Ethical Issues in ALARA Application

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“Radiation protection is not only a matter for science. It is a problem of philosophy, morality, and the utmost wisdom”

[Lauriston Taylor, 1980]

Ethics

- The question of how one should live and act.
- A dimension of every human experience and enterprise.
  - Question of Value.
  - Morality (individual right and wrong) is important but are only a subset of ethics as a whole
  - Private ethics is secondary to public.
- ‘Ethics’ comes from the Greek word *ethos,* meaning custom.
- Its philosophical usage refers
  - Not to *“how people actually do behave in their dealings with each other”*
  - But to *“how they ought to behave”.*
- The fundamental ethical question:
  - “How should one best live, or what should one best do?” (Socrates)

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Ethical Realism vs. Relativism

- Realism
  - There are things, values or ways of behaving that exist independently of whether anyone knows them.
- Relativism
  - Whether or not there are ‘things in themselves’, some things (and arguably all things) can never actually be known in themselves, because they can never be separated from our knowledge of them.
  - Therefore, ‘representations’ can only ever be compared with other ‘representations’, never with an unrepresented reality.
  - There are, therefore, and can be, only truths which are relative in the sense that they are not final, complete or absolute.

Objective vs. Subjective

- Everything we can know, think about, or discuss – including ethics – is a function of both of the ‘objective’ world and of our ‘subjective’ apprehension of it.
- The resulting knowledge is converted, through the same process of awareness, reflection and interaction, into decisions for action.

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Value

- Instrumental value vs. intrinsic value
- Instrumental value:
  - The value someone or something has as a means to something else, where that something else constitutes a good in itself.
- Intrinsic value:
  - When someone or something has a value as an end in itself.
- Value requires both a world and participation by valuers to be real. It is both objective and subjective.

Three Schools of Ethics

- Virtue Ethics
- Deontology (‘Rights’)
- Utilitarianism (‘Consequences’)

Virtue Ethics

- Stems from the philosophy of Plato.
- Its central focus is on *developing a virtuous character*.
- The exercise of virtue is what produces a good person.
- Such a character is marked by its possession of the four classical virtues: temperance, justice, courage, and (practical) wisdom.
- These attributes constitute *eudaimonia* (Aristotle), ‘well-being’.
- A person who embodies *eudaimonia* will also promote it among others.
- There is nothing in the theory itself limiting who or what can be the object of virtuous behavior.

Deontology (‘Right’)

- *deon* (Greek): ‘duty’ or ‘that which must be done’
- Actions fulfilling duty are morally right regardless of their consequences.
- Immanuel Kant:

  (1) act only on a maxim that you can will at the same time to be or become a universal law;

  (2) treat all people as ends or subjects in their own right and never merely to be followed regardless of the specific consequences.

  – Follows universal individual human rights.
  – Against the assertion by David Hume that ethical behavior is of people’s sympathy and emotion.
  – Unable to supply any substantive reason as to why non-rational beings (including the rest of nature) should be treated well (thus anthropocentric).

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Utilitarianism

- The highest good is the greatest happiness of the greatest number of people. (Jeremy Bentham (1748 –1832), John Stuart Mill (1806 – 1873))
- The decisive ethical question about an action is whether or not it is useful in relation to the general happiness of humanity.
- Happiness has to be susceptible to being 'objectively' measured - It tends to measure that which can be measured and ignore that which cannot.
- The subjective motivations of objective actions are irrelevant. It is the most powerful single philosophy in social and economic policy in the modern 'Western' world - Its emphasis on objectivity, on collectivity, and on measurement is a fundamental part of the modern project.
- 'Actions are right or wrong, good or bad, according to how they affect the experiences of beings capable of experience' (Wenz, 2000) – Non-sentient being, a species or an ecosystem, has little value.

ALARA

- “To keep radiation exposure as low as reasonably achievable (ALARA), taking into account economic and social factors.”

Optimization of radiation protection

- "There should not be any occupational exposure of workers to ionizing radiation without the expectation of an overall benefit from the activity causing the exposure."
- Optimization of radiation protection is to achieve maximum net benefit from radiation exposure after economic and social factors are taken into account.

