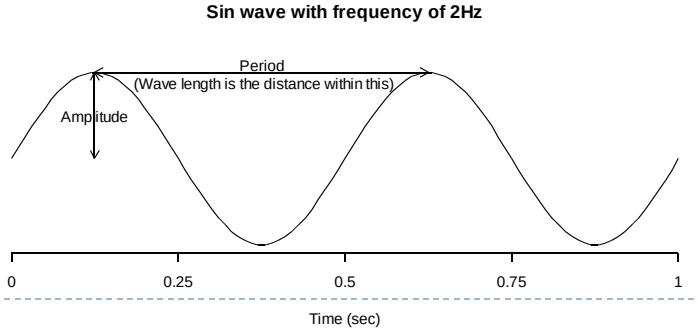
Noise, Vibration and Radiation

Upton AC: Chapter 21 "Radiation", In: Frumkin H. [Ed.] "Environmental Health: From Global to Local" Jossey-Bass, pp.769-804, 2010.

14 January 2016

Basics of noise, vibration and radiation

- All of these are "waves"
- Frequency (F) and wave length (L) are critical. Both are related with velocity (V).
  - V = L x F
  - In the case of noise, sound speed (340 m/s, air, room temp.)＝L(m)×F(/s)
  - In the case of electromagnetic wave, light speed (300000km/s＝300Mm/s)＝L(m)×F(MHz)
- Differences are **media**
  - Noise is (in general) air wave (atomospheric oscillations)
  - Vibration is ground (though underground is sometimes liquid) wave
  - Radiations are caused by accelerated particles (atom/electron) and photons (electromagnetic)

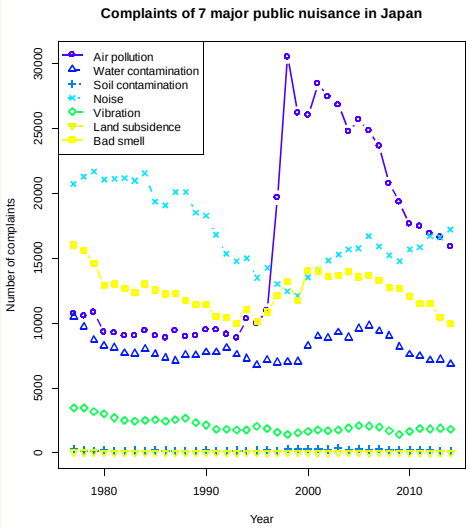


Noise

- References
  - WHO EUROPE http://www.euro.who.int/en/health-topics/environment-and-health/noise
  - Goelzer B, Hansen CH, Sehrndt GA: "Occupational exposure to noise: evaluation, prevention and control.", WHO http://www.who.int/occupational_health/publications/occupnoise/en/
  - Niemann E, Maschke C: "Noise Effect and Morbidity", WHO LARES Final Report, WHO EUROPE http://www.euro.who.int/__data/assets/pdf_file/0015/105144/WHO_Lares.pdf

Noise: disagreeable and undesirable sound or other disturbance

- Highly subjective: different by culture / individuals
  - Japanese famous *haiku* "Shizukasa ya iwa ni shimiiru semi no koe (How still it is here. Stinging into the stones. The locusts' trill)"
  - Most Western people feels noise as cricket's sound (According to Tadanobu Tsunoda, only Japanese and Polynesian recognize the insects' sound as similar to language)
  - Punk or heavy metal music are apparently noise for the people who hate those.
- Common sourse: Factory, Construction site, Car, Airplane
- In Japan, the top cause of complaints against public nuisances (almost same frequency as air pollution)



Data Source: http://www.e-stat.go.jp/SG1/estat/Xlsdl.do?sinfid=000031340236

What is sound?

