SCIENTIFIC BASIS OF ENVIRONMENTAL QUALITY GUIDELINES AND THEIR APPLICATION AT CONTAMINATED SITES

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Focus of Presentation

- Canadian Council of Ministers of Environment (CCME) Soil Quality Guidelines (SQG)
- Soil is most common media of concern at brownfield sites
  - Air, groundwater, surface water, sediments may also be of concern at some sites and appropriate guidelines for those media would be applied
- CCME SQG are most commonly applied environmental quality guidelines at Atlantic region brownfield sites

Overview

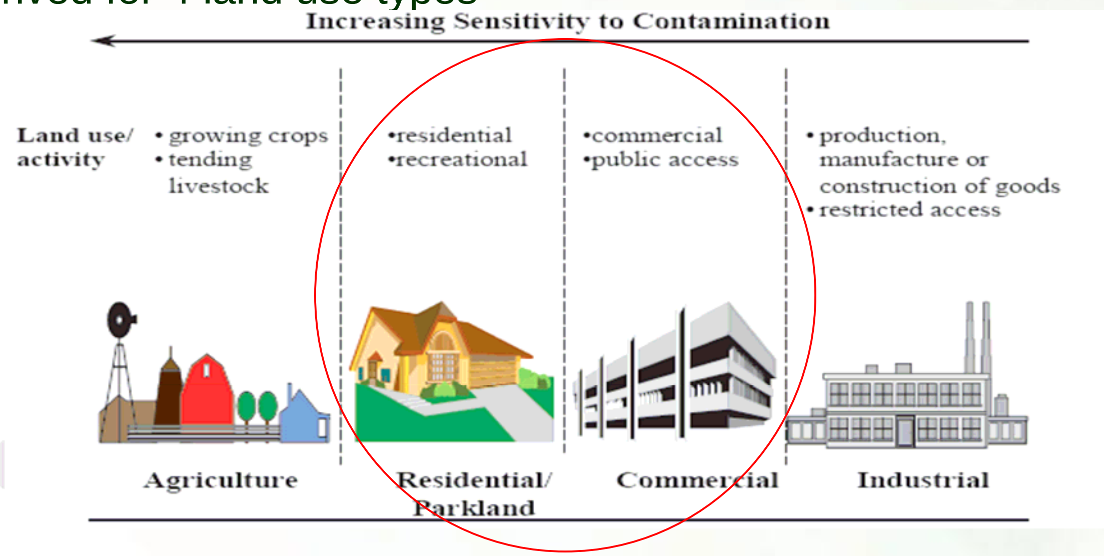
- What are CCME SQG?
  - description
  - scientific basis / how are they developed
- How are they used?
  - Typical use
  - Modification of generic SQG to reflect site-specific conditions
- Example of SQG application
  - Demonstrate how applying knowledge of SQG scientific basis and site-specific conditions can reduce # of chemicals of concern at a site, and possibly reduce remediation and/or risk assessment costs

What are CCME Soil Quality Guidelines?

- Numerical concentration limits (e.g., mg/kg or ppm) or narrative statements to support and maintain designated used of soil
  - not legally enforceable
  - Generic and national in scope – not reflective of unique conditions that may exist at a given site, but reflect typical central tendency conditions that are believed to exist at most sites

- represent "clean down to levels“, not "pollute up to” levels

- Derived for 4 land use types



What are CCME Soil Quality Guidelines?

- SQG have been developed for various chemicals - includes both carcinogens and non-carcinogens (~30 developed using CCME SQG Protocol to date)

- A SQG can be considered a risk assessment in reverse, with use of conservative and protective assumptions and RA principles/methods to ensure **protection of both sensitive human and ecological receptors** under typical conditions; thus they are risk-based guidelines






How are CCME SQG Developed?

- SQG development is complex. Details on history, principles, protection goals, process, the assumptions, considerations, scenarios, data requirements, derivation techniques, calculations, decision rules, and uncertainties within the SQG Protocol in:
  - CCME (2005; draft); CCME (1996); CCME (2000) and rest of the CCME contaminated sites library
- There are 2 SQG procedures: environmental (SQGe) and human health (SGQhh):
  - number of direct and indirect exposure scenarios considered under both – depends on land use category and chemical
  - lowest value from all environmental and human health scenarios is carried forward as the SQGe and SQGhh, respectively
  - lowest of either the SQGe or SGQhh becomes the final national generic SQG for each of the 4 land use categories where data allow **[final SQG are what is presented in CCME summary tables]**

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How are CCME SQG Developed?

