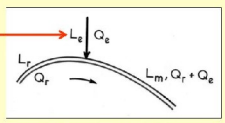
Effluent Quality

1.	 **Wastewater Treatment** **EFFLUENT QUALITY** Professor Mara	This presentation is about effluent quality requirements for wastewater treatment plants, and we need to know what these are before we start to design a plant.
2.	**EFFLUENT QUALITY REQUIREMENTS** • Set by a **regulatory authority** (eg, an environmental protection agency) empowered by legislation for this purpose • To protect inland surface waters (rivers, lakes), groundwater and coastal waters • Usually effluent quality requirements (or effluent "standards") are set for BOD, suspended solids, ammonia, *E. coli* …	Effluent quality requirements, or standards, are set by the local environmental regulatory agency set up by legislation for this purpose, and the aim is to protect inland surface waters, groundwaters and coastal waters from any adverse effects of treated wastewater discharges. Usually standards are set for BOD, suspended solids, ammonia, and possibly *E. coli*, but this list is not exhaustive.
3.	❑ The regulatory agency has a duty (either explicit in law, or at any rate implicit) to set SENSIBLE STANDARDS ❑ Unfortunately not all do so! ❑ Inappropriate standards waste money! ❑ *Always* discuss inappropriate standards with the regulator	The regulatory agency has a duty to set sensible standards, but unfortunately not all do so. This is important because unnecessarily stringent standards require a more expensive wastewater treatment plant and this may be unaffordable or, depending on the operational complexity involved, too complicated to be operated successfully. As a general point design engineers should always discuss inappropriate standards with the regulator.
4.	❑ The regulatory agency has a duty (either explicit in law, or at any rate implicit) to set SENSIBLE STANDARDS ❑ Unfortunately not all do so! ❑ Inappropriate standards waste money! ❑ *Always* discuss inappropriate standards with the regulator **Standards** are legally enforceable and so only apply in one jurisdiction. **Guidelines** are *not* legally enforceable – they are recommendations for 'good practice' made by national or international agencies	Standards are legally enforceable, so they apply only in one jurisdiction, usually a single country or a grouping of countries such as the European Union. Guidelines, on the other hand, are basically recommendations for good practice, and they're made by national or international agencies, but they're not enforceable by law.

5.	**UK Royal Commission (1898–1915)** • One of the earliest sets of effluent standards (to protect UK rivers) **UK RIVER WATER QUALITY:** ▪ Very clean: BOD_5 ≤ 1 mg/l ▪ Clean: = 2 mg/l ▪ Fairly clean: = 3 mg/l ▪ Doubtful: = 4 mg/l ▪ Bad: ≥ 10 mg/l	The UK Royal Commission on Sewage Disposal, which sat from 1898 to 1915, produced one of the earliest sets of effluent standards − to protect UK rivers. It classified river water quality on the basis of a new test that it introduced: the 5-day BOD of the river water. Very clean rivers had a BOD of ≤1 mg/l, clean was a BOD of 2 mg/l, and so on, as shown on the slide.
6.	**BOD mass balance** Q = flow (m^3/d), L = BOD_5 (mg/l, = g/m^3) Subscripts: r, river; e, effluent; m, river−effluent mixture *just below* point of effluent discharge Value? →  Thus "in" = "out" (in g BOD/d): $Q_rL_r + Q_eL_e = (Q_r + Q_e)L_m$	The Commissioners then set about determining the maximum permissible BOD of a treated wastewater that was to be discharged into a river. To do this, they considered a mass balance of BOD. Basically this says that, just downstream of the point of discharge, what goes 'in' must come 'out'. What goes 'in' is the BOD in g/day due to (a) the river water upstream and (b) the wastewater effluent; and this has to equal what goes 'out', the BOD, again in g/day, of the downstream river water-effluent mixture. So the BOD mass balance equation is: $$Q_rL_r + Q_eL_e = (Q_r + Q_e)L_m$$ where Q is the flow in m^3/day and L the BOD in mg/l (which is the same as g/m^3), and the subscripts r, e and m refer to the river, the effluent and the river-effluent mixture.
7.	$Q_rL_r + Q_eL_e = (Q_r + Q_e)L_m$ The Royal Commissioners assumed an 8-fold dilution of effluent with clean river water − ie, Q_r/Q_e = 8 and L_r = 2 mg/l; and to avoid pollution, L_m = 4 mg/l ("doubtful"). Therefore: **$L_e \leq 20$ mg/l** To this they added an SS requirement of ≤30 mg/l Known as: The "20/30" or *the* Royal Commission standard	To solve this equation, the Commissioners had to make some assumptions, such as an available dilution of 8, that is to say the river flow is 8 times the effluent flow; that the upstream river was clean, i.e. its BOD is 2 mg/l; and that, to avoid nuisance, the downstream river water has a BOD of 4 mg/l. Putting all these values into the BOD mass balance equation enabled the Commissioners to determine that the maximum BOD of the treated wastewater was 20 mg/l. To this BOD standard, they added a maximum suspended solids requirement of 30 mg/l. This became known as the "20/30" standard, often but erroneously, termed *the* Royal Commission standard.