- Physical strength of sound
  = sound power (W) and intensity (I)
  - $I = (p_{rms})^2/(\rho c)$ p_{rms}=root mean square amplitude, ρ=density of air, c=speed of sound
    * ρc= 414 (Ns/m² at 20˚C)
  - $W = 4\pi r^2 I$ r = distance from source
- Perception of sound
  =sound pressure level (Lp) and sound intensity level (Li)
  - Human sense is proportionate to the log of the stimulus (Weber-Fechner law)
  - Lp: $20 \log_{10} p_{rms} - 20 \log_{10} p_{ref} = 20 \log_{10} p_{rms} + 94$ (dB)
  - Li: $10 \log_{10}$ (I / reference I) = $10 \log_{10} I + 120$ (dB)
    reference I is the lowest sensible intensity for healthy youth
- Higher frequency sound corresponds to distant (apex side) hair cells, which makes human feel higher pitched, in the cochlea within the inner ear.

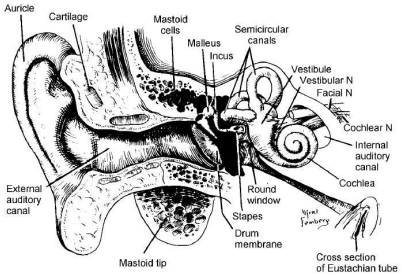


Figure 2.1. The pinna and external auditory canal form the outer ear, which is separated from the middle ear by the tympanic membrane. The middle ear houses three ossicles, the malleus, incus and stapes and is connected to the back of the nose by the Eustachian tube. Together they form the sound conducting mechanism. The inner ear consists of the cochlea which transduces vibration to a nervous impulse and the vestibular labyrinth which houses the organ of balance. (from Hallowell and Silverman, 1970)

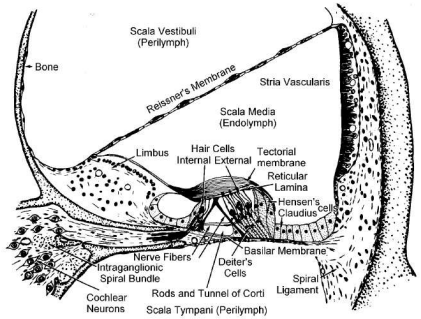


Figure 2.3. A cross section of one turn of the cochlea showing details of the membranous labyrinth. (from Hallowell and Silverman, 1970)

Source of illustrations:
http://www.who.int/occupational_health/publications/occupnoise/en/

Noise levels

- Human perception differs by the frequency even if the same pressure/intensity levels are given. Human is more sensitive for the lower frequency than 1,000 Hz (Hz is pronounced as hertz, 1 Hz =1 cycle per second), shown as the loudness level contour.
- Noise is a complex of various sounds with a variety of frequencies, which is evaluated as weighted intensity levels as dB(A) or dB(C), usually dB(A) is used.
- Equivalent sound level (*Leq*):
  - Sound intensity level (Li) shows instantaneous value, but noise levels vary with time.
  - *Leq* (equivalent continuous sound level) is the steady sound pressure level which, over a given period of time, has the same total energy as the actual fluctuating noise. For a duration of noise *T*, *Leq* is given as below (*p(t)* is sound pressue at time *t*, p_0 is the reference pressure, 20 microPa):

$$L_{eq} = 10 \log_{10} \left(\frac{1}{T} \int_0^T \left(\frac{p(t)}{p_0} \right)^2 dt \right)$$

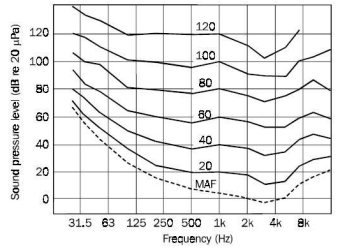


Figure 1.8. Loudness level (equal-loudness) contours, internationally standardised for pure tones heard under standard conditions (ISO 226). Equal loudness contours are determined relative to the reference level at 1000 Hz. All levels are determined in the absence of the subject, after subject level adjustment. MAF means minimum audible field.