- Before any SQG calculations, information is first compiled and reviewed on:
  - Phys-chem properties, analytical methods, production/use, levels in all Canadian environmental media, existing benchmarks from other jurisdictions, environmental fate and behaviour in all media, absorption, metabolism, elimination in species of interest, bioaccumulation, and toxicity in soil microbes, invertebrates, plants, livestock, wildlife, experimental animals, and humans
  - Consider transformation products formation, behavior and effects; factors that may modify toxicity, dietary essentiality
  - Animal and human toxicology information considered includes acute, subchronic and chronic data for wide range of endpoints/effects
  - Toxicology review identifies toxicity reference values (TRV) that are considered protective of the receptors of interest for the 4 land uses

How are CCME SQG Developed?

Environmental Soil Quality Guideline (SQGe) Procedure

- Calculate soil concentration values for following scenarios:
  - direct soil contact for plants
  - Direct soil contact for soil invertebrates
  - *nutrient and energy cycling
  - ingestion of contaminated food and soil by wildlife and/or livestock
  - transport through groundwater to potential livestock watering sources
  - transport via groundwater to surface water inhabited by aquatic life
  - *off-site migration
- lowest soil concentration from these scenarios becomes the SQGe.
- level of protection for each scenario is dependent on the land use
- some scenarios not evaluated for all land uses or all contaminant types
- '*' implies check mechanisms - management adjustment factors; not used as SQGe basis but can be used to adjust value from the other scenarios

How are CCME SQG Developed?

Soil Quality Guidelines Human Health (SQGhh) Procedure

- Calculate soil concentration values for following scenarios:
  - direct soil exposure (soil ingestion, dermal contact, and particulate (dust) inhalation)
  - transport of contaminants through groundwater to potential drinking water sources
  - intrusion of vapours into buildings
  - *human consumption of contaminated home-produced foods
  - *offsite migration
- lowest soil concentrations for these scenarios becomes the SQGhh
- again, scenarios dependent on land use, and not all scenarios evaluated for all land uses or contaminant types
- '*' implies check mechanisms - not used as SQGhh basis but can be used to adjust value from other scenarios

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How are CCME SQG Developed?

For SQGhh:

In addition…

- Non-soil exposures (EDI) estimated and accounted for (air, diet, water, consumer products); cannot exceed TRVs – if it does, CCME reverts to background or detection limit

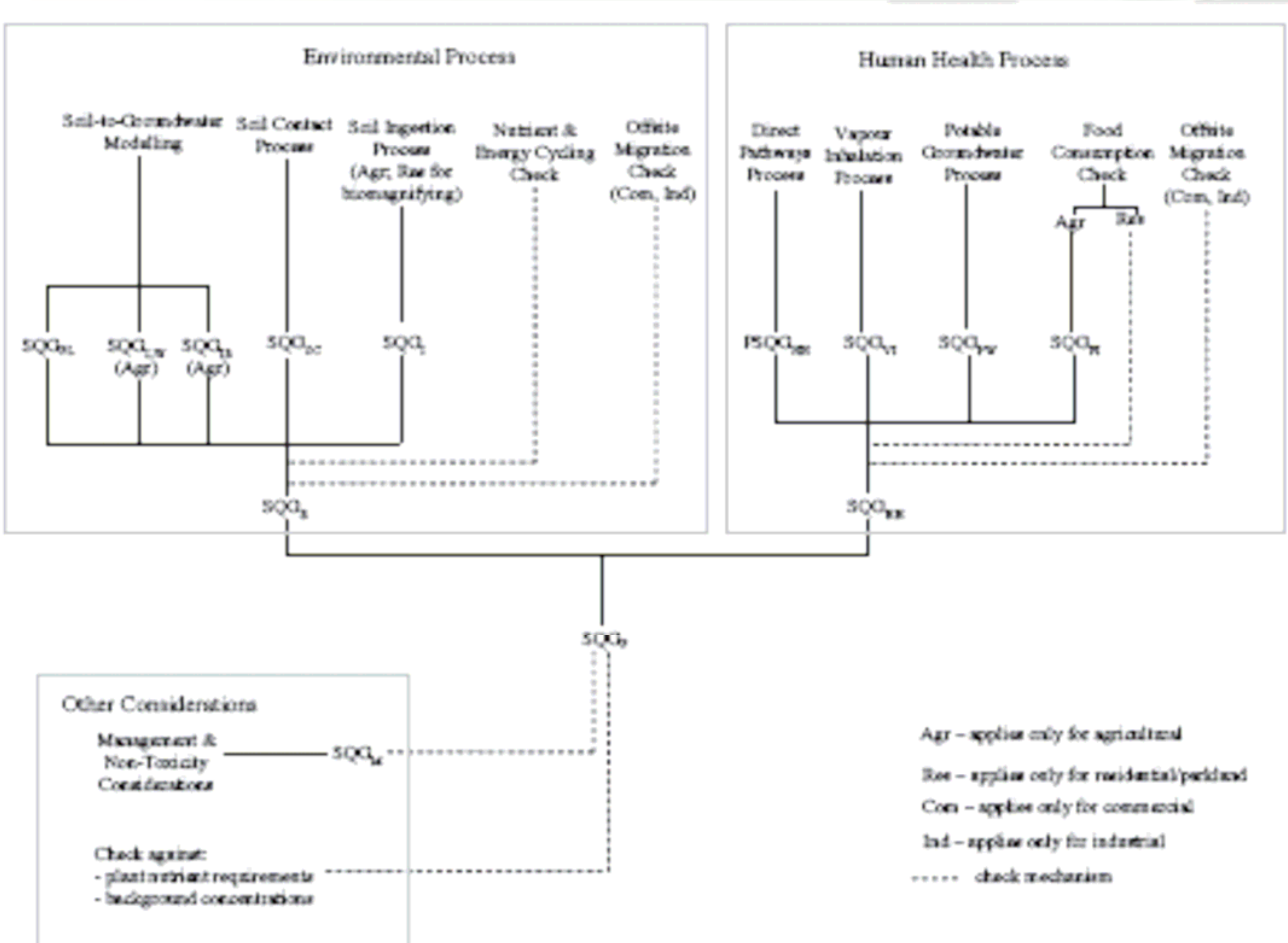
- apportion 20% of the allowable exposure to soils (Soil Allocation Factor) - allows for 80% of the remaining tolerable incremental exposure to be reserved for other media (i.e., food, air, water, consumer products)