Radiation Protection Cost-Benefit

$B = V - (P + X + Y)$

- B = the net benefit
- V = gross benefit
- P = basis production cost
- X = the cost of achieving a selected level of protection
- Y = the cost of detriment

- $B = V - (P + X + Y)$
- The changes are evaluated in each of these costs relative to change in collective dose S.
- The optimum net benefit is obtained when

$$\frac{dB}{dS} = 0 = \frac{dV}{dS} - (\frac{dP}{dS} + \frac{dX}{dS} + \frac{dY}{dS})$$

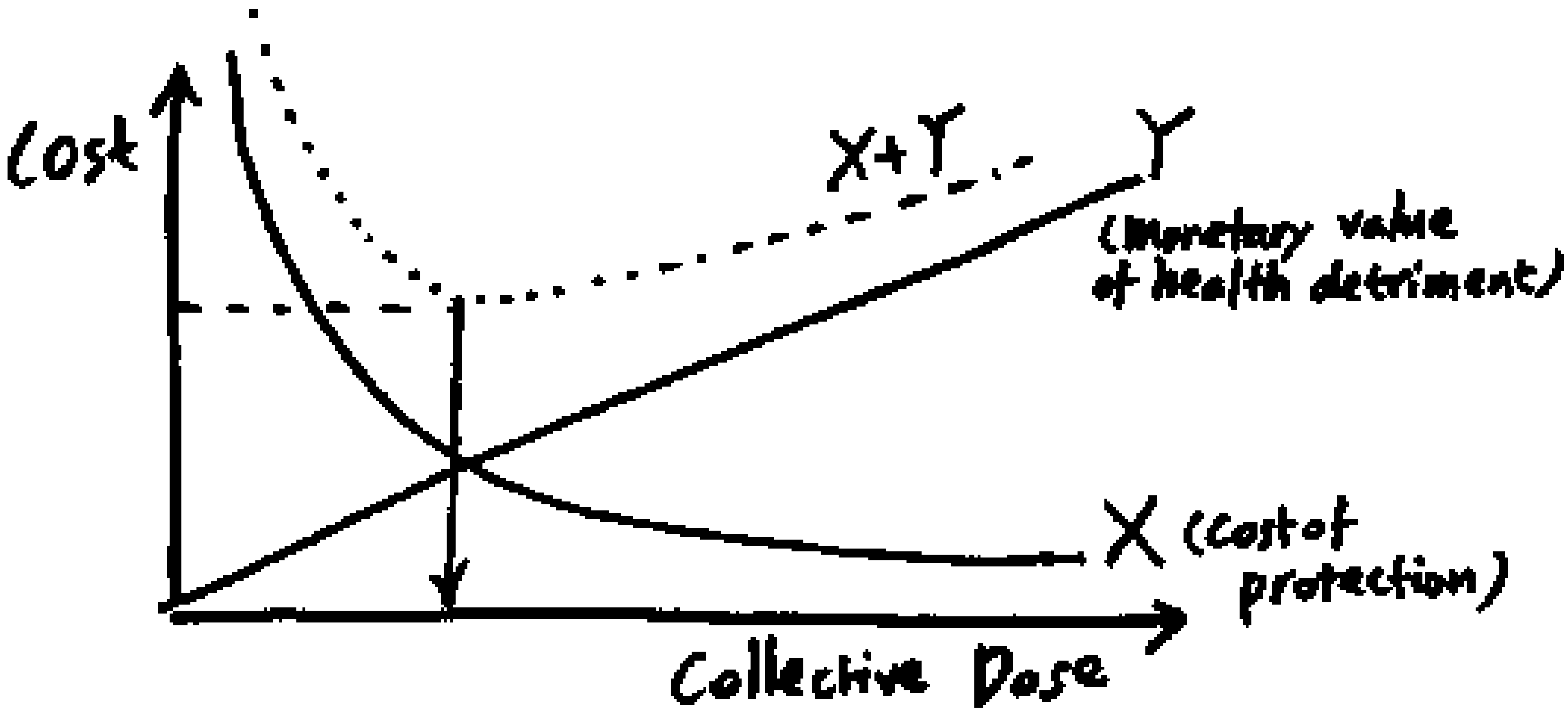
- Generally, V is considered constant. Then,

$$\frac{dX}{dS} = -(\frac{dP}{dS} + \frac{dY}{dS})$$

- If P (the basic production cost) is fixed,

$$\frac{dX}{dS} = -\frac{dY}{dS}$$

$$\frac{d(X+Y)}{dS} = 0$$



Cost
X+Y
Y
(Monetary value of health detriment)
X (cost of protection)
Collective Dose

