cutting process by lubricating the interface between the tool’s cutting edge and the chip.
- By preventing friction at this interface, some of the heat generation is prevented.
- This lubrication also helps prevent the chip from being welded onto the tool, which interferes with subsequent cutting.

• Delivery Methods:-

- Every conceivable method of applying cutting fluid (e. g., flooding, spraying, dripping, misting, brushing) can be used, with the best choice depending on the application and the equipment available.
- For many metal cutting applications the ideal would be high-pressure, high-volume pumping to force a stream of fluid directly into the tool-chip interface, with walls around the machine to contain the splatter and a sump to catch, filter, and recirculate the fluid.

- This type of system is commonly employed, especially in manufacturing.
- It is often not a practical option for MRO or hobbyist metalcutting, where smaller, simpler machine tools are used.

Active Cutting Oils:-

- Highly coloured mineral oil – Normally black in colour with a pungent smell
- Oils at above discussed point, diluted with low viscosity mineral oil – Lighter in colour.
- Light transparent mineral oil carrying sulphur or chlorine – Light in colour and suitable for even severe cutting conditions.
- Light transparent mineral oil carrying sulphur or chlorine mixed with sulfurised and chlorinated or fatty oils or acids – They find a common application.

Inactive Cutting Oils:-

- The Inactive cutting oils are the straight mineral oils or straight mineral oils mixed with neat fatty oils, acids or sulfurised fatty oils.
- Among the fatty oils commonly used are lard oil, tallow and some fatty acids.

Pastes Or Gels:-

Cutting fluid may also take the form of a paste or gel when used for some applications, in particular hand operations such as drilling and tapping.

Mists:-

Some cutting fluids are used in mist (aerosol) form, although breathing such a lubricant in mist form is a severe and immediate health hazard.

Present:-

- Kerosene, rubbing alcohol, and 3-In-One Oil often give good results when working on aluminium.
- Lard is suitable for general machining and also press tool work.
- Mineral oil
- WD-40
- Dielectric fluid is the cutting fluid used in Electrical discharge machines (EDMs). It is usually deionised water or a high-flash-point kerosene. Intense heat is generated by the cutting action of the electrode (or wire) and the fluid is used to stabilise the temperature of the work piece, along with flushing any eroded particles from the immediate work area. The dielectric fluid is nonconductive.
- Liquid- (water- or petroleum oil-) cooled water tables are used with the plasma arc cutting (PAC) process.

Past:-

- In 19th-century machining practice, it was not uncommon to use plain water. This was simply a practical expedient to keep the cutter cool, regardless of whether it provided any lubrication at the cutting edge-chip interface. When one considers that high-speed steel (HSS) had not been developed yet, the need to cool the tool becomes all the more apparent. (HSS retains its hardness at high temperatures; other carbon tool steels do not.) An improvement was soda water, which better inhibited the rusting of machine slides. These options are generally not used today because better options are available.
- Lard was very popular in the past. It is used infrequently today, because of the wide variety of other options, but it is still an option.

- Old machine shop training texts speak of using red lead and white lead, often mixed into lard or lard oil. This practice is obsolete. Lead is a health hazard, and excellent non-lead-containing options are available.
- From the mid-20th century to the 1990s, 1, 1, 1-trichloroethane was used as an additive to make some cutting fluids more effective.

5. Environmental Impact:-

- Old, used cutting fluid must be disposed of when it is fetid or when it is chemically degraded and has lost its performance.
- As with used motor oil or other wastes, its impact on the environment should be mitigated.
- Legislation and regulation specify how this mitigation should be achieved.
- Enforcement is the most challenging aspect.
- Modern cutting fluid disposal may involve techniques such as ultra filtration using polymeric or ceramic membranes which concentrates the suspended and emulsified oil phase.

6. Coolants:-

- A coolant is a fluid which flows through a device to prevent its overheating, transferring the heat produced by the device to other devices that use or dissipate it.
- An ideal coolant has high thermal capacity, low viscosity, is low-cost, non-toxic, and chemically inert, neither causing nor promoting corrosion of the cooling system.
- Some applications also require the coolant to be an electrical insulator.

- While the term coolant is commonly used in automotive, residential and commercial temperature-control applications, in industrial processing, heat transfer fluid is one technical term more often used, in high temperature as well as low temperature manufacturing applications.
- The coolant can either keep its phase and stay liquid or gaseous, or can undergo a phase change, with the latent heat adding to the cooling efficiency.
- The latter, when used to achieve low temperatures, is more commonly known as refrigerant.

1) Gases:-

- Air is a common form of a coolant.
- Air cooling uses either convective airflow (passive cooling), or a forced circulation using fans.
- Hydrogen, the first hydrogen-cooled turbo generator went into service with gaseous hydrogen as a coolant in the rotor and the stator in 1937 at Dayton, Ohio, by the Dayton Power & Light Co, because of the thermal conductivity of hydrogen gas this is the most common type in its field today.
- Inert gases are frequently used as coolants in gas-cooled nuclear reactors.
- Helium is the most favored coolant due to its low tendency to absorb neutrons and become radioactive.
- Nitrogen and carbon dioxide are frequently used as well.

- Sulfur hexafluoride is used for cooling and insulating of some high-voltage power systems (circuit breakers, switches, some transformers, etc.).
- Steam can be used where high specific heat capacity is required in gaseous form and the corrosive properties of hot water are accounted for.