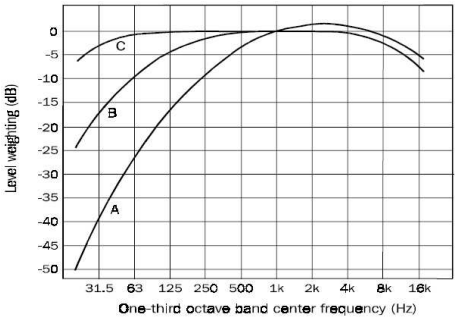


Figure 1.9. Frequency weighting characteristics for A and C networks.

Source of illustrations:
http://www.who.int/occupational_health/publications/occupnoise/en/

Classification of sounds

- Pure sound vs noise
  - Pure sound is sine wave
  - Noise is usually a complex of the pure sounds with various frequencies
  - Pure sound with too high intensity makes human noisy
- Ultrasound
  - The sound with higher frequencies than the human audible ranges (usually considered as 20～20,000 Hz)
    - Human can feel ultrasound even if one cannot listen = hypersonic effect, possibly via bone conduction
  - Sensitivity to the sound with higher frequencies declines with ageing
    - So called "mosquito sound" is used to make youth gangs away
  - The ultrasound with MHz frequencies is used for "Echo" diagnosis, in which device the reflections at tissues are detected, so that gastrointestinal tract and lung – including air in those organs – cannot be examined by this device

Inaudible High-Frequency Sounds Affect Brain Activity:
Hypersonic Effect

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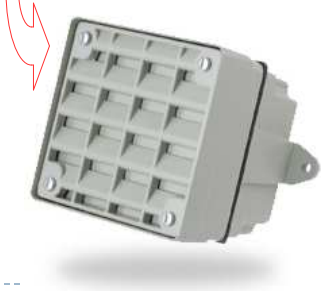


http://www.compoundsecurity.co.uk/security-information/mosquito-devices

Noises in living environment

- Noise levels in living environment
  - Near the engine of airplane, 120-130 dB(A)
  - Car's alert noise, 110 dB(A)
  - Under the bridge where train passing, 100 dB(A)
  - Ambulance siren, 100 dB(A)
  - Loudly singing alone, 90 dB(A)
  - Town's crowded street, 70 dB(A)
  - Usual talk, 60 dB(A)
  - In the library, 40 dB(A)
  - Late night in rural area, 30 dB(A)
  - The sound of clock's second hand at 1 m distance, 20 dB(A)
- Various frequencies
  - Insects' sound
    - Suzumushi (Homoeogryllus japonicus) 4,000-5,000 Hz
    - Kirigirisu (*Gampsocleis* spp.) 9,500 Hz
    - Kantan (*Oecanthus longicauda*) 2,000 Hz
  - Human talk is mostly around 1,000Hz, so that analog phone only transmits 300-3,400 Hz, thus suzumushi's voice is not audible via analog phone (PHS or Hikari digital phone can pass through)
  - Ambulance siren is composed of the pure sounds with 2 frequencies (960 Hz and 770 Hz)
  - **Listening ability is usually tested for the frequency range of 125Hz～8,000Hz by audiometer (if 0 dB is not audible, the one has hearing impairment).**
  - Sensorineural hearing impairment is tested about bone conduction

Health effect of noises

- Noise induced hearing impairment
  - NITTS (Noise Induced Temporary Threshold Shift)
  - NIPTS (Noise Induced Permanent Threshold Shift) = hearing impairment by noise=c^5-dip
    - Exposuse to 90dB(A) for 8 hrs everyday makes human difficult to hear the sounds with 3,000-4,000 Hz (The peak frequency of impairment is about 5,000 Hz). c^5-dip is named by German researcher, so that the name is German style. In international (USA) way, it's C8 (The highest key of the piano).
- Low frequency noise
  - Many people complains the noise of outer machines of air conditioner, of which frequency is usually lower than 100 Hz.