How are CCME SQG Developed?

Final Soil Quality Guideline (SQGf)

- lowest of final SQGe and SQGhh becomes final generic soil quality guideline (SQGf) for each land use
- SQGf is then checked against non-toxicity considerations (e.g, plant nutrition, geochemical background, analytical detection limits); SQQf must be practical
- Data not always adequate to derive SQGe or SQGhh for all scenarios for all land uses; for a number of chemicals with current CCME SQG, some scenarios could not be completed, and some SQGe or SQGhh are either provisional or could not be calculated
- Final generic SQGf is soil concentration at or below which no appreciable risk to human health and environmental health is expected

Summary of CCME SQG Process



Example Calculations

Direct soil contact (ingestion, dust inhalation, dermal contact)

$$PSQG_{HH} = \frac{(TDI - EDI) \times SF \times BW}{[(AF_G \times SIR) + (AF_S \times SR) + (AF_L \times IR_S) \times ET_2] \times ET_1} + BSC$$

Non-carcinogens

$$PSQG_{HH} = \frac{RsD \times BW}{[(AF_G \times SIR) + (AF_S \times SR) + (AF_L \times IR_S)] \times ET} + BSC$$

Carcinogens

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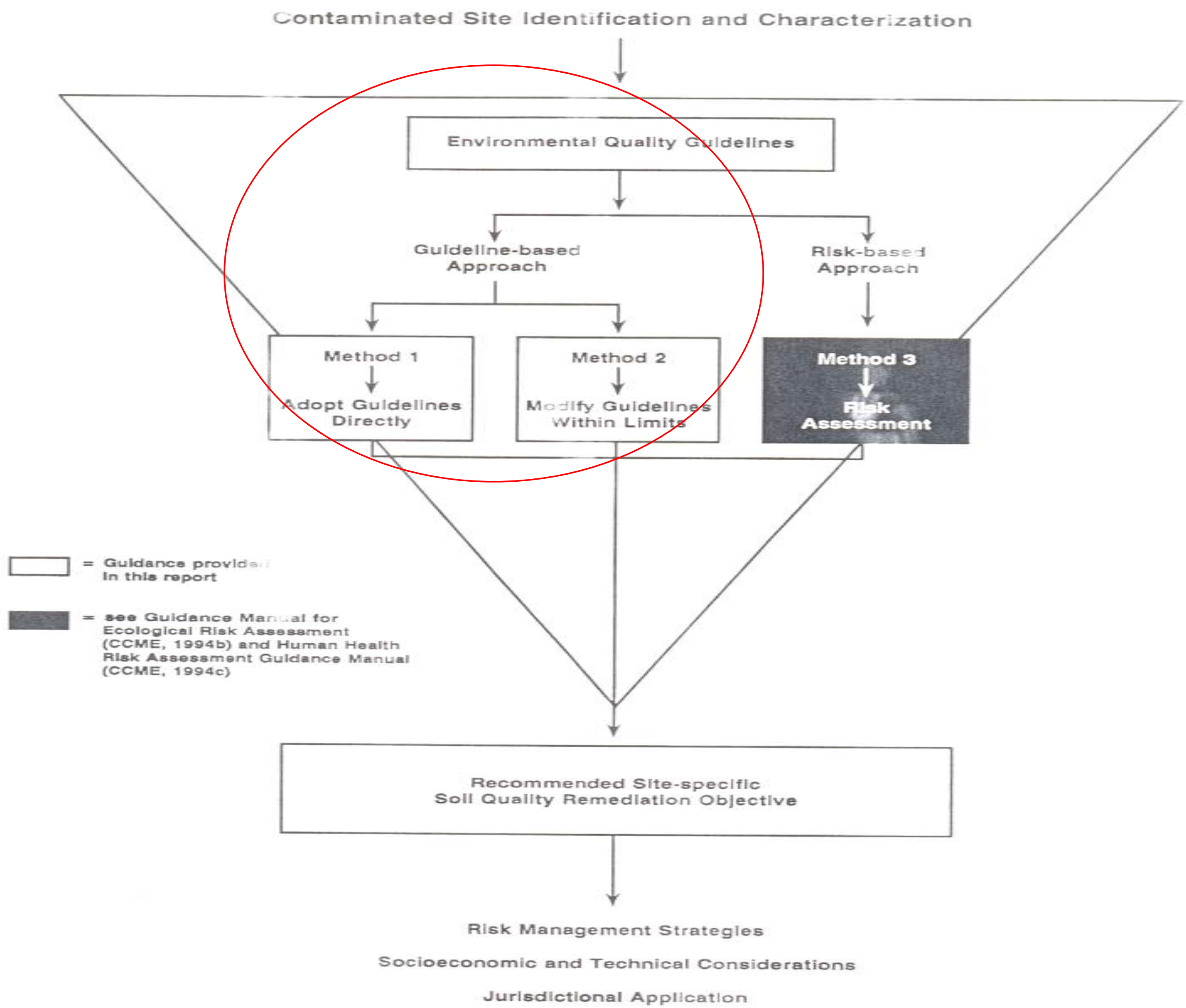
Example Calculations Cont'd

- Other calculation procedures to deriving SQGe and SGQhh in other scenarios are more complex and are detailed in CCME 2005
- In all, default Canadian receptor parameters and standard risk assessment assumptions and methods are used (CCME, Health Canada, Environment Canada)

How are CCME SQG Used?

FIGURE 2

NATIONAL FRAMEWORK FOR CONTAMINATED SITE ASSESSMENT AND REMEDIATION



How are CCME SQG Used?