2) Liquids:-

- The most common coolant is water.
- Its high heat capacity and low cost makes it a suitable heat-transfer medium.
- It is usually used with additives, like corrosion inhibitors and antifreezes.
- Antifreeze, a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol) in water, is used when the water-based coolant has to withstand temperatures below 0 °C, or when its boiling point has to be raised.
- Butane is a similar coolant, with the exception that it is made from pure plant juice, and is therefore not toxic or difficult to dispose of ecologically.
- Very pure deionised water, due to its relatively low electrical conductivity, is used to cool some electrical equipment, often high-power transmitters.
- Heavy water is used in some nuclear reactors; it also serves as a neutron moderator.
- Cutting fluid is a coolant that also serves as a lubricant for metal-shaping machine tools.

- EX:-. Some fast breeder nuclear reactors. Sodium or sodium-potassium alloy NaK are frequently used; in special cases lithium can be employed. Another liquid metal used as a coolant is lead, in
- EX:- lead cooled fast reactors, or a lead-bismuth alloy. Some early fast neutron reactors used mercury.

7. Lubrication

Lubricant:-

- A lubricant (sometimes referred to as “ lube”) is a substance (often a liquid) introduced between two moving surfaces to reduce the friction between them, improving efficiency and reducing wear.
- They may also have the function of dissolving or transporting foreign particles and of distributing heat.
- One of the single largest applications for lubricants, in the form of motor oil, is to protect the internal combustion engines in motor vehicles and powered equipment.
- Typically lubricants contain 90% base oil (most often petroleum fractions, called mineral oils) and less than 10% additives.
- Vegetable oils or synthetic liquids such as hydrogenated polyolefin, esters, silicones, fluorocarbons and many others are sometimes used as base oils.
- Additives deliver reduced friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination, etc.
- Lubricants such as 2-cycle oil are also added to some fuels.
- Sulfur impurities in fuels also provide some lubrication properties, which have to be taken in account when switching to a low-sulfur

diesel; biodiesel is a popular diesel fuel additive providing additional lubricity.

- Non-liquid lubricants include grease, powders (dry graphite, PTFE, Molybdenum disulfide, tungsten disulfide, etc.), teflon tape used in plumbing, air cushion and others.
- Dry lubricants such as graphite, molybdenum disulfide and tungsten disulfide also offer lubrication at temperatures (up to 350 °C) higher than liquid and oil-based lubricants are able to operate.
- Limited interest has been shown in low friction properties of compacted oxide glaze layers formed at several hundred degrees Celsius in metallic sliding systems, however, practical use is still many years away due to their physically unstable nature.

Purpose:-

Lubricants perform the following key functions:-

- 1) Keep moving parts apart
- 2) Reduce friction
- 3) Transfer heat
- 4) Carry away contaminants & debris
- 5) Transmit power
- 6) Protect against wear
- 7) Prevent corrosion
- 8) Seal for gasses

9) Stop the risk of smoke and fire of objects

General Composition:-

Lubricants are generally composed of a majority of base oil and a minority of additives to impart desirable characteristics.

Types Of Lubricants:-

1) Gas

2) Liquid including emulsions and suspensions

- e, natural water repellent)
- Water
- Mineral oils
- Vegetable (natural oil) Synthetic oils
- Other liquids

3) Solid

4) Greases

5) Adhesive

8. Use And Application Of Cutting Fluids:-

Automotive

Engine oils

- Petrol (Gasoline) engine oils
- Diesel engine oils

Automatic transmission fluid

Gearbox fluids

Brake fluids

Hydraulic fluids

Tractor (one lubricant for all systems)

- Universal Tractor Transmission Oil – UTTO
- Super Tractor Oil Universal – STOU – includes engine

Other motors

2-stroke engine oils

Industrial

- Hydraulic oils
- Air compressor oils
- Gas Compressor oils
- Gear oils
- Bearing and circulating system oils
- Refrigerator compressor oils
- Steam and gas turbine oils

Aviation

- Gas turbine engine oils
- Piston engine oils

Marine

- Crosshead cylinder oils

- Crosshead Crankcase oils
- Trunk piston engine oils

9. Components Of Fluid Management Program

Administration:-

- Commit the personnel, equipment and other resources necessary for the program.
- Encourage employee support and participation.
- Designate fluid management personnel to implement the program.
- Survey the fluids, machines and sump capacities of the shop.
- Develop a record keeping system to track the program.

Monitoring And Maintenance

- Prepare and mix the fluid according to manufacturer's directions.
- Use quality water to dilute fluid concentrate and replenish evaporation losses.
- Monitor and maintain proper fluid concentration.
- Monitor for microbial contamination and control microbial growth through water quality control, maintaining proper fluid concentration and pH, routine maintenance of equipment, biocide additions and aeration.
- Monitor pH for signs of fluid degradation.
- Perform regular machining system inspections and maintenance practices, particulate removal, tramp oil control, general housekeeping and annual cleanouts.
- Prevent foaming with proper fluid concentration, quality water and eliminating mechanical effects that agitate cutting fluid.

- Recycle fluid well before it becomes significantly degraded. Never attempt to recycle rancid fluid.
- Select fluid recycling equipment based on the needs, objectives and financial resources of the shop.

10. Chemical Treatment:-

- Chemical treatment is the addition of chemicals which change the nature of the liquid waste.
- Simple chemical-treatment methods work well on some wastewater. Metalworking wastes are too complex for most treatment processes.
- Chemical treatment beyond pH control is generally not an option for small facilities.

11. Ultra Filtration System:-

- Ultra filtration systems were created for the metalworking industry to treat such wastes as used cutting fluids, detergents, parts-washing solutions, and other oily wastewaters.
- Strict environmental laws require proper treatment prior to discharge.
- Ultrafiltration systems provide effective treatment of this wastewater by separating the water from the oily waste.
- The quality of water is then ready for sewer disposal.

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