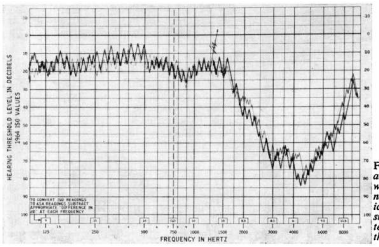


Fig 4 Sweep frequency Békésy audiogram of right ear of man with history of occupational noise exposure, showing classical high-tone notch. Note also superimposition of sustained test tone and pulsed test tone thresholds

Source: Hinchcliffe R (1967) Occupational noise-induced hearing loss. Proc. Royal Soc. Med., 60: 1111-1117.

Table 5.2. Number and percentages for some selected occupational diseases/disorders in 1998 (total in Germany, from BMA, 1999).

	cases registered for first time		cases recognized for first time without indemnity		cases registered & indemnified for first time (reduction of earning ability ≥ 20%)	
Occupational diseases/disorders	number	%	number	%	number	%
meniscus	2398	2.8	418	2.0	275	4.5
damage from vibrations	1797	2.1	234	1.1	154	2.5
impaired hearing	12400	14.5	7439	36.5	1012	16.4
silicosis	2813	3.3	2100	10.3	391	6.4
skin disorders	23349	27.3	1855	9.1	582	9.5

Source: http://www.who.int/occupational_health/publications/occupnoise/en/

Environmental regulation criteria

- Noise regulation act (in Japan)
  - http://law.e-gov.go.jp/htmldata/S43/S43HO098.html
  - Within the area specified by the prefecture governer (densely inhabited area, close to hospital or school), the noise caused by factory, constructing action, car is regulated
  - In AA area (eg., close to many rehabilitation hospitals): less than 50 dB(A) during daytime, 40 dB(A) at night
  - In A and B area (mostly for houses): AA criteria + 5 dB
  - In C area (for commercial and factory): AA criteria + 10 dB
  - Along the road: Daytime 60 dB(A) and Night 55 dB(A) in A area, +5 dB in B and C area
  - Along the main road: Less than 70 dB(A) in daytime, 65 dB(A) at night
  - Airplane noise is specially regulated with weighted equivalent continuous perceived noise level (WECPNL).

Vibration

- References
  - ILO (1977) Protection of workers against noise and vibration in the working environment http://www.ilo.org/safework/info/standards-and-instruments/codes/WCMS_107878/lang--en/index.htm
  - WHO Occupational health section "Protecting Workers' Health Series No. 10 - Occupational exposure to vibration from hand held tools: A teaching guide on health effects, risk assessment and prevention" http://www.who.int/occupational_health/publications/Protecting_Workers_Health_Series_No_10/en/

Vibration

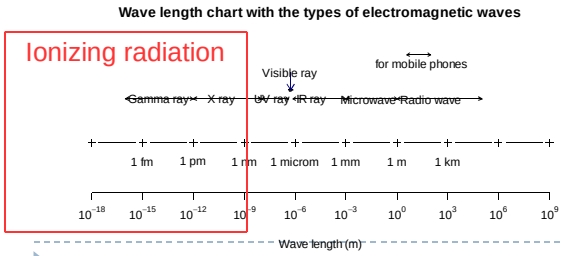
- Frequency and its intensity
  - Frequency (Hz): numbers per sec
  - Intensity (dB): vibration acceleration level
- Health impairment of local organ and whole body
  - Local organ: eg., "Raynaud's disease" causes some areas of your body — such as your fingers and toes — to feel numb and cold in response to cold temperatures or stress. Smaller arteries that supply blood to your skin narrow, limiting blood circulation to affected areas (vasospasm).
  - Whole body vibration: eg. vomitting, nausea, gastrointestinal disorder, abnormal menstruation, etc.
- Basic features
  - Measured by vibration meter or vibration level monitor (see above photo)
  - Human sensible frequencies of vibration: 0.1 – 500 Hz
- Environmental regulation act in Japan = Vibration regulation act
  - http://law.e-gov.go.jp/htmldata/S51/S51HO064.html for regulating vibration caused by the road traffic (less than 65 dB in daytime, 60 dB at night in the area 1, +5 dB in the area 2)
  - Claimed intensity as a public nuisance are usually 60 – 80 dB
  - The vibration with 70 dB corresponds to level 2 earthquake. Level 6-7 earthquake corresponds to the vibration of 110 – 115 dB.