- Comparing against soil chemistry data in Environmental Site Assessments (Phase 2 and 3 ESAs) and in Problem Formulation or Planning Stages of Risk Assessments (human health and ecological); In RA's, SQG used to help select chemicals of potential concern (screening)

- Common for ESAs to compare soil chemistry statistics (usually max) to final generic SQG

How are CCME SQG Used?

- Generally,
  - if max <SQG, no problem
  - if max >SQG, **potential** problem – further study (such as more sampling or risk assessment) or cleanup, or modification of generic SQG to reflect site-specific conditions
- Exceedance (especially of a final SQG) does not necessarily mean ‘dig it up’ or proceed directly to risk assessment
- By understanding SQG scientific basis and considering site-specific conditions, may be able to reduce # of contaminants of concern at a given site, such that risk assessment or cleanup costs may be reduced

Modifying Generic CCME SQG

- Modification of generic SQG to develop site-specific ‘objectives’ is endorsed and recommended by CCME within the National Framework for the Assessment and Remediation of Contaminated Sites.
- Acknowledged by CCME that assumptions and conditions in final SQG derivation may not apply at every site – flexibility is important in being able to modify a generic SQG to reflect site-specific conditions
- CCME produced a guidance document in 1996 that recommends procedures for evaluating applicability of generic guidelines to contaminated sites and for modifying generic guidelines to account for atypical or unique site characteristics.
- Must be sound rationale for modification, and should seek approval by regulators
- While site-specific objectives will be higher than generic SQG, must be cautious about compromising level of protection