8.	**RC's recommendations for other ranges of dilution** ❑ The "20/30" standard is generally considered *the* Royal Commission standard, **but:** Available dilution / BOD_5 / SS >500 / – *† / – *† → 300–500 / – * / 150 150–300 / – * / 60 **8–150** / **20** / **30** <8 / <20 ** / <30 ** * No standard recommended † Screening & grit removal ** Precise values to be decided on local situation	Actually the 20/30 standard wasn't the only one recommended by the Royal Commission. In fact the Commissioners recommended a range of standards depending on the dilution available. They applied their 20/30 standard to dilutions in the range 8−150; for dilutions <8 the precise values for BOD and suspended solids were to be set based on the local situation; and for dilutions >150 they recommended only standards for suspended solids, and when the dilution was >500 no standards were deemed necessary and the wastewater only required screening and grit removal.
9.	**Example of dilution >500** • City of Manaus (Amazonas, Brazil), population 1.4m in 2000, discharges its wastewater untreated into the Rio Negro (which joins the River Amazon just downstream of the city) • Rio Negro: dry season flow of ~30,000 m^3 per second! • Dilution >>500, so no treatment!	A good example of dilution much greater than 500 is at the city of Manaus, the capital of Amazonas state in Brazil. The city had a population of ~1.4 million in 2000, and all its wastewater is discharged without treatment, just coarse screening, into the Rio Negro which joins the Amazon River just downstream of the city. The Rio Negro has a dry season flow of ~30,000 m^3 per *second*, so the dilution is vastly greater than 500 and no treatment is necessary.
10.	**OTHER BOD STANDARDS** For example: • India: ≤30 mg/l • European Union (91/271/EEC): ≤25 mg/l (but for WSP effluents this is *filtered* BOD − ie, excluding the BOD of the algae) ❖ BOD standard is now often for carbonaceous BOD (ie, nitrification-inhibited, so excluding O_2 demand of nitrification*) * $NH_3 \rightarrow NO_2 \rightarrow NO_3$	Other examples of BOD standards include ≤30 mg/l in India and ≤25 mg/l in the European Union, but for waste stabilization pond effluents in the EU this is ≤25 mg *filtered* BOD/l − i.e., excluding the BOD due to the algae in pond effluents. Generally BOD standards are now set for just carbonaceous BOD, sometimes called 'nitrification-inhibited' BOD as a chemical is added to the BOD dilution water to stop the growth, and hence, the oxygen demand, of nitrifying bacteria.
11.	**COASTAL DISCHARGES: Aruba Protocol (1999) to Cartagena Convention (1983)** ❖ Reduction of Marine Pollution in the "Wider Caribbean Region" from 'Land-based Sources and Activities' DOMESTIC WASTEWATER EFFLUENT QUALITY: Discharge into Class I waters: • SS (exc. WSP algae): ≤30 mg/l • BOD: ≤30 mg/l • FC: ≤200 per 100 ml* *assumes discharge is into surf zone of bathing beach.	Good examples of standards for coastal discharge are in the Aruba Protocol of the Cartagena Convention which basically a treaty signed by all states in and around the Caribbean. The Aruba Protocol seeks to reduce marine pollution from 'land-based activities' which basically means wastewater discharges to the sea. For discharges into 'Class I' waters, which I'll define in a moment, the BOD