Radiation

- In Japanese
  - 牧野淳一郎 (2015)『被曝評価と科学的方法』岩波科学ライブラリー236
  - 中西準子 (2014)『原発事故と放射線のリスク学』日本評論社
  - 田崎晴明 (2012)『やっかいな放射線と向き合って暮らしていくための基礎知識』朝日出版社
  - 小豆川勝見 (2014)『みんなの放射線測定入門』岩波科学ライブラリー224
  - 木村真三 (2014)『「放射能汚染地図」の今』講談社
  - 小出裕章 (2011)『原発のウソ』扶桑社新書
  - 長崎・ヒバクシャ医療国際協力会（編著）(2011)『21世紀のヒバクシャ：世界のヒバクシャと放射線障害研究の最前線』長崎新聞新書
- WHO web sites
  - "Environmental radiation" [http://www.who.int/ionizing_radiation/env/en/]
  - "Ionizing radiation" [http://www.who.int/topics/radiation_ionizing/en/]
  - "Non-ionizing radiation" [http://www.who.int/topics/radiation_non_ionizing/en/]
- Other web sites
  - UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [http://www.unscear.org/]
  - EURATOM [https://ec.europa.eu/energy/node/1183]
  - International Commission on Radiological Protection (ICRP) [http://www.icrp.org/]
  - International Atomic Energy Agency (IAEA) [https://www.iaea.org/]
    - https://www.iaea.org/OurWork/ST/NE/NEFW/documents/ENVIRONET/TM_ER_Radiologically_Contaminate_Sites_ANL/DI/Radiation_Overview.pdf

Radiation ray

- Accelerated particle ray + Electromagnetic wave
  - Accelerated particle ray: α ray (atomic nuclei of He), β ray (electron), Carbon ray, etc.
  - Electromagnetic wave: Photon ray, including X ray, γ ray, ultraviolet ray, visible ray, infrared ray, microwave, radio wave, etc.
- Radiation ray can be classified into ionizing and non-ionizing radiation
  - Ionizing: making electrons released when the ray goes through: X ray, γ ray, α ray, β ray, etc. The shorter wave length is, the stronger biological effects are.
  - The electromagnetic waves of which length is longer than ultraviolet are non-ionizing



Ray	Particle	Shielded by	Reachable distance in air
α	Atomic nuclei of He	A paper	Several centimeters
β	electron	Thin alminum board	About half meter
γ	photon	Thick lead board	Several hundreds meters

Basics on ionizing radiation (1)

- Radioactivity: The ability of releasing radiation ray of radionuclides: Unit is becquerel (Bq), 1 Bq is 1 disintegration per second.
- The half-life of the radionuclide is the time required for the radioactivity to decrease by decay to half of its initial value. The half-life of ^{131}I is 8 days, ^{14}C is 5,730 days, ^{134}Cs is 2.1 years, ^{137}Cs is 30.1 years, ^{90}Sr is 28.9 years, ^{239}Pu is 24,100 years, ^{235}U is 0.7 billion years, ^{238}U is 4.48 billion years: ^{239}Pu is included in the high-level radioactive wastes, which has been stored in the water pools of nuclear power stations.
- Absorbed dose: Strength of radiation damage to tissues/organs = the dose of radiation received/absorbed = Making 1 kg material to generate 1 joule (J) = 1 gray (Gy)
- Dose equivalent: The unit to measure ionizing radiation in terms of the potential for causing harm in tissues/organs = sievert (Sv)
  = Gy · Q (radiation weighting factors: α ray=20, protons and charged pions = 2, β, γ and X ray=1)