Example: Choosing effluent treatment options

- For liquid effluents

Treatment option	Cost of options ($\$ \times 10^6$)	Remaining health effects (30 yrs)
0	0	159
L1	1.30	2.82
L1+L2	2.24	0.51
L1+L2+L3	3.54	-

Example: Choosing effluent treatment options

- For gaseous effluents (excluding iodine)

Treatment option	Cost of options ($\$ \times 10^6$)	Remaining health effects (30 yrs)
0	0	0.93
G1	0.35	0.19
G1+G2	0.89	0.10
G1+G2+G3	3.54	0.02

Example: Choosing effluent treatment options

- For iodine release

Treatment option	Cost of options ($\$ \times 10^6$)	Remaining health effects (30 yrs)
0	0	0.17
I1	0.95	0.05
I1+I2	2.72	0.02
I1+I2+I3	3.31	0.01

Example: Choosing effluent treatment options

- Assume
  - The cost of detriment depends on residual health effects only.
  - The monetary value of an effect is $\$0.5x10^6$.

Example: Choosing effluent treatment options

- For liquid effluents

Treatment option	X: Cost of options ($\$ \times 10^6$)	Y: Cost of detriment ($\$ \times 10^6$)	X+Y: Total Cost ($\$ \times 10^6$)
0	0	79.5	79.5
L1	1.30	1.41	2.71
L1+L2	2.24	0.26	2.50
L1+L2+L3	3.54	-	3.54

Example: Choosing effluent treatment options

- For gaseous effluents (excluding iodine)

Treatment option	X: Cost of options ($\$ \times 10^6$)	Y: Cost of detriment ($\$ \times 10^6$)	X+Y: Total Cost ($\$ \times 10^6$)
0	0	0.465	0.465
G1	0.35	0.095	0.445
G1+G2	0.89	0.05	0.94
G1+G2+G3	3.54	0.01	3.55