		and suspended solids both have to be ≤30 mg/l and the faecal coliform count in the surf zone just off beaches has to be ≤200 per 100 ml.
12.	**COASTAL DISCHARGES: Aruba Protocol (1999) to Cartagena Convention (1983)** ❖ Reduction of Marine Pollution in the "Wider Caribbean Region" from 'Land-based Sources and Activities' DOMESTIC WASTEWATER EFFLUENT QUALITY: Discharge into Class I waters: — Class II: • SS (exc. WSP algae): ≤30 mg/l — ≤150 mg/l • BOD: ≤30 mg/l — ≤150 mg/l • FC: ≤200 per 100 ml* — ---- *assumes discharge is into surf zone of bathing beach.	For discharge into Class II waters the only requirements are that the BOD and suspended solids both have to be ≤150 mg/l.
13.	**COASTAL DISCHARGES: Aruba Protocol to Cartagena Convention** Definition of Class I waters: • Areas containing coral reefs, seagrass beds or mangroves, • Areas critical for breeding, nursery or foraging for marine life, • Areas providing habitat for protected marine species, • Recreational waters. Details at www.cep.unep.org Class II waters: other waters not affected by wastewater discharges.	Class I waters are sensitive waters, of the types shown on the slide; and Class II waters are all other waters which are essentially not affected by wastewater discharges. Discharges from long sea outfalls are almost always into Class II waters.
14.	**COASTAL DISCHARGES: Aruba Protocol to Cartagena Convention** Discharge into Class I waters: — Class II: • SS (exc. WSP algae): ≤30 mg/l — ≤150 mg/l • BOD: ≤30 mg/l — ≤150 mg/l • FC: ≤200 per 100 ml — – ➢ High wastewater quality to protect Class I waters ➢ Low wastewater quality for discharge into Class II waters (because of huge dilution available)	The requirements of the Aruba Protocol are basically very sensible: strict quality requirements are applied when the discharge is into sensitive Class I waters, but quite relaxed requirements when the discharge is into Class II waters.
15.	**SHELLFISH WATERS** EU Directive 79/923/EEC: Shellfish growing waters: ≤10 *E. coli* per 100 ml 	Another example applying to coastal waters is for shellfish-growing waters; in the European Union the *E. coli* count in such waters should be ≤10 per 100 ml.

16.	**BATNEEC or CATNAP?** BATNEEC: Best Available Technology Not Entailing Excessive Cost	Governments and regulators often want BATNEEC for wastewater treatment. BATNEEC is the 'best available technology not entailing excessive cost'. This is fine from their perspective, but …
17.	**BATNEEC or CATNAP?** BATNEEC: Best Available Technology Not Entailing Excessive Cost **CATNAP:** **Cheapest Available Technology** **Narrowly Avoiding Prosecution**	what the plant owner and operator wants is CATNAP, the 'cheapest available technology narrowly avoiding prosecution'. CATNAP started off as a joke, but it has its serious side. After all, why have an expensive plant that produces an effluent BOD of ~3 mg/l when the regulator only specifies ≤20 mg/l? A cheaper one that produces 18 or 19 mg/l would be perfectly OK. Unfortunately there are too many examples of unnecessarily expensive treatment technologies being 'sold' to the unwary.