Basics on ionizing radiation (2)

- Natural radiation exposure varies by area, in average 2.4 mSv/year
- α ray mostly causes internal radiation exposure (eg. when the one take Pu-contaminated food) because it cannot reach a distant objects
- β ray from radioactive I, Cs, or Sr may also cause internal radiation exposure if the one accidentally takes those (cf. Hot spot problem)
- 3 Principles of radiation protection = distance, time, shielding
- Biological effects of ionizing radiation
  - Early onset effect: Mostly dose > 1 Sv, usually fatal
  - Late onset effect: According to the follow up data of Hiroshima and Nagasaki atomic bomb victims (so called "Hibakusha"), 100 mSv exposure proved to significantly increase the risk of cancer. After the Chernobyl accident, child thyroid cancer significantly increased due to internal exposure by ^{131}I.
  - The effect of lower dose than 100 mSv is still under discussion.
- ICRP (2007) recommends to keep additional radiation exposure less than 1 mSv/year for the public. During the recovery from emergency, 1-20 mSv/year, during emergency, 20-100 mSv/year.

Average amounts of ionizing radiation received annually by a resident of USA

- Source: Upton 2010, ibid., p.774

Source		Dose (mSv)	% of Total
Natural			
	Radon	**1.9**	**31**
	Cosmic	**0.27**	**4**
	Terrestrial	**0.28**	**4**
	Internal	**0.39**	**7**
	Total Natural	**2.84**	**46**
Artificial			
	X-ray diagnosis	**2.4**	**39**
	Nuclear medicine	**0.8**	**13**
	Consumer products	**0.10**	**2**
	Occupational	**<0.01**	**<0.03**
	Nuclear fuel cycle	**<0.01**	**<0.03**
	Nuclear fallout	**<0.01**	**<0.03**
	Miscellaneous	**<0.03**	**<0.03**
	Total artificial	**3.35**	**54**
Total natural and artificial		**6.2**	**100**

Major 4 forms of acute radiation syndrome / Lifetime risk of 100 mSv whole-body exposure

Major forms and features of acute radiation syndrome

Time after irradiation	Cerebral form (>50 Sv)	Gastrointestinal form (10-20 Sv)	Hemopoietic form (2-10 Sv)	Pulmonary form (>6 Sv to lungs)
Day 1	Nausea Vomiting Diarrhea Headache Disorientation Ataxia Coma Convulsions Death	Nausea Vomiting Diarrhea	Nausea Vomiting Diarrhea	Nausea Vomiting
2nd week		Nausea Vomiting Diarrhea Fever Erythema Prostration Death		
3rd to 6th weeks			Weakness Fatigue Anorexia Fever Hemorrhage Epilation Recovery (?) Death (?)	
2nd to 8th months				Cough Dyspnea Fever Chest pain Respiratory failure

Estimated lifetime risks of fatal cancer attributable to 100 mSv whole-body irradiation

Type or site of cancer	Excess cancer deaths per 100,000 No.	(% excess above baseline)
Colon	61	3
Lung	200	7
Bone marrow (leukemia)	65	13
Stomach	22	4
Breast	40	2
Urinary bladder	25	4
Esophagus	20	6
Liver	16	9
Gonads	24	5
Thyroid	8	8
Bone	5	5
Skin	2	2
(Remainder)	87	2
Total	575	2

- Source: Upton 2010, ibid.(pp.780, 784)

Risk assessment of radiation exposure by Nakanishi (2014)

(Yasutaka T, Naito W, Nakanishi J (2013) Cost and effectiveness of decontamination strategies in radiation contaminated areas in Fukushima in regard to external radiation dose. PloS ONE, 8(9): e75308.)