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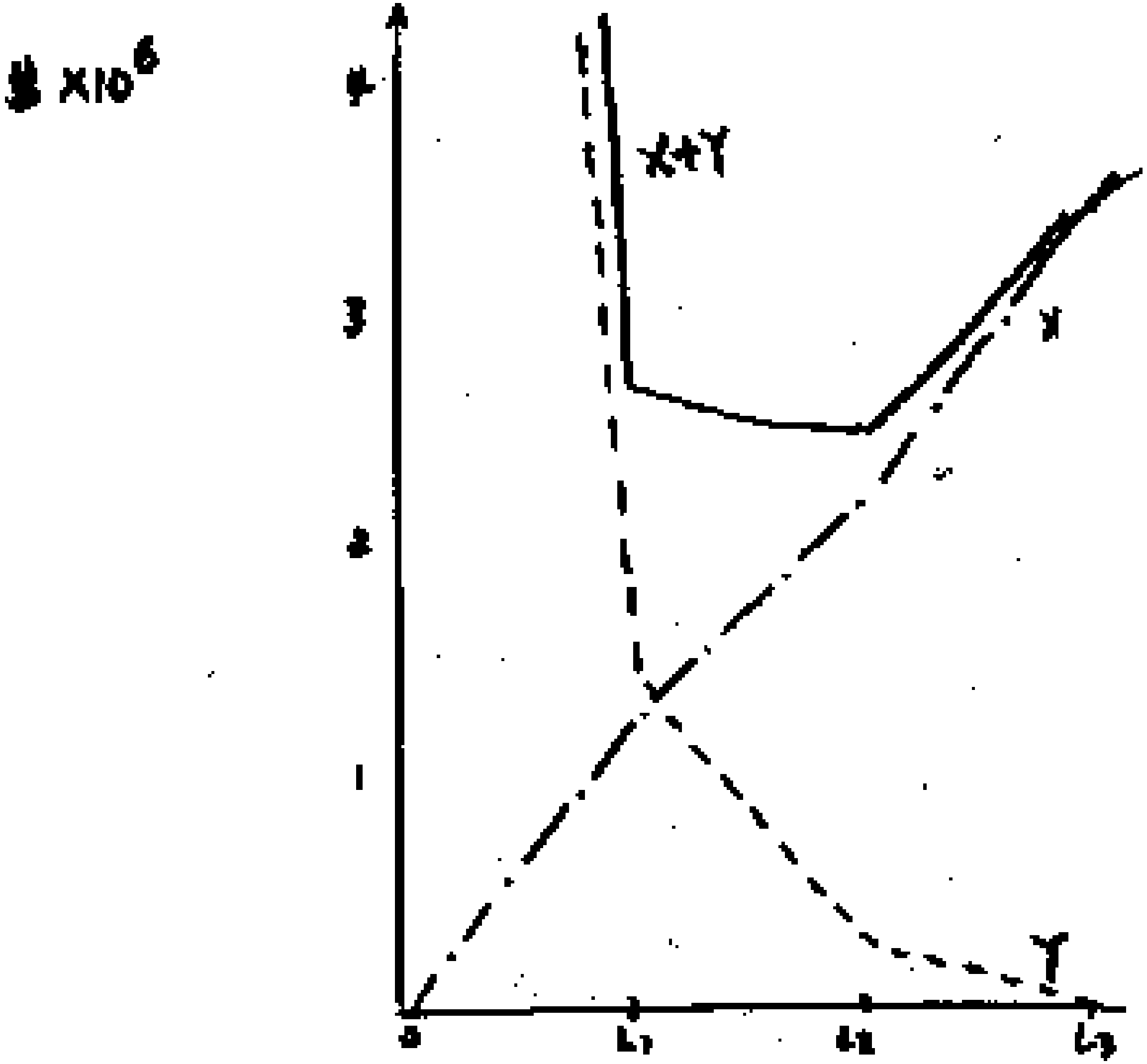
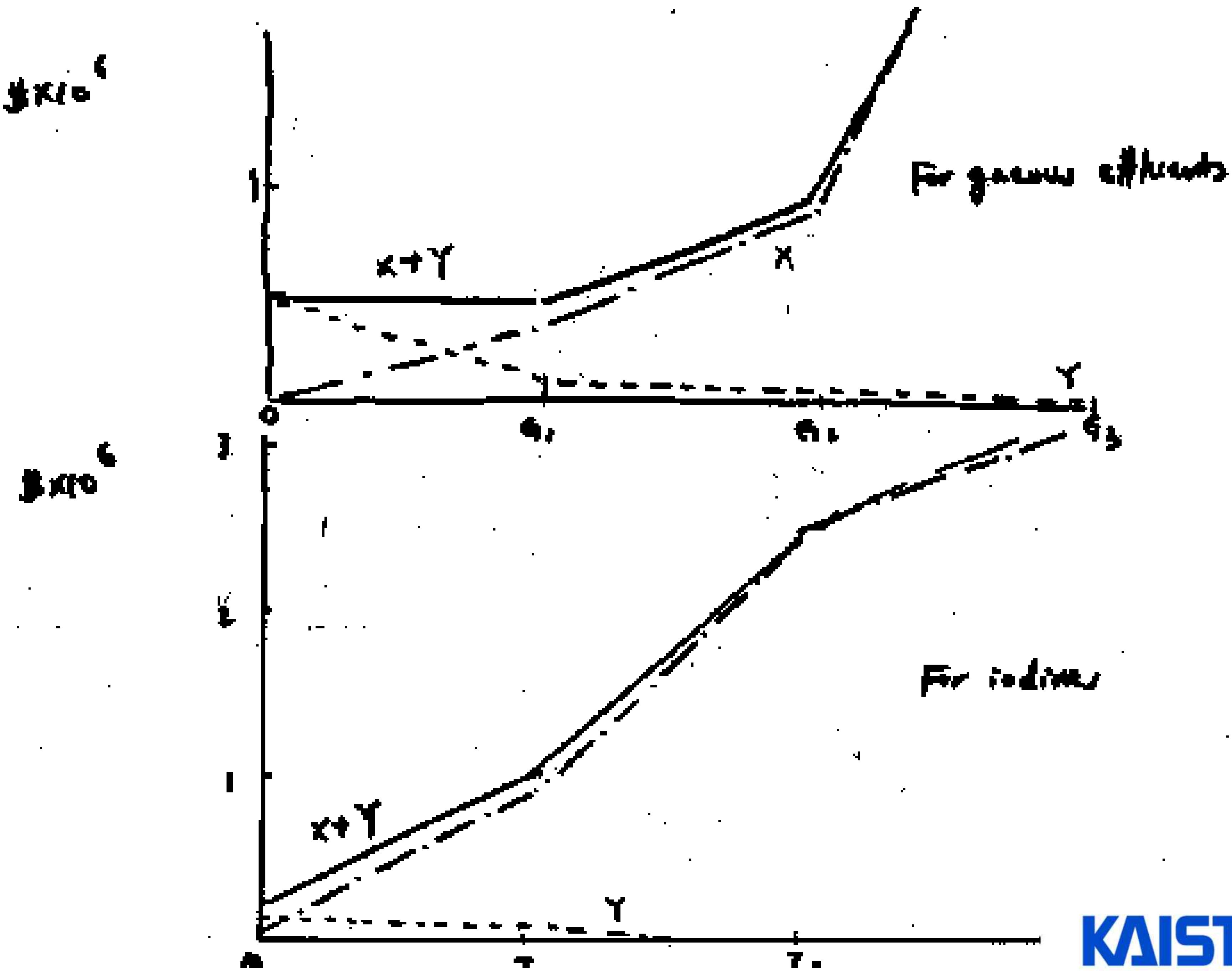
Example: Choosing effluent treatment options