Modifying Generic CCME SQG

- CCME (1996) outlines situations in which generic SQG can be modified to become site-specific objectives
  - Background concentrations
  - Toxicity values (typically, **only** if SQG was based on outdated value and updated value has been accepted by Health Canada, or a strong toxicological argument can be made)
  - receptor parameters and assumptions
  - default assumptions for soil phys chem properties
  - the operable exposure pathways at a site
- Can also possibly modify (with approval)
  - Carcinogen target risk level (current CCME SQG assume 1 in 1 million acceptable cancer risk level, but Atlantic Canada governments endorse 1 in 100,000
  - EDI from non-soil sources
  - Amount absorbed from soil (if have site-specific bioaccessibility or literature strongly shows lower absorption from soil than assumed in generic SQG derivation)
- If are several desired modifications to a generic SQGhh, consider site specific risk assessment

What if no CCME SQG exists?

- If have chemicals measured in soil and no CCME SQG exists, it does not mean chemical is not of potential health significance
  - Can compare to background data if available
  - Can compare to other jurisdictions soil quality guidelines (eg., Ontario, US EPA (Regions III, VI, and IX), Massachusetts DEP etc.)
  - If no background and no other guidelines exist, may need to collect background data, or include chemical in a risk assessment or provide some other sound rationale for why its not a concern (eg., nutritional essentiality)

Case Study

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Case Study of CCME SQG Application and Modification

- Assume:
  - urban site with no ecological habitat
  - coarse soil texture
  - soil is only media of concern (deep aquifer, no evidence of leaching, no adjacent or down gradient surface water)
  - direct soil pathways (ingestion, inhalation, dermal) only viable exposure pathways
- Assume no potable groundwater use in area
- Assume recreational parkland is future land use with no anticipated buildings
- Thus, interested only in human health protection
- Assume following chemicals were measured in surface soil and exceed regional background concentrations

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Case Study

Chemical	Max Soil Concentration (mg/kg)	CCME Final Generic SQG (mg/kg)
Arsenic	24	12
Cadmium	12	10
Chromium (total)	75	64
Copper	80	63
Nickel	85	50
Manganese	260	NGA
Zinc	500	200
Benzene	0.5	0.0095

All chemicals max soil concentrations > final CCME SQG!

Case Study

Chemical	Max Soil Concentration (mg/kg)	CCME Final SQGhh (mg/kg)
Arsenic ✖	24	12
Cadmium √	12	**14**
Chromium √	75	**220**
Copper √	80	**1100**
Nickel ✖	85	**No CCME SQGhh!**
Manganese ✖	260	NGA
Zinc ✖	500	**No CCME SQGhh!**
Benzene ✖	0.5	0.0095

By using SQGhh instead of final SQG, Cd, Cr, Cu no longer an issue, as final SQG for these metals is based on environmental effects!

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Case Study

Chemical	Max Soil Concentration (mg/kg)	CCME Final SQGhh (mg/kg) - focused on direct contact pathways only
Arsenic ✖	24	12
Nickel ✖	85	**No SQGhh!**
Manganese ✖	260	NGA
Zinc ✖	500	**No SQGhh!**
Benzene √	0.5	**240**

Final benzene SQGhh based on indoor vapour intrusion – replace with direct contact SQGhh and benzene is no longer an issue

Case Study

Chemical	Max Soil Concentration (mg/kg)	Using Ontario and US EPA human health based SQG where no CCME SQGhh exists
Arsenic ✖	24	12
Nickel √	85	**310 (Ontario)**
Manganese √	260	**320 (US EPA)**
Zinc √	500	**16,000 (Ontario)**

Applying human health-based SQG from Ontario and EPA for chemicals with no CCME SQGhh removes Ni, Mn, and Zn from consideration

Case Study

Chemical	Max Soil Concentration (mg/kg)	CCME SQGhh with Atlantic region target risk level (1 in 100,000) instead of CCME default
Arsenic √	24	31

The current arsenic CCME final SQGhh assumes target risk level of 1 in 1 million - changing the risk level in the CCME equation for direct soil contact SQGhh from 1 in 1 million to 1 in 100,000 (which is used in Atlantic Canada) results in a SQGhh of 31 mg/kg (Health Canada, 1995).

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Case Study

- What initially looked like a need for risk assessment or remediation for 8 chemicals based on final SQG comparisons with maximum site soil concentrations is no longer necessary when SQG basis is considered in light of site-specific conditions, and other agencies guidelines are used where no CCME guidelines exist

Thankyou!