- Exposure to toxic chemical substances: different [exposure→absorption] pathways (oral, inhalation, skin) → different target organs
- Two kinds of exposure to radiation should be distinguished:
  - Internal exposure: via oral or inhalation, radioactive materials attach and generate radiation rays
  - External exposure: via skin-attached radioactive materials or gamma ray from distant radioactive materials
- External exposure: effective dose = (air dose)×(conversion coefficients by age)×(shielding factor) = (air dose rate)×(time spent there)×1 (in Japan; UNSCEAR suggests 0.7-0.8 for adults)× 0.6
  - (eg.) At the Katsurao village office, Fukushima in the evening on 15 Sep. 2013, air dose rate was 0.257μSv/h. If a person lives there for a year, cumulative external exposure becomes 0.257・24・365・0.6=1351 μSv (≈1.4 mSv/year)
  - In Chernobyl, shielding (behavioral) factors were 0.36 in rural, 0.18 in urban area (UNSCEAR, 2008)
- Internal exposure: Using dose conversion factor (DCF; Sv/Bq), Internal exposure dose = effective dose = (intake / Bq)×DCF = (intake/Bq/day)×(days)×DCF
  - (eg.) If a person orally ingests 170 g/day rice (375 g/day as cooked rice) with the radioactive Cs of 100 Bq/kg (maximum tolerable level) everyday, assuming that Cs is composed of half ^{134}Cs, half ^{137}Cs, of which DCFs are 1.9×10^{-8} and 1.3×10^{-8} Sv/Bq, respectively (thus 1.6×10^{-8} in average), $100・0.17・365・1.6・10^{-8} = 0.1$ mSv/year

Comic "Oishinbo" nose bleeding problem (*1)

- Based on the experience during the writer's activity at Fukushima to collect information, the protagonist of the comic Mr. Yamaoka suffered from sudden nose bleeding just after their activities at Fukushima in the story.
- The wide-range of protests occurred
  - The Fukushima prefectural government issued a protest against the comic for inflaming fears about the safety of the prefecture's fish.
  - The episodes of nose bleeding may be only highlighted by diagnostic suspicion bias.
  - Many professionals (including medical doctors) judged the story is a kind of denial of the fact, because the nose bleeding cannot be caused by the radiation emitted from Fukushima nuclear power plant (Nose bleeding is usually included in whole body acute radiation syndrome, caused by several Sv exposure).
- There were some supportive opinions, too.
  - The nose bleeding observed among the people in Fukushima and surrounding area could be caused by radiation.
  - If psychological effects contribute to the nose bleeding, it's still the effect of the accident.
- The comic clearly stated that the radiation exposure dose was much lower than the critical level to cause acute whole body syndrome.
- Mr. Kariya, the writer of the comic published the book to answer this issue. In that book, he suggest "hot" particles attached to the inner-nose skin to harm the local (inner-nose) capillary vessels, then to cause nose bleeding. Makino (2015) also suggests this possibility.
- The writer actually met many people who suffered from strange nose bleeding after the accident, so that, besides the cause, epidemiologists and/or public health specialists should assess the incidence or prevalence of the nose bleeding episode. According to the data by Nakachi and Tsuda (2013), nose bleeding incidence was significantly higher (by 3-4 times) in towns close to Fukushima daiichi nuclear power plant (*2).

Item	Kinomoto Shiga	Futaba Fukushima	Marumori Miyagi
Pop.	7056	6730	733
Res.	3775	3872	637
(%)	(56.1)	(54.9)	(86.9)
Fever	50	58	5
(%)	(1.3)	(1.5)	(0.8)
Cough+	386	521	59
(%)	(10.3)	(13.7)	(9.5)
Gum*	142	212	17
(%)	(3.8)	(5.6)	(2.7)
Nose*	14	43	5
(%)	(0.4)	(1.1)	(0.8)

Odds Ratios of Nose bleeding (adjusted for sex, age, smoking, etc. using multiple logistic regression model) were:
3.8 [1.8-8.1] for Futaba
3.5 [1.2-10.5] for Marumori
to Kinomoto as reference
Prevalences (%) of fever, cough, gum were higher than national statistics (Kokumin-seikatsu kiso chosa).