- For iodine release

Treatment option	X: Cost of options ($\$ \times 10^6$)	Y: Cost of detriment ($\$ \times 10^6$)	X+Y: Total Cost ($\$ \times 10^6$)
0	0	0.085	0.085
I1	0.95	0.025	0.975
I1+I2	2.72	0.01	2.73
I1+I2+I3	3.31	0.005	3.315



For liquid effluents



$ x10^6
1
X+Y
X
Y
0
For gaseous effluents
$ x10^6
3
2
1
X+Y
Y
For iodines

Example: Choosing effluent treatment options (with the monetary value of an effect is $\$5.0 \times 10^6$)

- For liquid effluents

Treatment option	X: Cost of options ($\$ \times 10^6$)	Y: Cost of detriment ($\$ \times 10^6$)	X+Y: Total Cost ($\$ \times 10^6$)
0	0	795	795
L1	1.30	14.1	15.4
L1+L2	2.24	2.6	4.84
L1+L2+L3	3.54	-	3.54

Example: Choosing effluent treatment options (with the monetary value of an effect is $5.0x10^6)

- For gaseous effluents (excluding iodine)

Treatment option	X: Cost of options ($x10^6)	Y: Cost of detriment ($x10^6)	X+Y: Total Cost ($x10^6)
0	0	4.65	4.65
G1	0.35	0.95	1.3
G1+G2	0.89	0.5	1.39
G1+G2+G3	3.54	0.1	3.64

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Example: Choosing effluent treatment options (with the monetary value of an effect is $\$5.0 \times 10^6$)

- For iodine release

Treatment option	X: Cost of options ($\$ \times 10^6$)	Y: Cost of detriment ($\$ \times 10^6$)	X+Y: Total Cost ($\$ \times 10^6$)
0	0	0.85	0.85
I1	0.95	0.25	1.2
I1+I2	2.72	0.1	2.82
I1+I2+I3	3.31	0.05	3.36

ALARA

- The principle of reducing exposure to levels that are 'as low as reasonably achievable' (ALARA) is typically implemented in two different ways.
  - First, it is applied to the engineering design of facilities so as to reduce, prospectively, the anticipated human exposure.
  - Second, it is applied to actual operations; that is, work practices are designed and carried out to reduce the human exposure.