***1 http://www.japanfocus.org/-Eiichiro-Ochiai/4138/article.pdf**
***2 http://www.saflan.jp/wp-content/uploads/47617c7eef782d8bf8b74f48f6c53acb.pdf**

Non-ionizing radiation (1): UV ray

- UV=ultraviolet ray
  - Wave length ranges from 10 to 400 nm.
  - UV-A: 320-400, UV-B: 280-320, UV-C: 190-280 nm
  - 10-190 nm UV cannot reach the earth surface.
    - UV of shorter wave length than 290 nm has strongly harm organism, but mostly absorbed in ozone layer.
    - Absorbed in skin or mucosa, harms skin and/or eyes
    - **UV-C**: **cytotoxic, 250-280 nm has strong effect, used for sterilization**
    - **UV-B**: weak cytotoxicity, 290-320 nm can activate vitamin D in skin.
    - **UV-A**: related with tanning, cataract, and oxidant generation
  - Snow enhances reflected exposure (75% of UV is reflected by snow)
  - T-dimer of DNA generation increases the risk of skin cancer.

Non-ionizing radiation (2): visible and infrared

- Visible ray
  - Wave length: 400-700 nm. From short to long wave length: violet, blue, green, yellow, red
  - Illuminance (lx) = luminous flux (lm) / area (m^2) = brightness (cd) / squared distance (m)
  - For safe walk, 20 lx; for working, 100 lx are needed.
- Infrared ray (IR)
  - Wave length: 700 nm – 1 mm. **Heat ray**: Absorbed by materials to make them heated.
  - Near IR (700 nm – 2.5 μm, remote controller), Mid IR (2.5 μm – 4 μm), Far IR (4 μm – 1 mm)
  - Reach the subcutaneous tissues, 1 – 1.4 mm beneath the skin. If eyes absorb IR, cataract may occur.

Non-ionizing radiation (3): radiowave and microwave

- Microwave
  - Wave length = 1 mm - 1 m
  - Frequency = 300 GHz - 300MHz
    - According to the Ministry of Public Management in Japan, 1 – 10 mm is mm-wave, 10 – 100 mm is microwave, 100 mm – 1 m is extremely ultra-short wave or ultra-high-frequency wave (UHF: for digital TV and microwave oven [2.45 GHz])
- Radiowave
  - Wave length = 1 m -
  - Frequency = - 300 MHz
    - Frequencies of several MHz – 80 MHz radiowave is used in MRI. Biological influence is only seen at high energy. Regulated by SAR (specific absorption rate; W/kg). The places where SAR exceeds the criteria is restricted to enter.
    - The safety criteria of local exposure by mobile phone / PHS (800 MHz, 1.5 GHz, 1.9 GHz, 2 GHz): SAR < 2 W/kg
      - Local exposure SAR is measured as energy absorption of 10 g cube at temporal region of head of phantom.
    - Behavioral change of monkey exposed to 1 GHz radiowave occurred at 4 W/kg exposure for 1 hour, so that tolerable whole body SAR for human is 0.4 W/kg (6 minutes) in USA.

Effect and regulation for the GHz band radio waves http://www.soumu.go.jp/main_content/000328161.pdf

- SAR (specific absorption rate, W/kg) is important to assess the risk
- The radio wave's power for mobile phones is regulated by SAR levels.
- Regulation in Japan
  - The level to affect human body = 138 W/kg for 10 g
  - The regulation criteria by Ministry statement = 2 W/kg for 10g
  - The maximum SAR levels of commercially available mobile phones = 0.183 W/kg – 1.60 W/kg (Average 0.693 W/kg)
    - PHS phones showed very low SAR (eg. 0.045 W/kg for WX01K, Kyocera)