ALARA in practice

- IAEA Safety Series No. 109 :
  - $200 per person-rem (range of $100 to $400 depending upon specific country's economy/society)
- NUREG-1530 (1995)
  - $2,000 per person-rem
- DOE standard, applying the ALARA process for radiation protection of the public and environmental compliance with 10 CFR part 834 and DOE 5400.5, ALARA program requirements (1997)
  - $1000-$6000 per person-rem with nominal value of $2000 per person-rem

$2000 per person-rem

- Fatal cancer risk coefficient = 5×10^{-4} per rem
- \$2000 per rem ÷ (5×10^{-4} per rem) = \$ 4 million per fatal cancer case

Issues with ALARA

- Based on the use of collective dose
  - The detriment was assumed to be proportional to the collective dose.
  - This ignores individual variability
- Based on economic considerations
  - Implied a monetary equivalent to the collective dose.
  - Maximizing the net benefit is based on a tradeoff between health or safety and economic gain.
  - Societal benefits are exchanged with individual radiation exposures.
  - Costs and benefits are not distributed homogeneously or equitably throughout the society.
  - This sanctions a utilitarian ethics.
- Based on applying a value on health effects or human life.
  - Human life is not a commodity to be bought, sold, or bid on a market.
  - Depending upon the value assigned, the outcome of ALARA could be different.
- Based on estimated risk
  - ALARA cannot take into account the multidimensionality of risk involved with radiation exposure.

Collective dose

- The concept of collective dose is applied only if the following assumptions are valid [NCRP, Report No. 121, 1995]:
  - The relationship between the dose and its resulting biological effects is linear;
  - The potential effects of the rate at which the doses are received (and whether they are fractionated or protracted) are unimportant;
  - The individual doses and dose rates are sufficiently low that only stochastic (latent) effects need to be considered;
  - The doses are sufficiently high to be statistically significant. (But in reality, most radiation exposures are at low levels. Effects of low-level exposures are not well known.)

Individualism

- Optimization based on collective dose assumes linear-no-threshold dose response, ignores individuals and can result in high dose to an individual.
- Each individual is different and unique.
  - One should treat individuals equally with respect to distribution of social risks, costs, and benefits.
  - The individuals have to be informed of the risk involved and included in the decision making process.
  - Individual variability (e.g., genetic susceptibility) should be considered.
  - Inequities between individuals should be minimized and compensated.

Economic Considerations under Utilitarianism

- Utilitarians point out that the social costs of more stringent risk standards include reduced productivity and profit (e.g., reduced funds available for new jobs, for expansion of markets and services, and for provision of other health, education, and welfare benefits).
- Egalitarians argue that it is unacceptable to use other people as means to some end.
- Egalitarians believe that money-for-safety tradeoffs are often unacceptable. Some harms are so serious that no amount of money could possibly compensate the victims or their survivors.
- Utilitarian ethics are challenged by the post-modern thinking.

Using "Value of Life" or "Value of Safety"

- There is no monetary value that can be ascribed to a human life.
- By assigning a monetary value to human safety, members of the industry would be openly encouraged to sacrifice their workers' safety for their own economic gain. While this may be practical on a small scale, it becomes a slippery slope.
- By changing the value of life or safety, the outcome of ALARA application could vary.
- Current consideration takes into account fatal cancers but non-fatal cancers or non-cancer health effects are unaccounted for.

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Estimated Risk vs. Perceived Risk

- Risk estimation is based on technical rationality
  - Trust in scientific methods, explanations, evidence.
  - Boundaries of analysis are narrow.
  - Risks are depersonalized.
  - Emphasis on statistical variation and probability.
  - Those impacts that cannot be uttered are irrelevant.
- Risk is multidimensional in nature
  - Affected by familiarity, understanding, controllability, voluntariness, dread, trust in institutions, equity, benefits, effects on children, etc.
- The public's view of risk is based on cultural understanding.
  - Different types of people facing a similar societal problem react in different ways.
  - The public's view of risk is affected by political culture, traditions, and democratic process.
  - Risk is personalized emphasizing the impacts on the family and community.
  - Unanticipated or unarticulated particular risks are relevant.

ALARA vs. Health-based individual radiation protection limits

- Use of ALARA was a compromise against a truly health-based standards.
- *De Minimis* Risk - An example of health-based limit.
  - *De Minimis* risk originates from Latin words *de minimis non curat lex* which means the law does not concern with trifles. It implies that, below some level of risk, it is not worth the allocation of social or personal resources to address the problem. Defining *De Minimis* risk level is still subject to human value judgment.
- US Nuclear Regulatory Commission policy statement:
  - Operation of a commercial nuclear power plant should pose, to the public, no more than one tenth of one percent (0.1%) of the background risk to which the public is normally exposed; both acute fatality and latent cancer risks considered.

US NRC's *De Minimis* risk rule

- Background individual accidental acute fatality risk is about 1 in 2,000 per year (5×10^{-4}) so the goal is 5×10^{-7} per year.
- Background individual latent cancer risk is about 1 in 500 per year (2×10^{-3}) so the goal is 2×10^{-6} per year.
- This indicates that one in a million risk per year could be considered *De Minimis* risk.
- In relation to the risks of getting killed in mass transportation accidents, the general public seem to ignore the risk lower than 10^{-5} excess lifetime risk.

ICRP Recommended Dose Limits (ICRP60)

Application	Occupational	Public
Whole body	20 mSv (2 rem)/year Effective dose averaged over 5 years, maximum is 50 mSv/year	1 mSv (100mrem)/year
Annual equivalent dose to Lens of the eye Skin Hands and feet	 150 mSv (15 rem) 500 mSv (50 rem) 500 mSv (50 rem)	 15 mSv (1.5 rem) 50 mSv (5 rem) 50 mSv (5 rem)

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10 CFR Part 20: “Standards for Protection against Radiation” **(in Rems)**

	Previous 10CFR Part 20 Limits		Revised Part 20 Limit
	Quarterly limit	Annual dose limit	Annual dose limit (rems)
Whole-body[a]	1.25	5	5 TEDE[b]
Gonads	1.25	5	5 TEDE[b]; 20 organ
Lens of the eyes	1.25	5	15
Skin (averaged over $1cm^2$)	7.5	30	50[c]
Extremities [d]	18.75	75	50[c]
Minors	10% of above limits		10% of above limits
Embryo/fetus [e]	-	0.5 [f]	0.5 [f]

Risk associated with Dose Limits

- Fatal cancer risk coefficient: 500×10^{-4} per Sv
- Occupational whole body dose limit:
  - 20 mSv per year (ICRP): $20 \times 10^{-3} \times 500 \times 10^{-4} = 10^{-3}$ per yr
  - 5 rem per year (US NRC): $5 \times 5 \times 10^{-4} = 2.5 \times 10^{-3}$ per yr
- Public whole body dose limit:
  - 1 mSv per year (ICRP): $1 \times 10^{-3} \times 500 \times 10^{-4} = 5 \times 10^{-5}$ per yr

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Average Annual Occupational Exposures (with ALARA in the U.S.)

- Waste disposal (burial) – 0.12 ~ 0.45 cSv (1982-1996)
- Power reactors – 0.03 ~ 0.32 cSv (2009-2011)
- Manufacturing and distributions – 0.08 ~ 0.34 cSv (2009-2011)
- Industrial radiographers – 0.04 ~ 0.74 cSv (2009-2011)
- Physicians (private) – 0.28 cSv (interventional cardiologists – 0.4 cSv)
- Other medical – 0.17 cSv
- Teletherapy – 0.15 cSv
- Broad medical institutions – 0.07 cSv
- Academic – 0.03 cSv

- Commercial air crews – 0.20 ~ 0.50 cSv (1996-1997)

Estimated Risk Levels: 1.5×10^{-5} ~ 3.7×10^{-4}

Fatal accident rates in various industries, 1976 and 1991

	Mean rate in 1976 (10^{-4} y^{-1})	Mean rate in 1991 (10^{-4} y^{-1})
All groups	1.42	0.90
Trade Manufacture Service Government	0.64 0.89 0.86 1.11	0.40 0.40 0.40 0.90
Transport and public utilities	3.13	2.20
Construction Mines and quarries Agriculture (1973-80)	5.68 6.25 5.41	3.10 4.30 4.40

Summary

- Radiation protection system with ALARA application appears to work in terms of controlling radiation exposures among workers.
- However, application of ALARA presents a number of challenges.
- Depending upon how economic and social factors are taken into account, the outcome of ALARA application could be different.
- Challenges associated with ALARA application are related to scientific uncertainty, post-modern thinking, cultural understanding of risk, and consideration of individualism, egalitarianism, etc.
- These challenges seem to be exacerbated when the use of nuclear energy is questioned by the public.
- Use of more stringent limits for individuals without ALARA considerations could ameliorate some of the challenges.
- Ethics opens up a question toward philosophical legitimization. As long as the system is not accepted as philosophically legitimate, there will be continuing ethical challenges.